What's Happening in the Delaware River Basin

Carol R. Collier, AICP
Executive Director
Delaware River Basin Commission

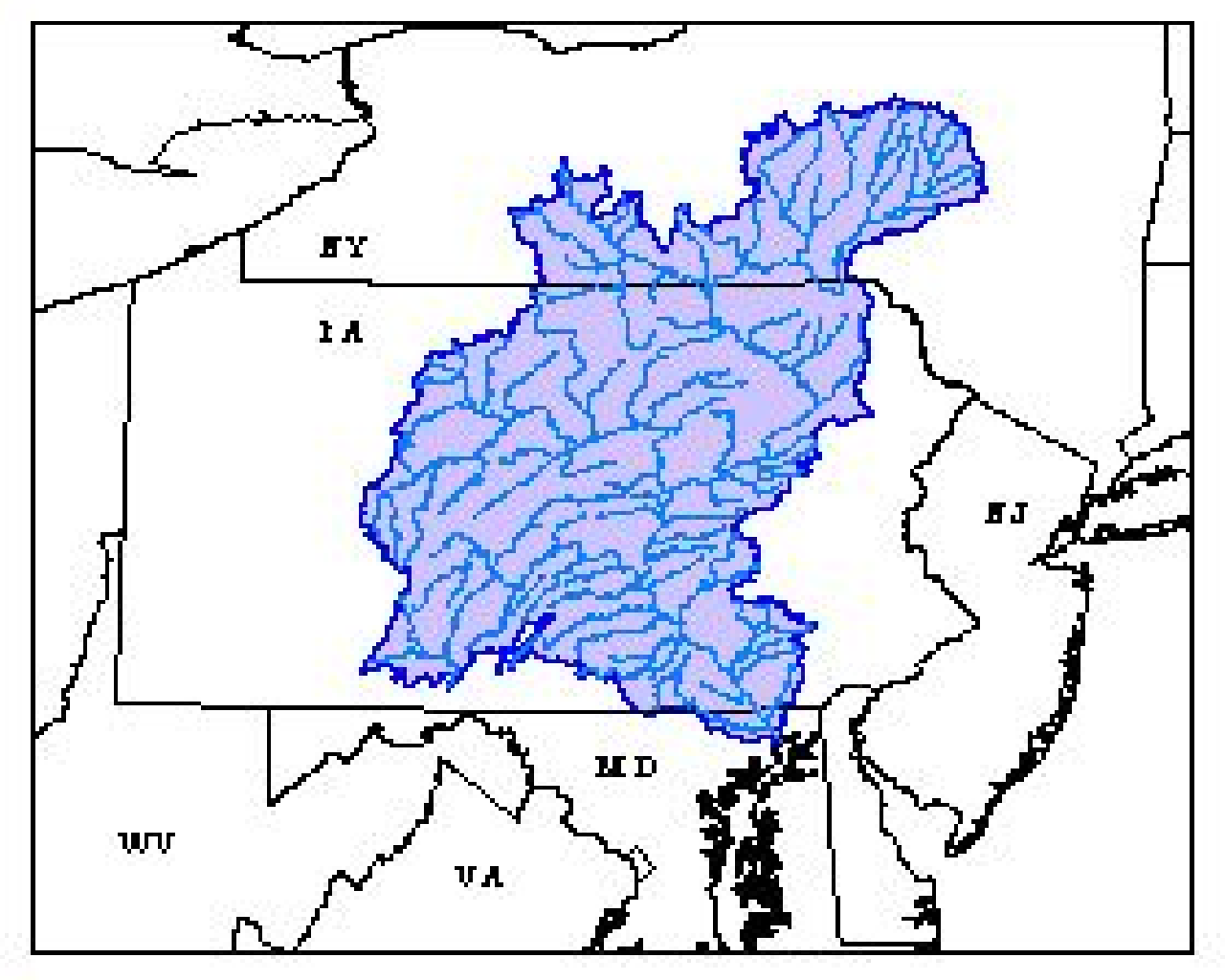
Air & Waste Management
A s s o c i a t i o n
Mid-Atlantic States Section

RBCs

- 95% of fresh water resources are interstate and governed by interstate water compacts
- Created to jointly manage the water resources of a river and/or its watershed

- ORSANCO – Ohio River Sanitation Commission
- ICPRB – Interstate Commission for the Potomac River Basin
- SRBC – Susquehanna River Basin Commission
- DRBC – Delaware River Basin Commission

SUSQUEHANNA RIVER BASIN



Delaware River Basin

Delaware River Basin Facts

- Over 15 million people (about 5% of the U.S. population) rely on the waters of the basin for water supply
- Drains 13,539 mi²
- Daily water withdrawal in the DRB = 8.7 BGD

Delaware River

Longest Undammed River
East of the Mississippi

330 miles

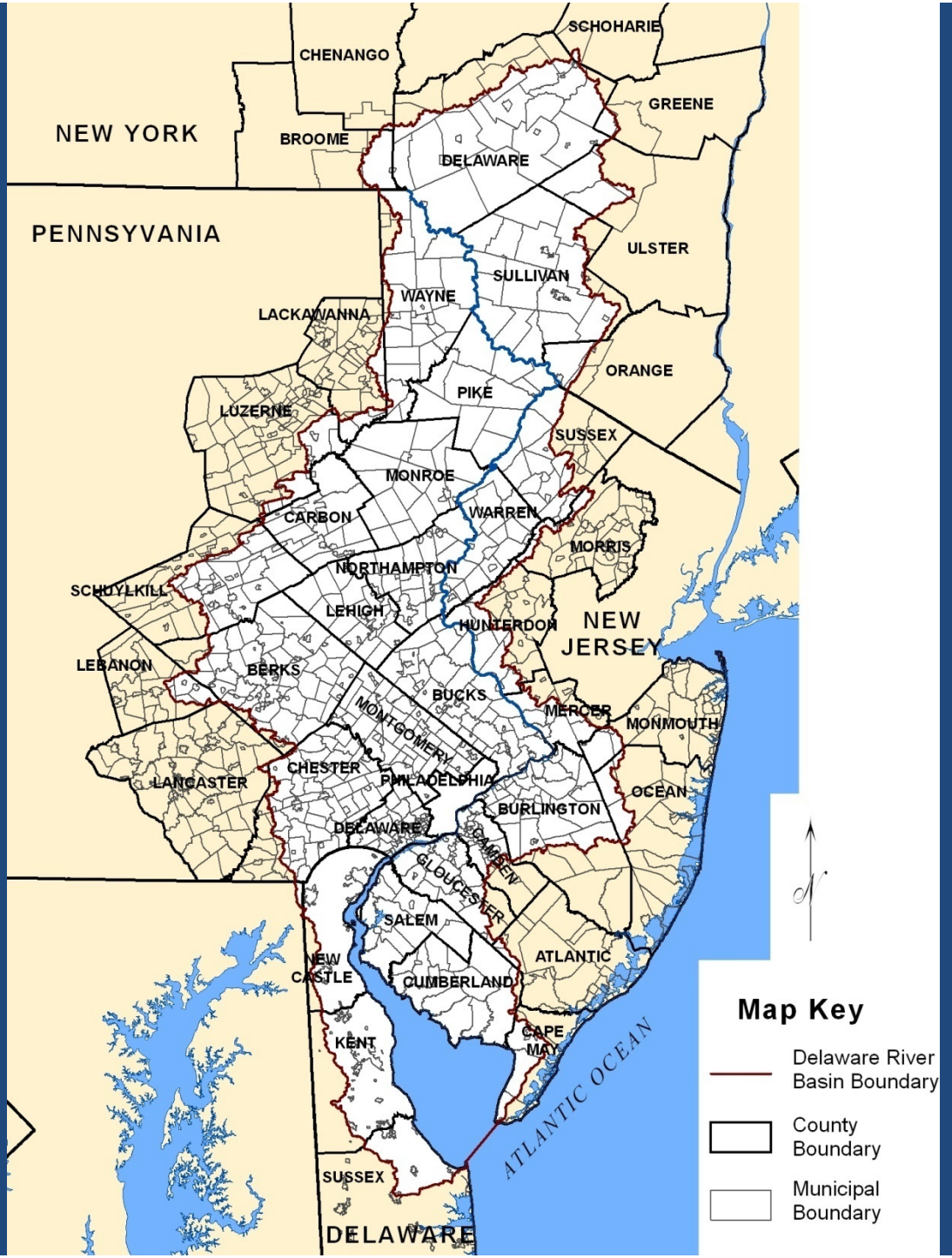
Delaware River Port Complex – Largest Fresh Water Port

Why was the Delaware River Basin Commission (DRBC) Created?

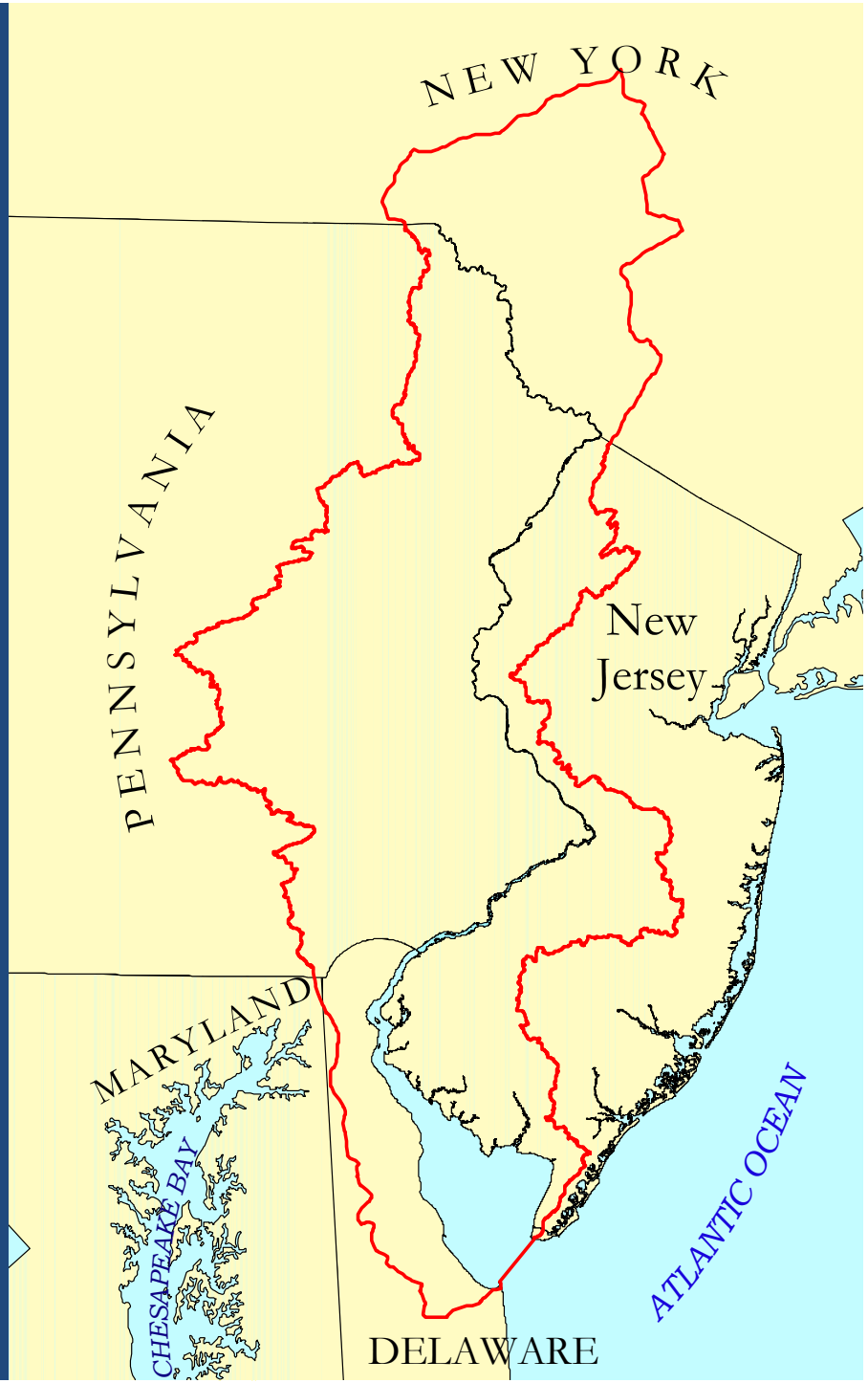
- Water supply shortages and disputes over the apportionment of the basin's waters;
- Severe pollution in the Delaware River and its major tributaries; and
- Serious flooding.

The Need for Basin-Scale Planning

- 4 States
- 25 Congressional Districts
- 42 Counties
- 838 Municipalities



Delaware River Basin Commission



Why Does DRBC Work?

- One vote for each state and federal government
- Members gave up portion of their sovereignty to manage a watershed
- DRBC is *OF*, not *ABOVE* the states
- Engage Stakeholders
- Forum for Adaptation

DRBC's Charge

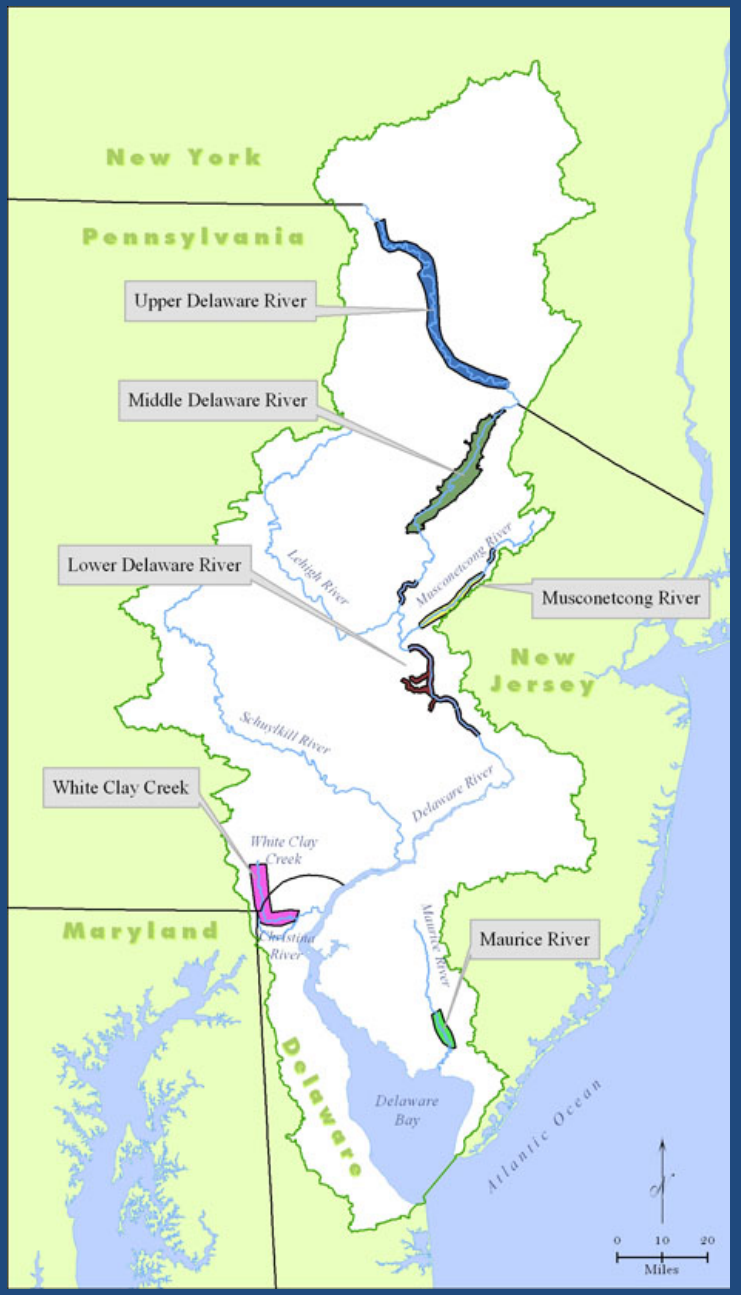
- Manage water resources w/out regard for political boundaries
- Regulate water quantity (equitably allocate, maintain streamflow) and water quality
- Plan and Develop (e.g., Basin Plan 2004; State of the Basin Report 2008; stored water)
- Coordinate between federal, state & local governments and private entities w/ role in managing water resources
- Educate the Basin community about water resources
- **Forum for adaptive management**

DRBC Value Added

- Manages the watershed holistically
- Provides a voice for individual states and federal agencies on use of the shared resources
- Evaluates benefits and costs of any proposals to all parts of the basin
- Fills in gaps where states do not have authority (water withdrawal)
- Creates a uniform baseline of regulations for the shared waters
- Cost effective allocation of funds

The U.S. has 3.5 million miles of rivers. The National Wild and Scenic Rivers System includes 11,434 miles of this total, or just over one-quarter of one percent.

Three-quarters of the non-tidal Delaware River (about 150 miles) has been included in the National Wild and Scenic Rivers System.

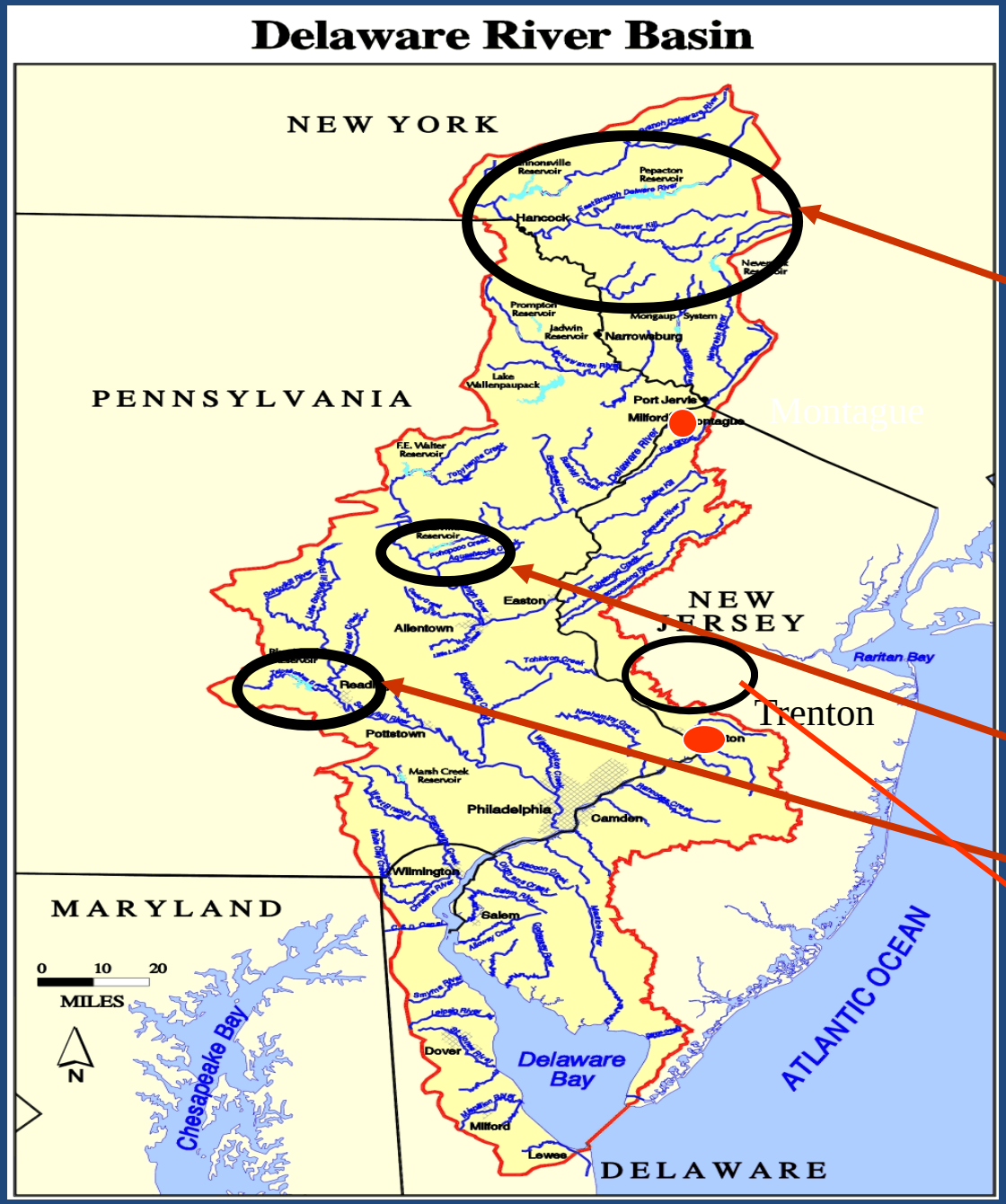


NATIONAL WILD AND SCENIC RIVERS SYSTEM

PARTNERING TO PROTECT THE RIVER
UPPER DELAWARE
Scenic & Recreational River
30 years
1978 - 2008

Unique Resource

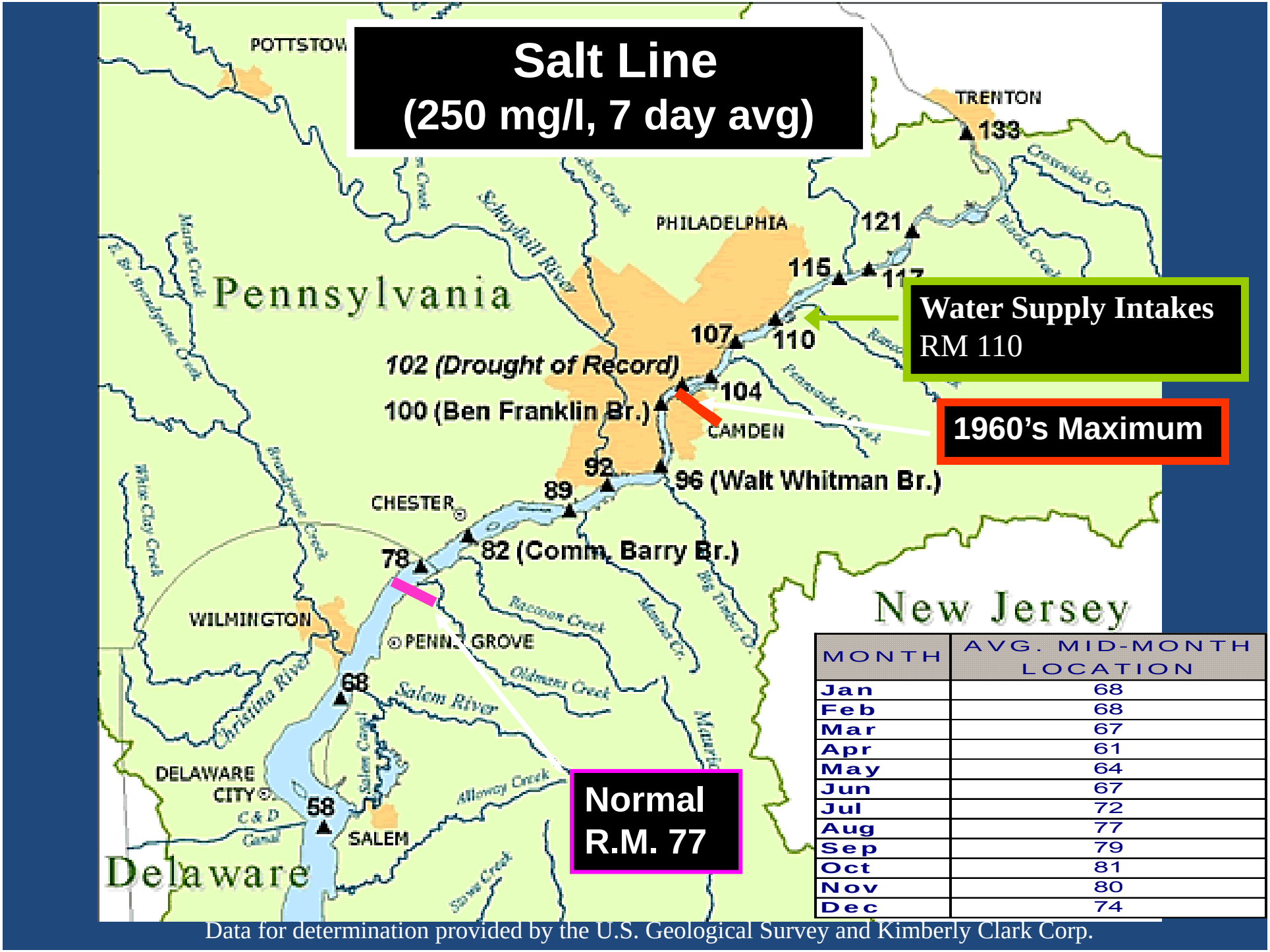
- Exceptional water quality, high ecological diversity
- Water supply for > 15 million people
  - NYC takes half its water supply from 3 reservoirs in the Delaware headwaters
  - 7.8 million in-Basin also rely on the Delaware
  - Major intakes incl. City of Philadelphia and NJ American's intake at Delran
- Recreational Gem = world class trout fishery, paddling, easily accessible in dense metro area



Operating Plans

- New York City Delaware Basin Reservoirs drive the Basin wide Operating Plan.
  - Cannonsville
  - Pepacton
  - Neversink
- Two Corps of Engineers Reservoirs drive Lower Basin Operating Plan
  - Beltzville
  - Blue Marsh
- Merrell Creek Reservoir

Delaware River Basin Commission



MONTH	AVG. MID-MONTH LOCATION
Jan	68
Feb	68
Mar	67
Apr	61
May	64
Jun	67
Jul	72
Aug	77
Sep	79
Oct	81
Nov	80
Dec	74

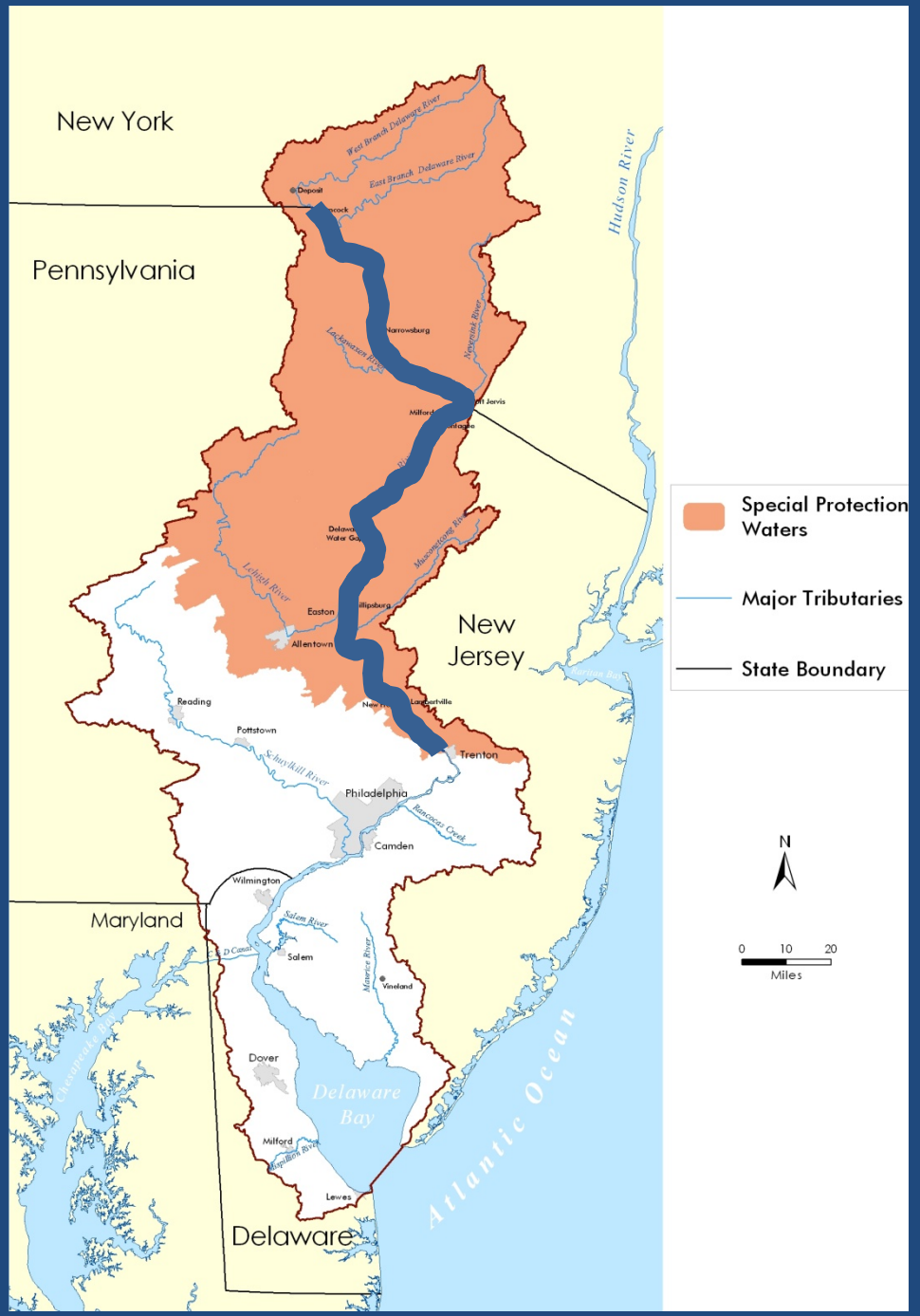
Data for determination provided by the U.S. Geological Survey and Kimberly Clark Corp.

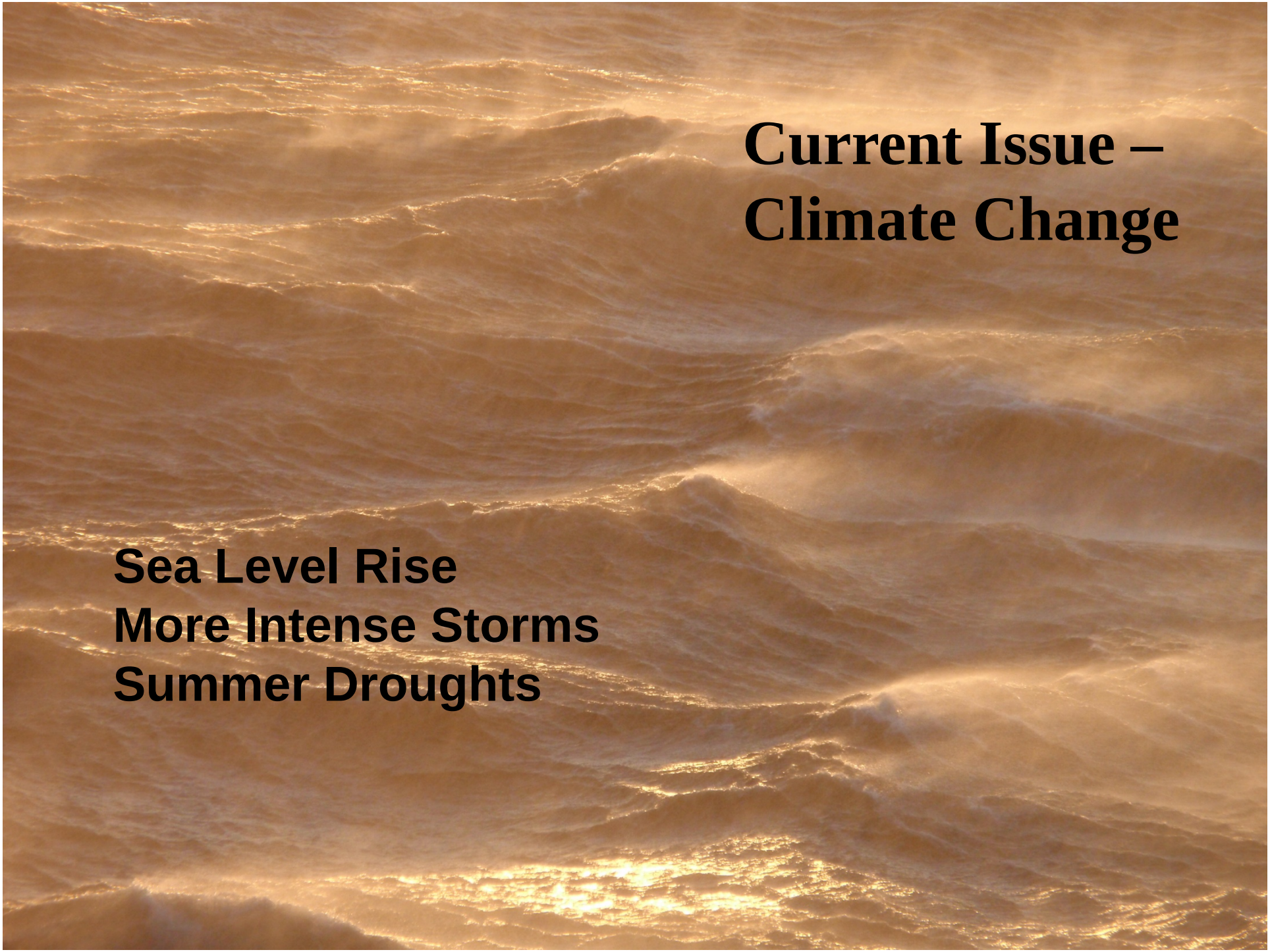
Flood Mitigation

Fish Consumption Advisories - PCBs

Water Quality

- Federal Wild and Scenic River Designation – ¾ of non-tidal river
- Total non-tidal river and its watershed designated DRBC Special Protection Waters
- Mainstem = longest stretch of anti-degradation waters in U.S.
- No measurable change in water quality

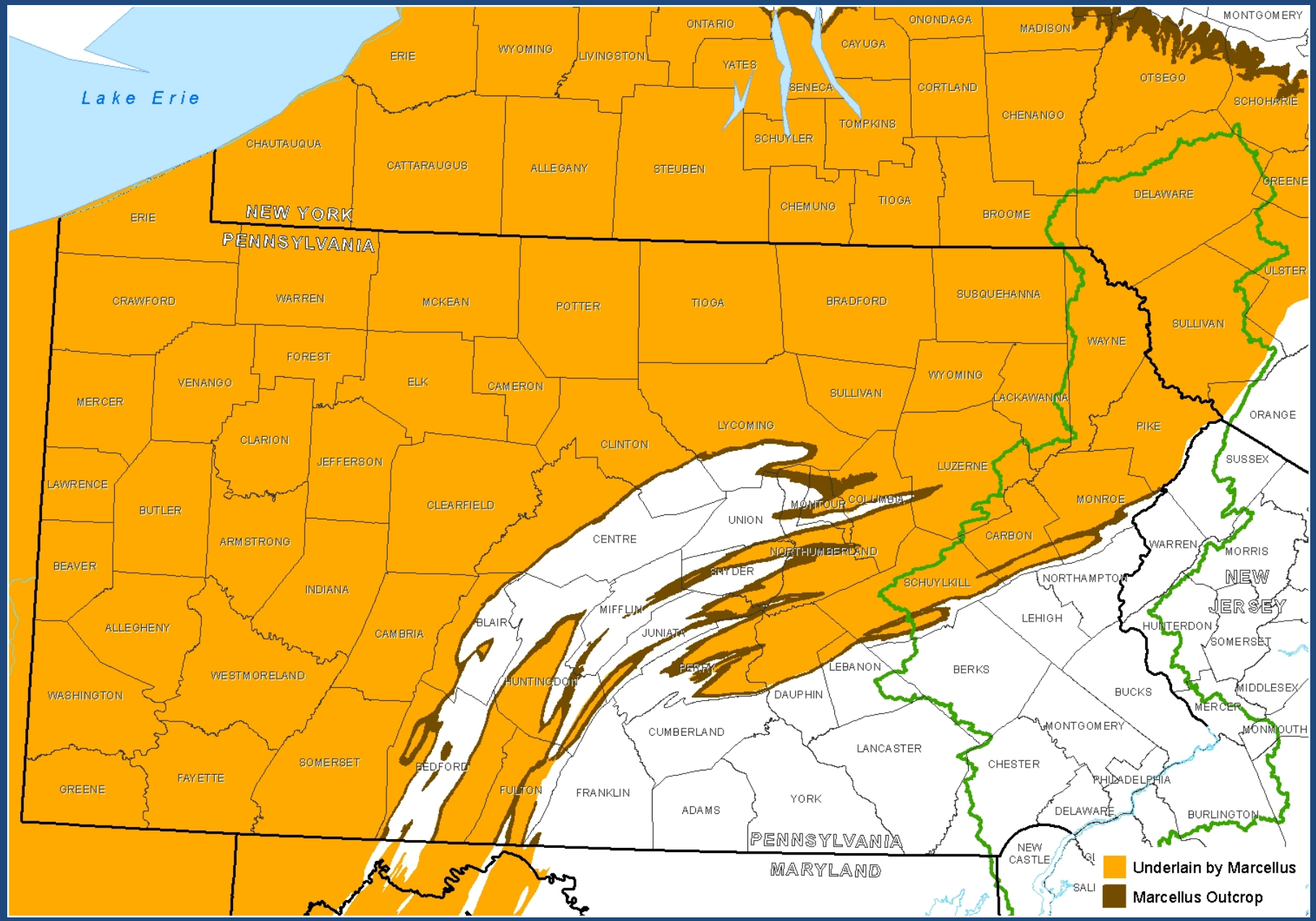




Current Issue – Climate Change

Sea Level Rise
More Intense Storms
Summer Droughts

Marcellus Shale, Delaware Basin Boundary

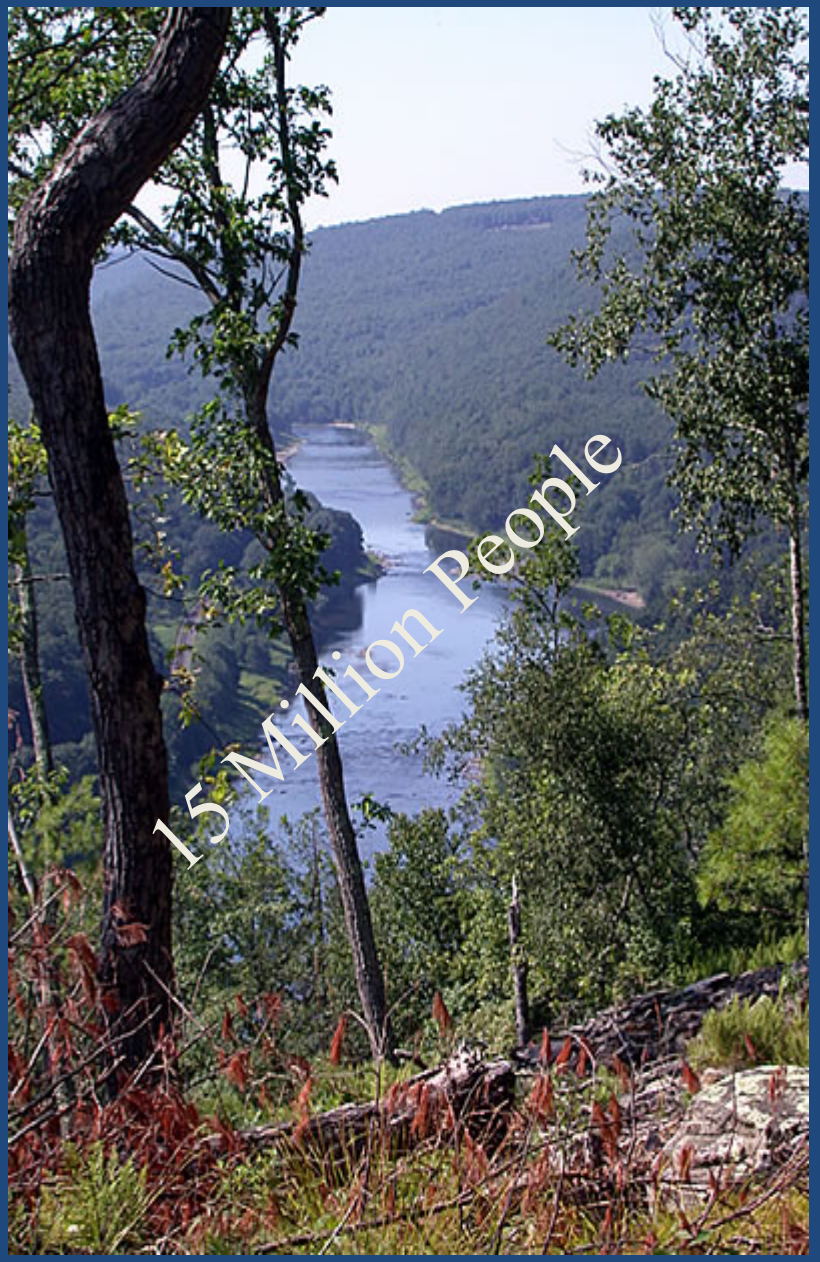


Two Value Sets

- NG – national, state, local value
  - security, economy
- Environment and Community
  - Sensitive Environments
  - Major Water Supply
  - Tourism Economic Base
  - Very different environment for TX, OK, etc.

Vulnerability of Headwaters

- **Headwaters are the most sensitive areas of a watershed**
- **Existing contiguous forest is critical to water quantity and quality**
- **Philadelphia Source Water Protection Analysis**
  - **#1 – Change in Delaware River Headwaters**



Regulation Development

- May, 2010 - Commissioners requested staff to develop draft regulations
- December, 2010 – Draft Regulations Posted
  - – Started Public Review process with hearings
- April, 2011 – Comment period Closed –
  - – 69,000 comments

Concerns

1. Water Withdrawals, Use, and Tracking
2. Well Pads and Ancillary Infrastructure
3. Wastewater Tracking and Disposal

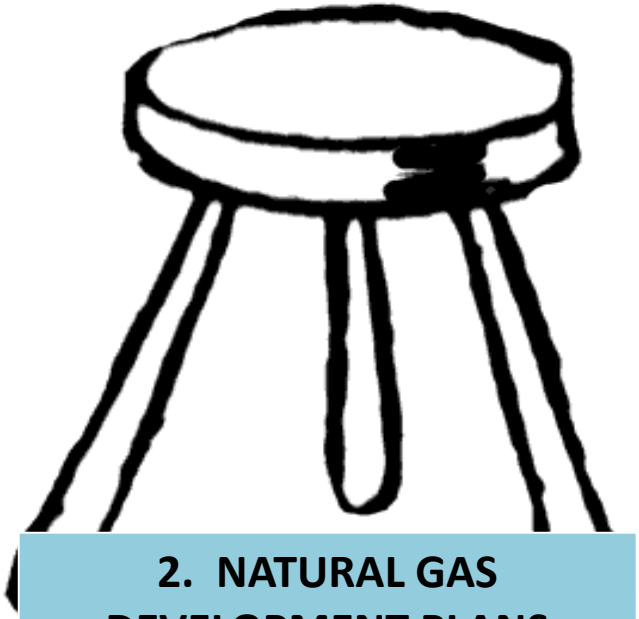
Hydro-fracking Phase –
(a week or two)

Injection pumps, supplies, and many frac tanks for fresh and flowback waters

Article 7 Natural Gas Rule Strategy

1. WATER WITHDRAWAL & USE

- Protect surface and groundwater supplies
- Preserve ecological flows
- Ensure assimilative capacity for discharges
- Monitoring, Tracking & Reporting Source & Usage
- Manage Wastewater Storage & Discharge



2. NATURAL GAS DEVELOPMENT PLANS

- Evaluates alternatives to minimize Impacts
- Siting/setback Limits
- Mitigation of unavoidable impacts
- Financial assurance requirements

3. WASTEWATER TREATMENT & DISCHARGE

- Protect receiving water bodies
- Track wastewater production, reuse, and disposal
- Ensure adequate treatment is available for expected waste stream

Natural Gas Development Plan

- Purpose – Reduce cumulative impacts; reduce NG development on landscapes important to water resources
- Review “multiple” pads/wells instead of individually
- Evaluate lease holdings (~ 10,000 - 50,000 acres), or smaller units based on location or timing
- Using mapping of constraints and developable areas developed by DRBC
- Optimize locations of proposed well pads and infrastructure and establish mitigation requirements.

Working with Our Members

- PA has regulations, NY in the process
- Our regulations required to address concerns of all 4 states and federal gov't.
- Will work though AAs with PA and NY states to avoid duplication in implementation.

In Summary

- Natural gas play is significant and valuable
- Still many unknowns - environmental, community, infrastructure impacts.
- DRBC's interest is protection of water resources.
- Need to be cautious to protect the existing outstanding resources and economic future of the area.
- DRBC Regulatory Action –Nov, 2011 special commission meeting cancelled. Commissioners deciding on path forward.

Air & Waste Management
A s s o c i a t i o n
Mid-Atlantic States Section

THE MARCELLUS SHALE GAS PLAY
Geology and Development Technology

John H. Williams
New York Water Science Center
Troy, New York

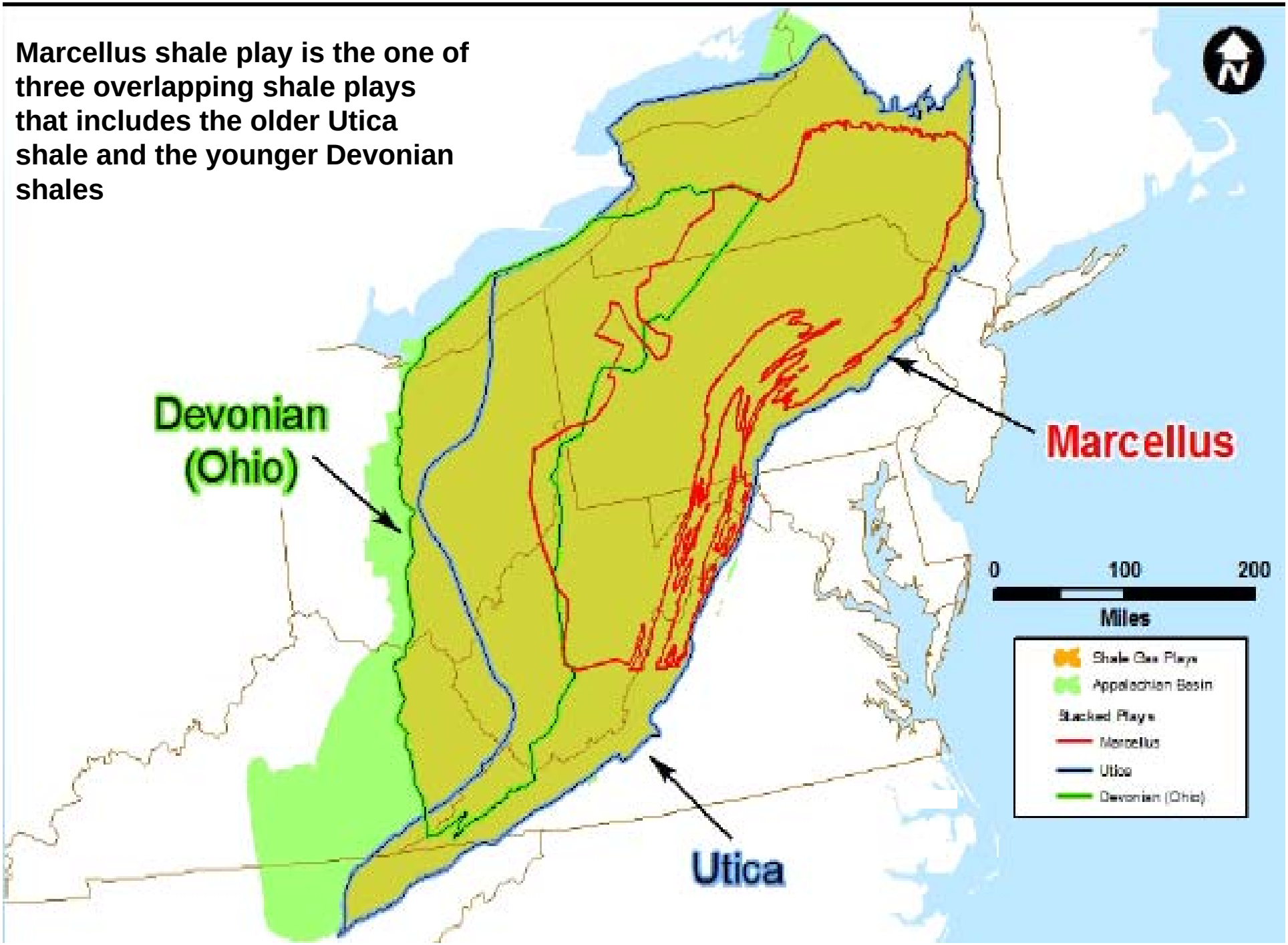
USGS

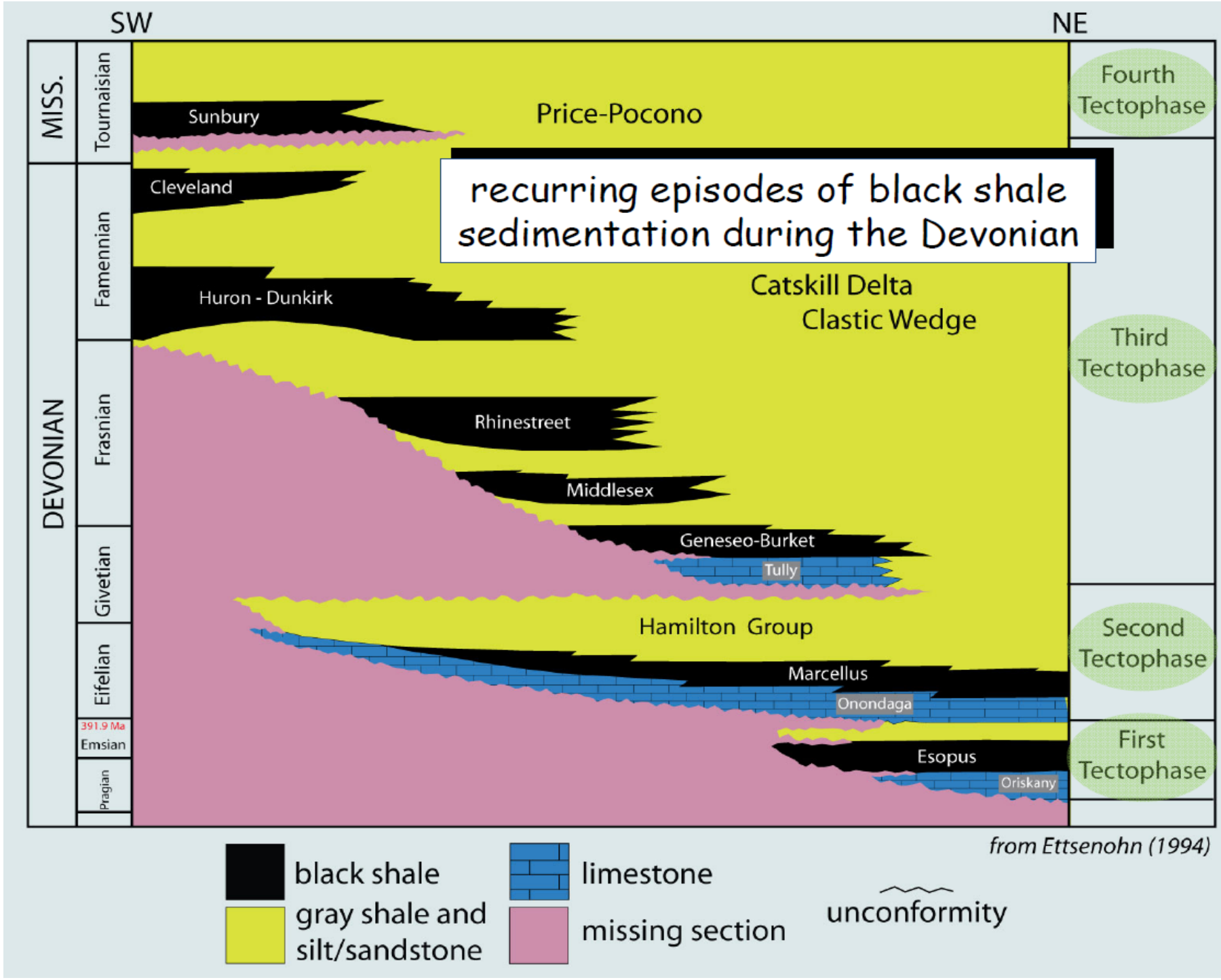
Air & Waste Management Association
Mid-Atlantic States Section
/

Shale Gas Plays, Lower 48 States

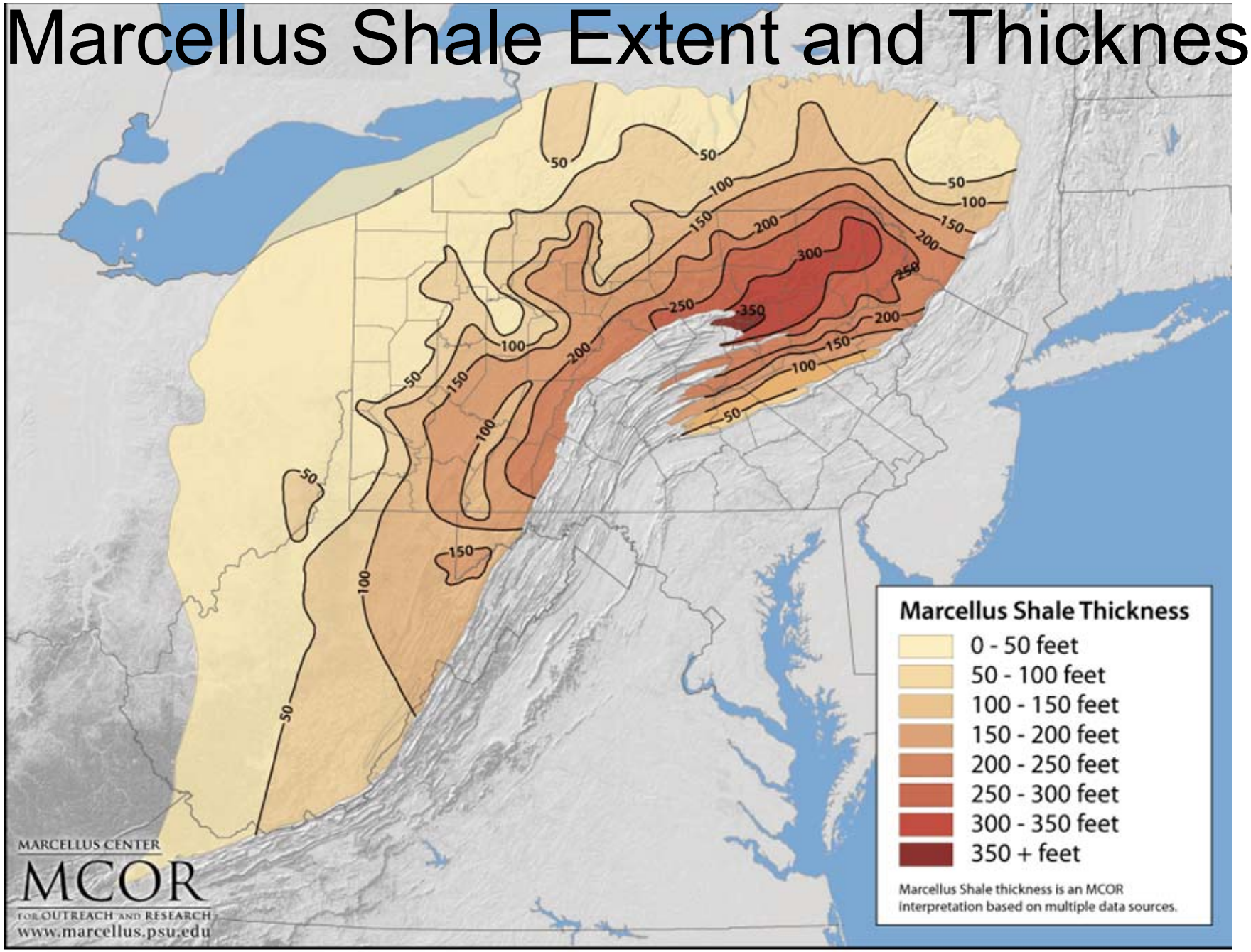
Source: Energy Information Administration based on data from various published studies
Updated: May 28, 2009

Marcellus shale play is the one of three overlapping shale plays that includes the older Utica shale and the younger Devonian shales

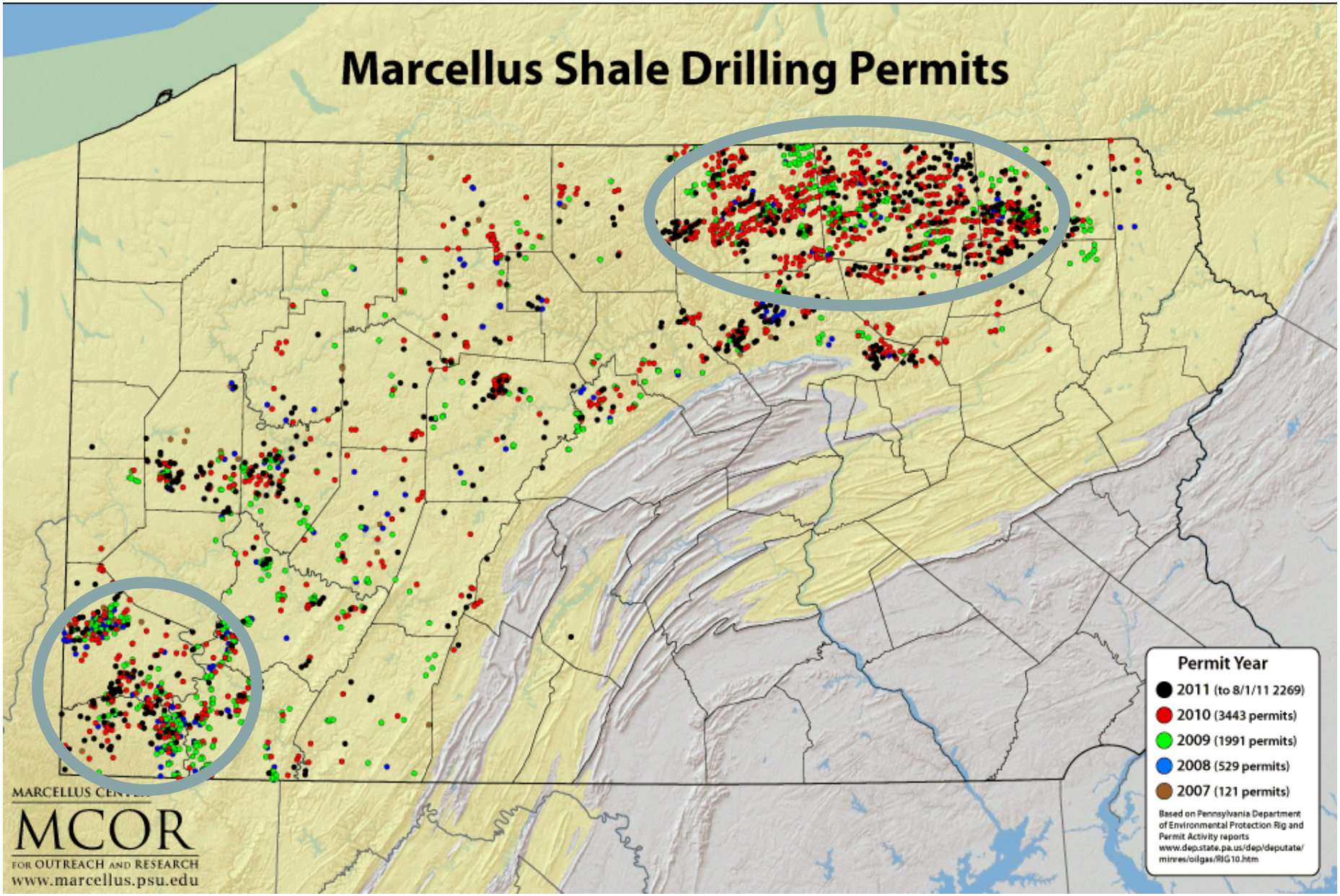



SW
NE
MISS.
DEVONIAN
Tournaisian
Famennian
Frasnian
Givetian
Eifelian
391.9 Ma
Emsian
Pragian
Sunbury
Price-Pocono
Cleveland
recurring episodes of black shale sedimentation during the Devonian
Huron - Dunkirk
Catskill Delta Clastic Wedge
Rhinestreet
Middlesex
Geneseo-Burket
Tully
Hamilton Group
Marcellus
Onondaga
Esopus
Oriskany
Fourth Tectophase
Third Tectophase
Second Tectophase
First Tectophase
from Ettsenohn (1994)
black shale
gray shale and silt/sandstone
limestone
missing section
unconformity

Marcellus Shale Extent and Thickness



http://www.marcellus.psu.edu/resources/maps.php



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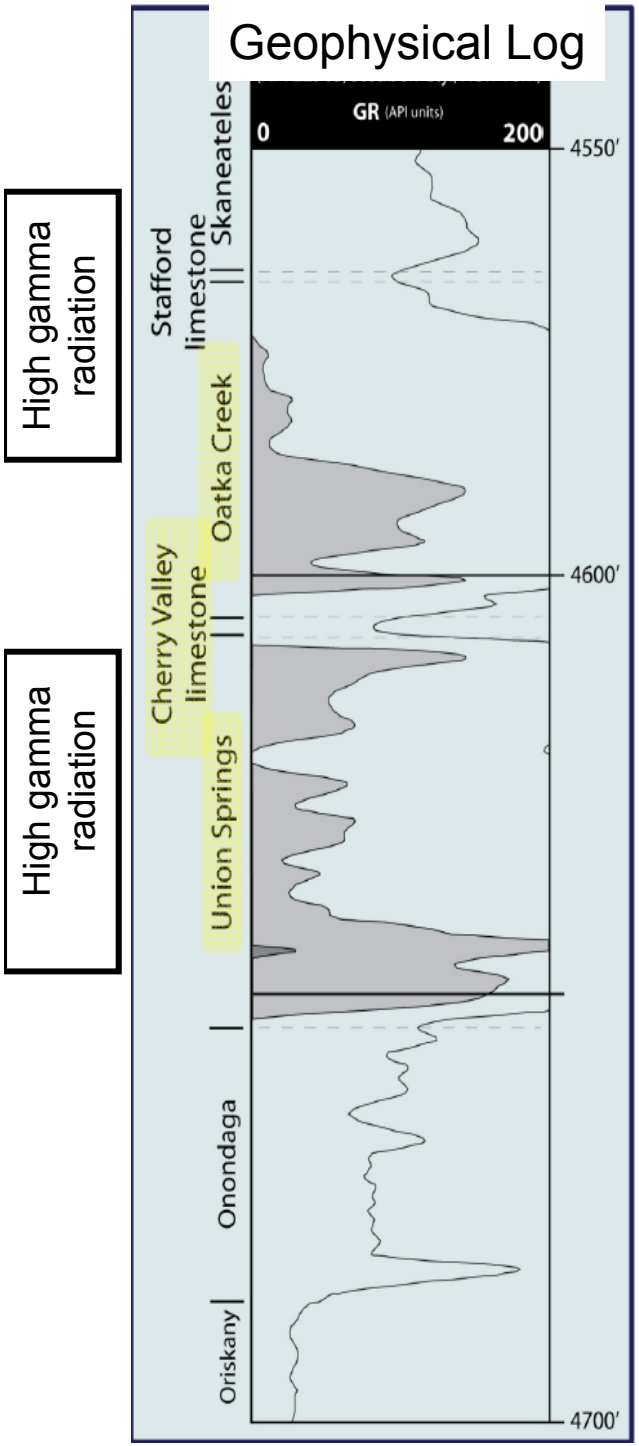
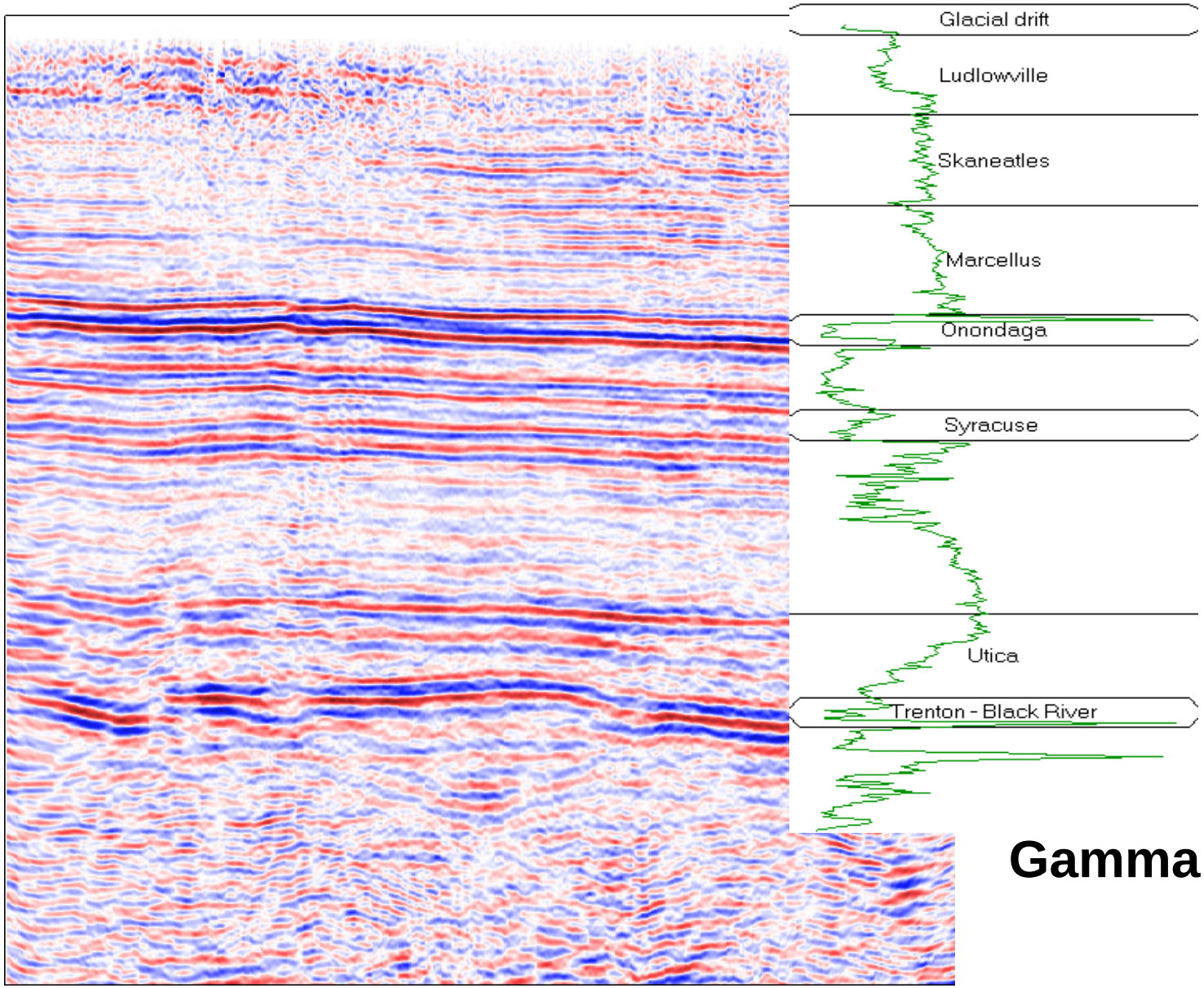
Marcellus Stratigraphy



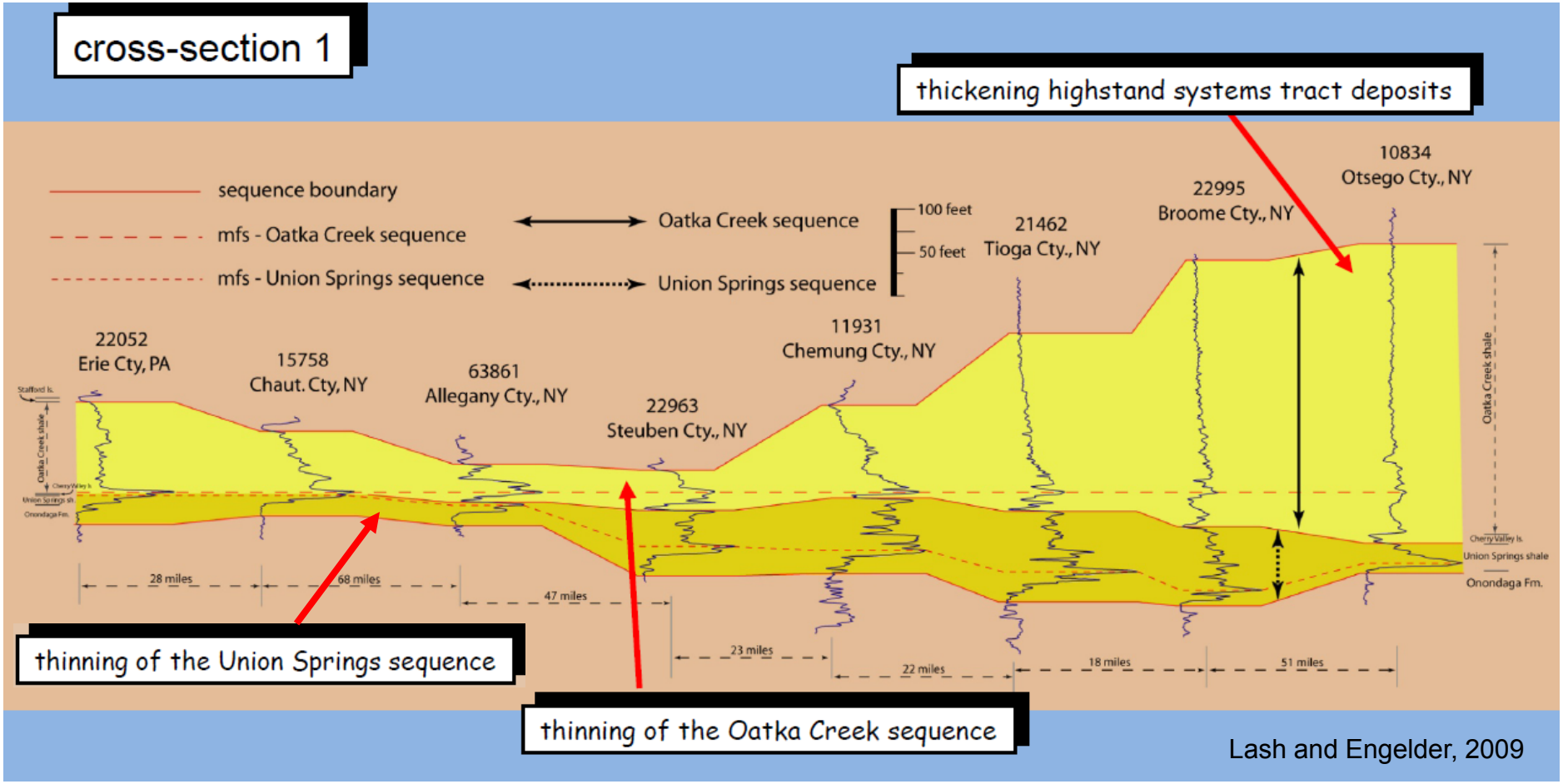
Lash and Engelder (2009)

Seismic survey from Otsego County



Gamma log

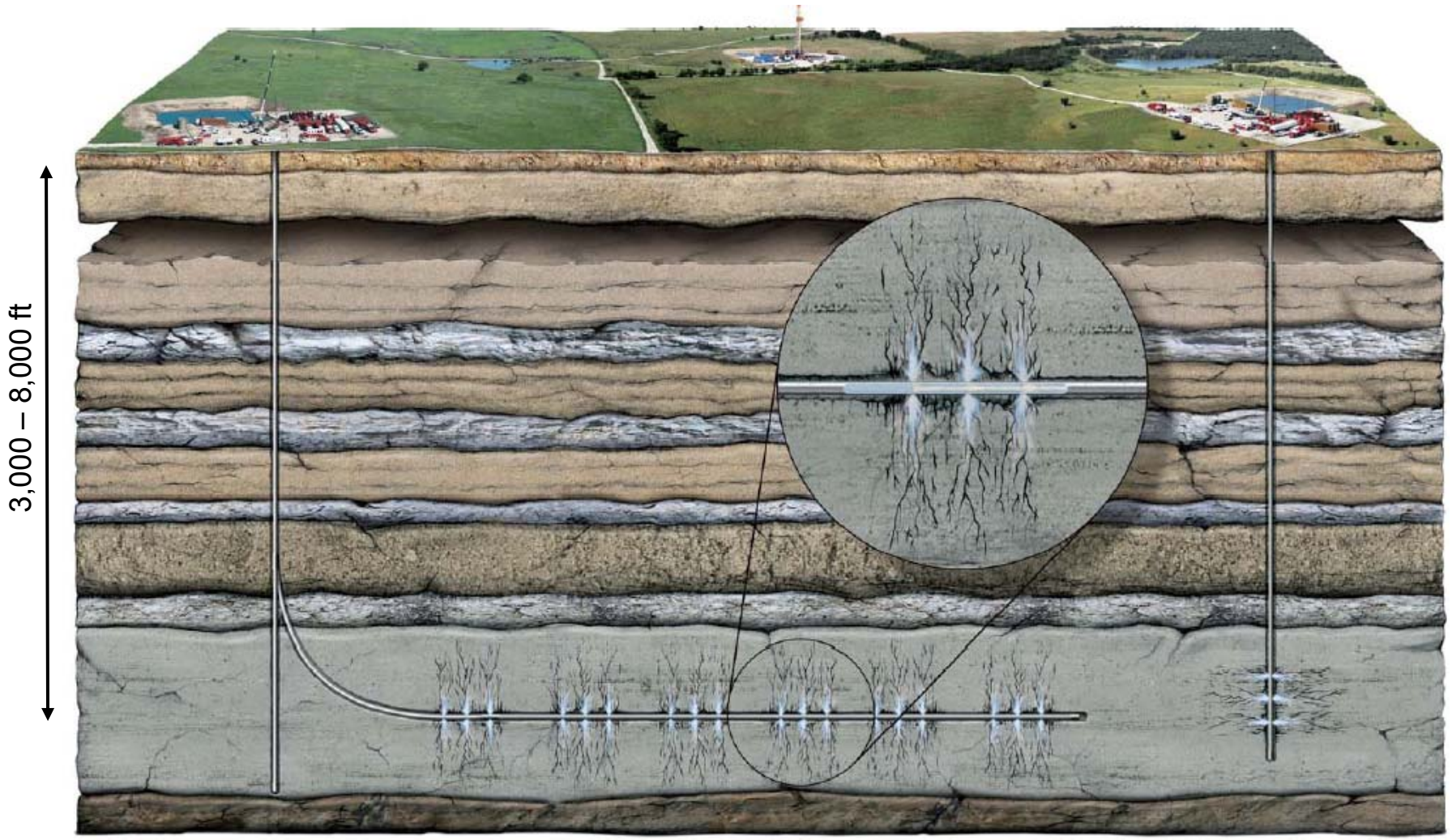
Seismic image courtesy of Gastem



Lash and Engelder, 2009

Marcellus Shale Gas Development

Horizontal Drilling and Hydraulic Fracturing



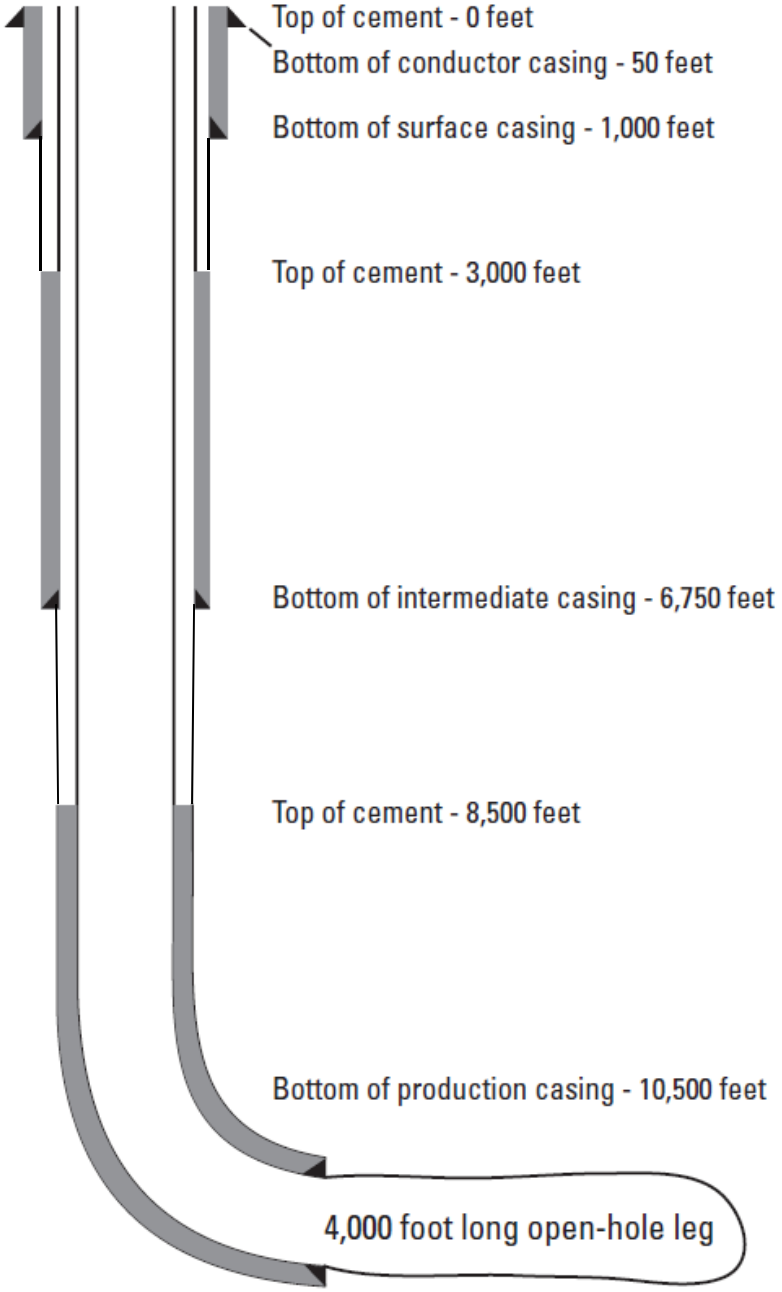
Source: Independent Oil and Gas Association of Pennsylvania

Horizontal Drilling

- **First horizontal well was drilled in 1948**
- **First horizontal shale gas well was drilled in 1988 in the Antrim Shale, Michigan**
- **First horizontal gas well in New York was drilled in 1989**

NYSERDA

Trenton/Black River well

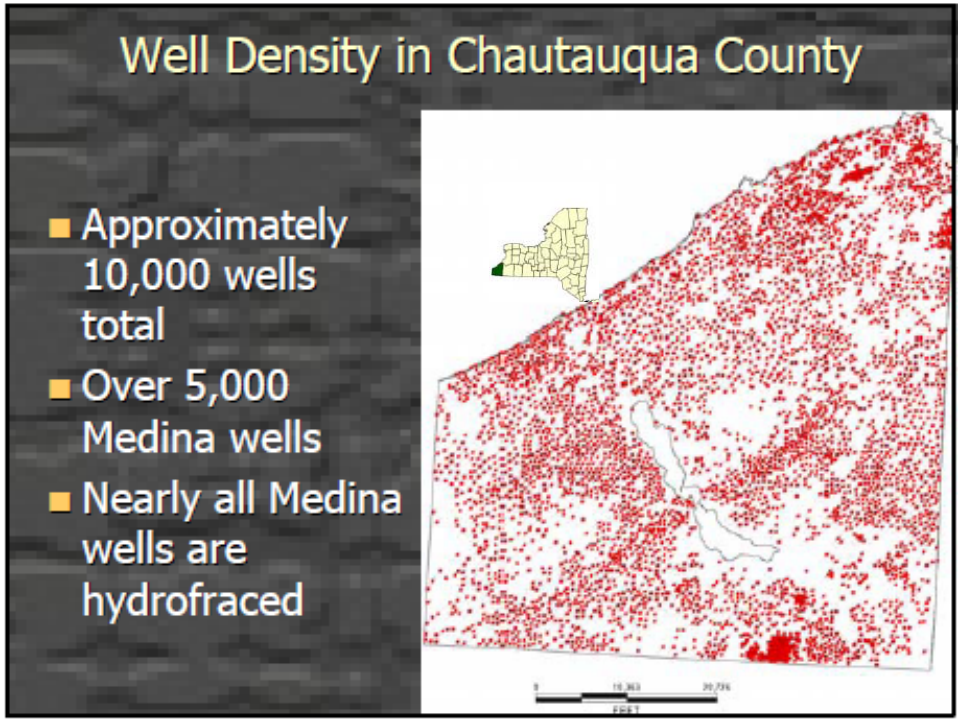


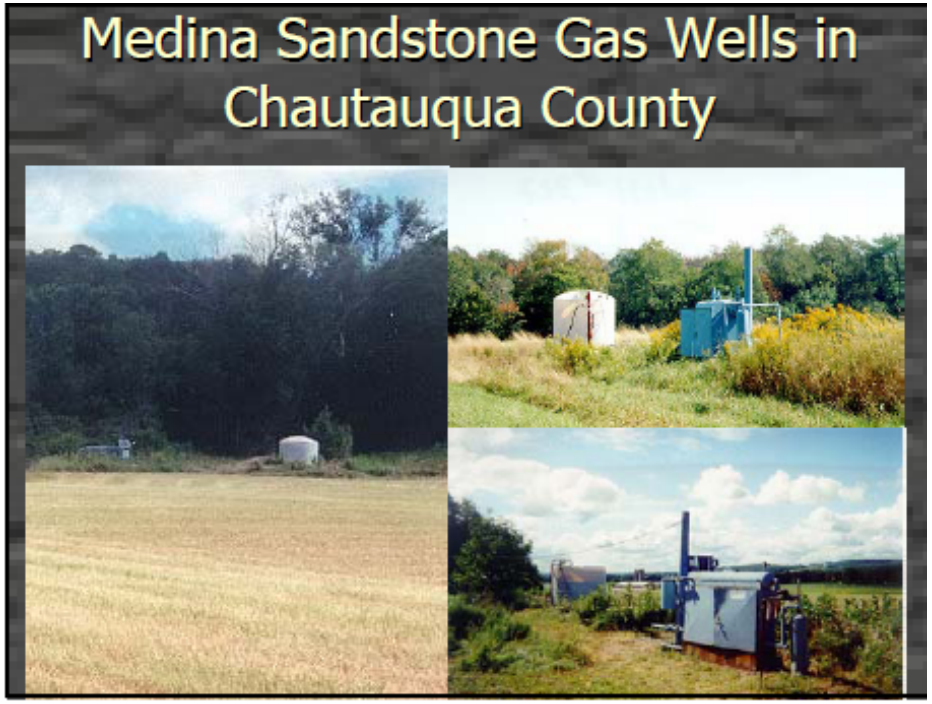
Hydraulic Fracturing

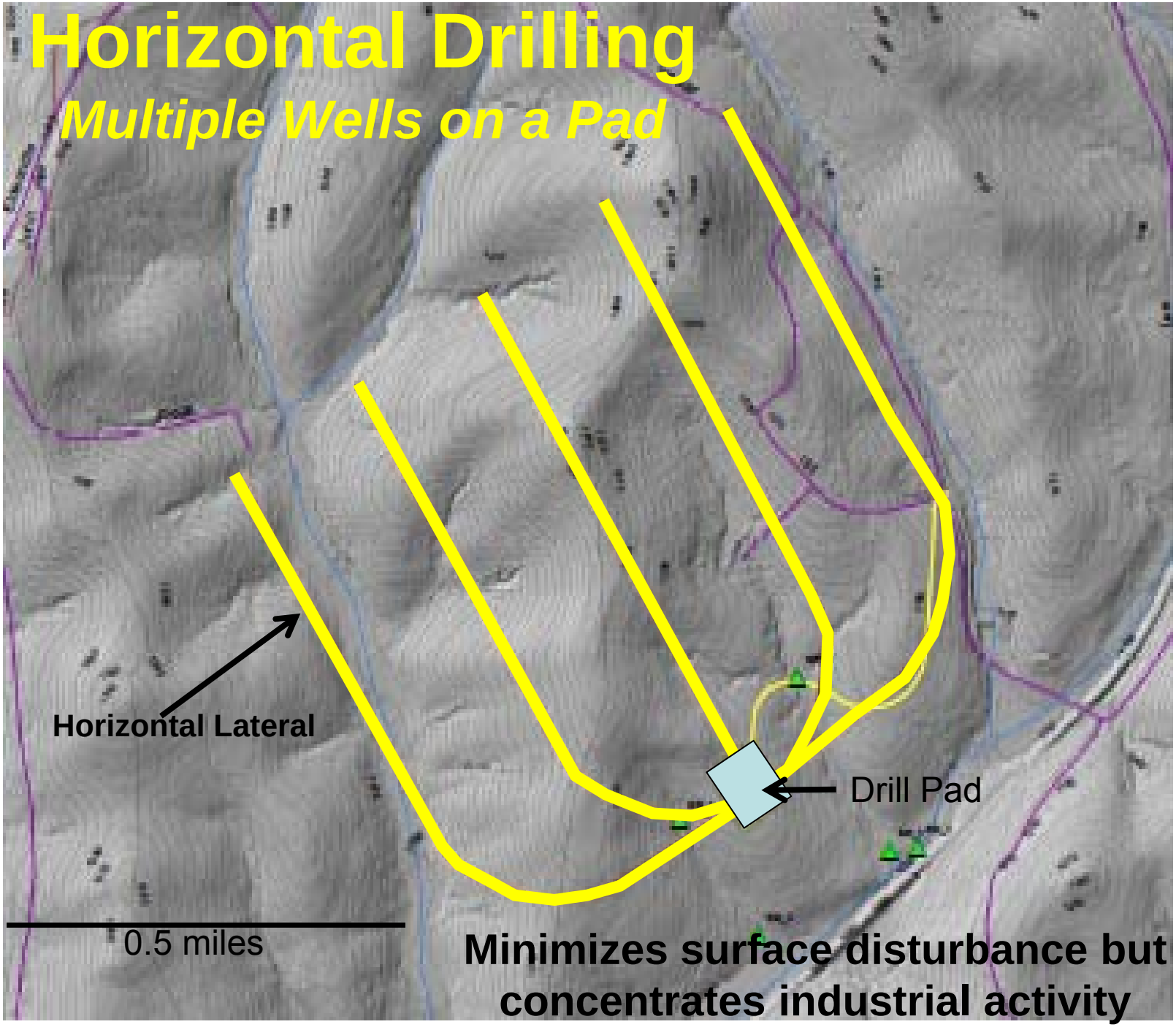
- **First hydraulic fracturing of oil & gas well was in 1948**

- **Hydraulic fracturing water used extensively on Medina Sandstone, a tight gas reservoir, in western New York and Pennsylvania during the 1970s**

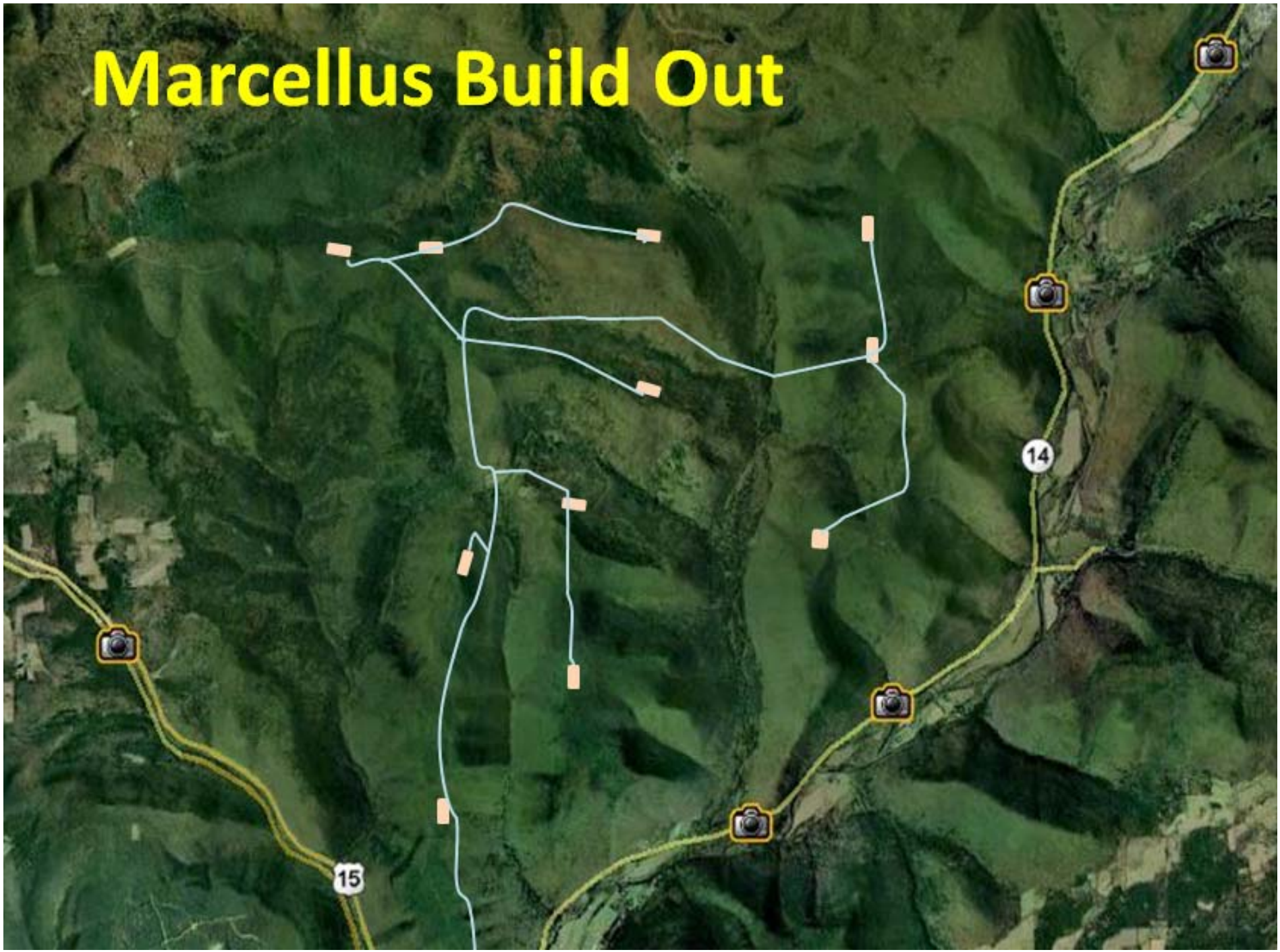
- **100,000 wells are developed by hydraulic fracturing per year**

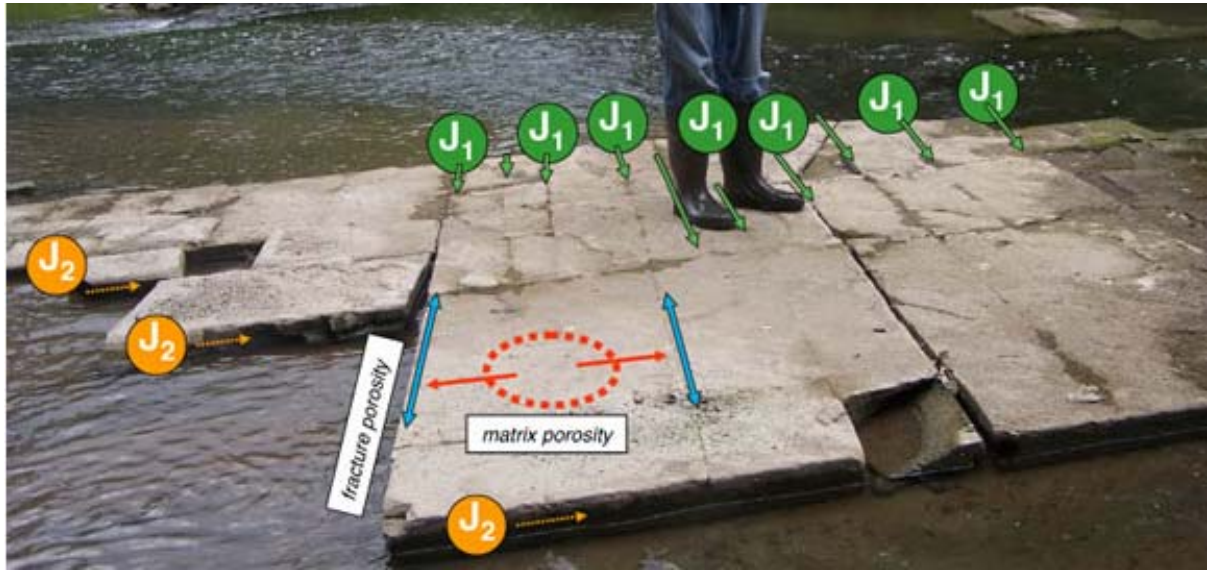





Horizontal Drilling
Multiple Wells on a Pad
Horizontal Lateral
Drill Pad
0.5 miles
Minimizes surface disturbance but concentrates industrial activity

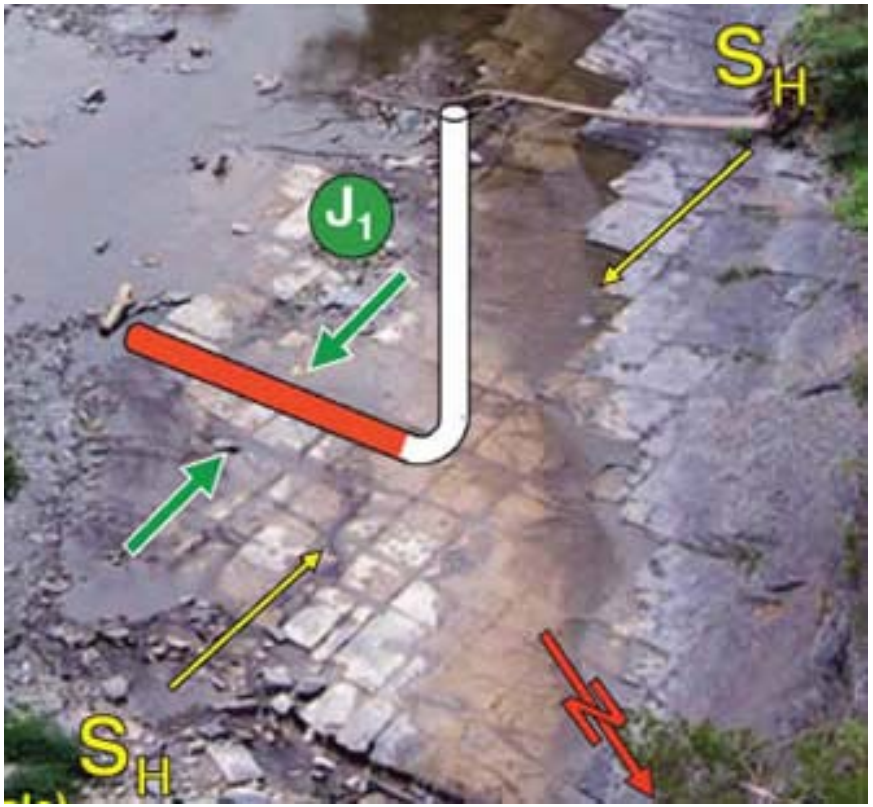

Drill Pad


Marcellus Build Out
14
15



Orthogonal joint sets
East-northeast trending J1 fractures and northwest-trending J2 fractures

Dual porosity gas reservoir where fractures drain rapidly and matrix drain slowly



Drill horizontal wells to the north-northwest or south-southeast perpendicular to major horizontal stress and J1 fractures

Free gas and adsorbed gas in matrix

Connect matrix porosity to the wellbore by intersecting multiple J1 fractures

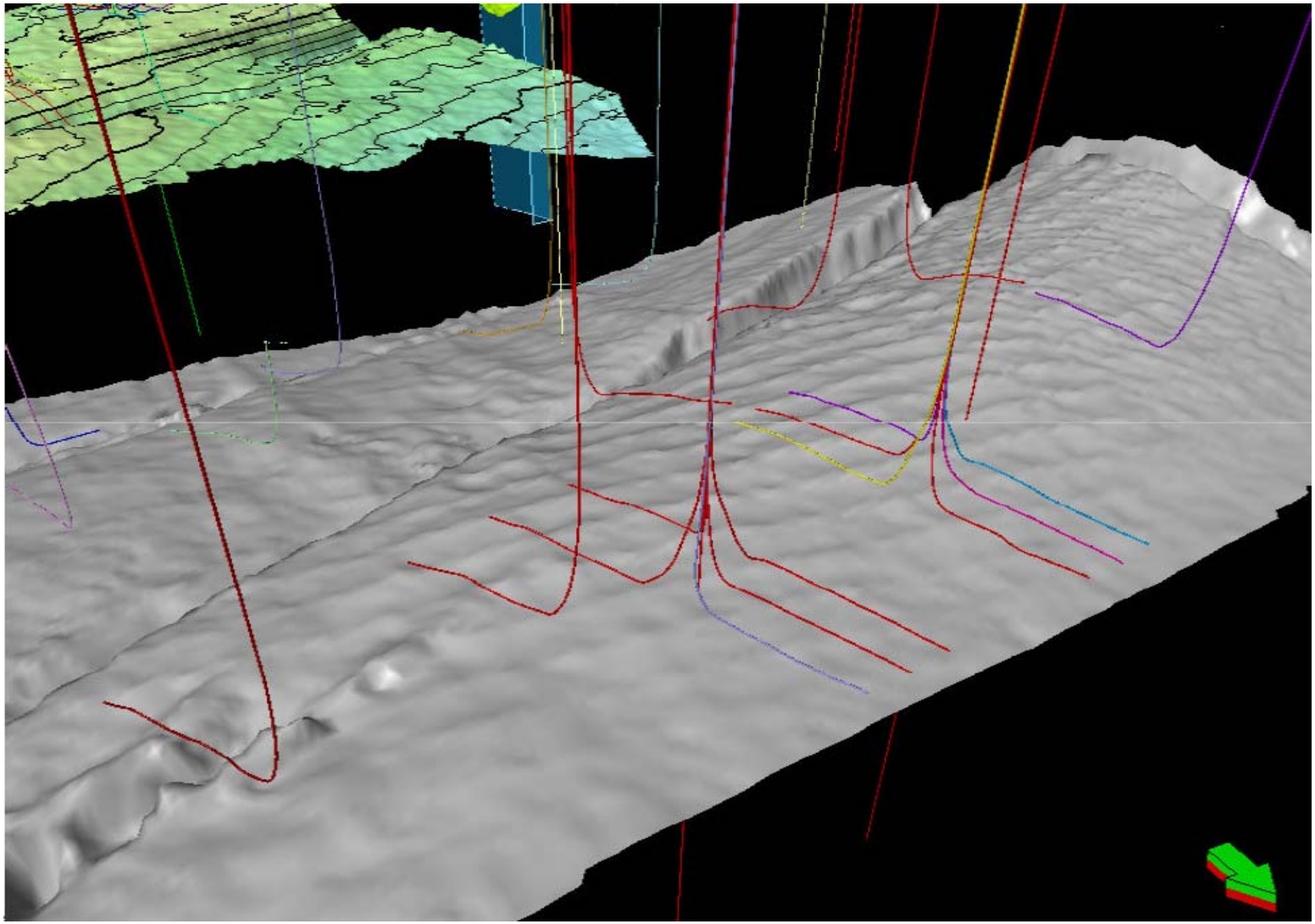
Terry Engelder PSU

Top-set rig for drilling vertical surface-cased interval

Directional rig for drilling horizontal leg

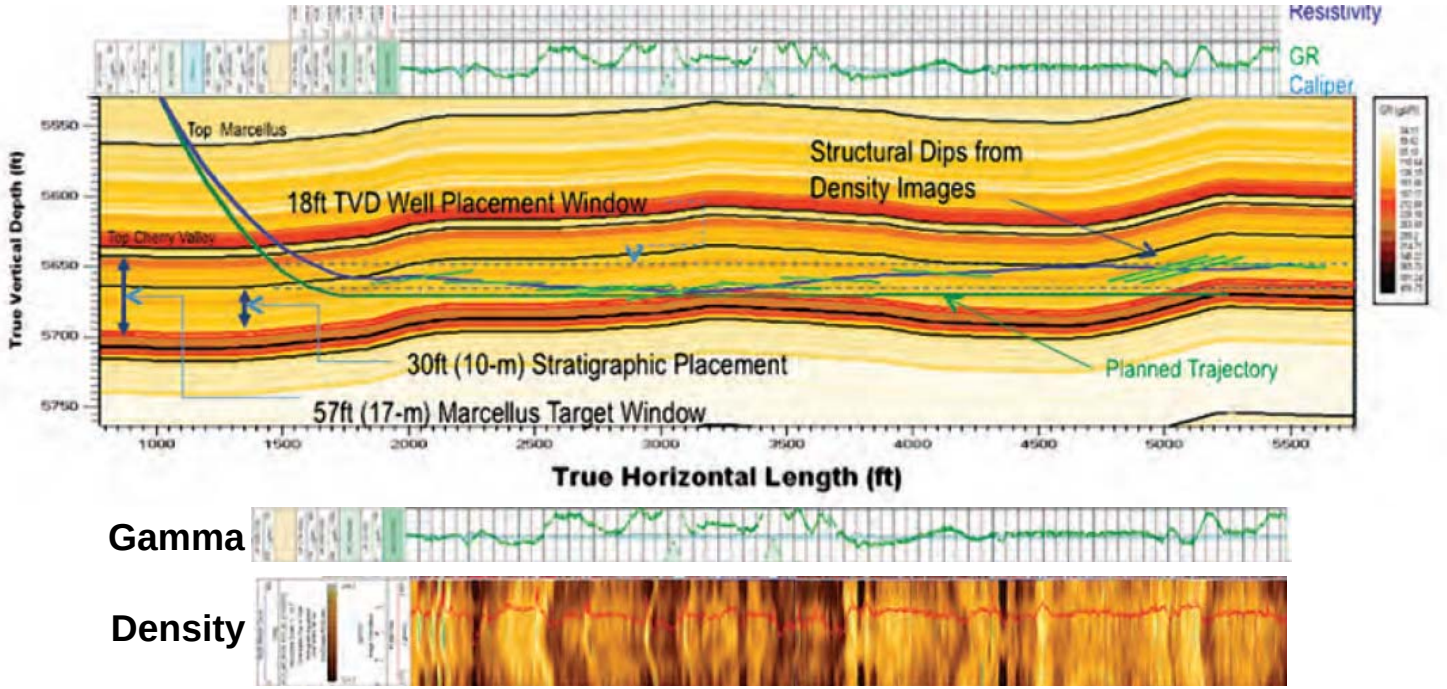
Big Rig for Horizontal Drilling

Horizontal wells target basal Marcellus Shale



Teff (2011)

Target horizon in basal Marcellus shale mapped using offset well logs and seismic



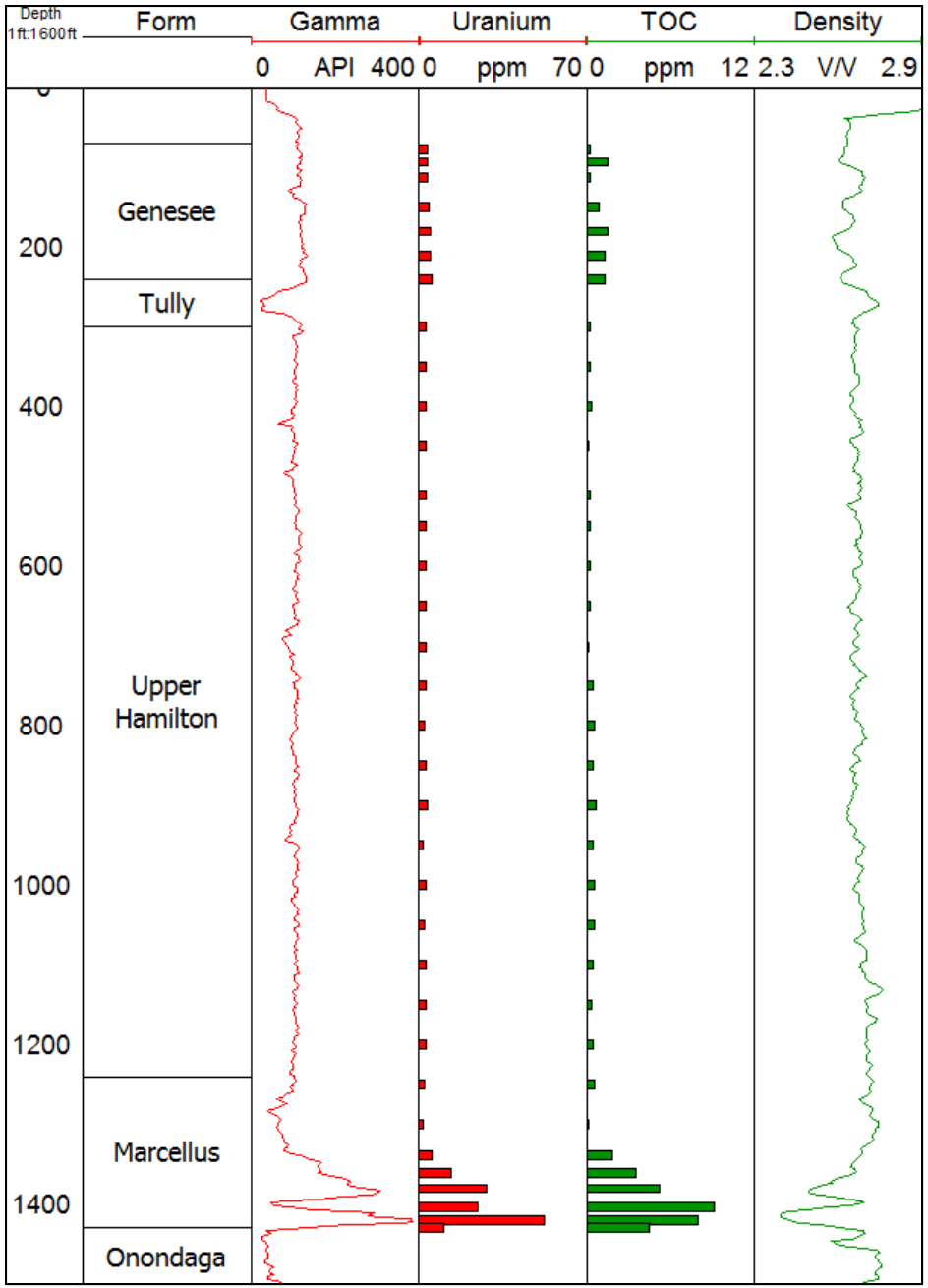
Logging-while-drilling used to steer lateral within target beds

Schlumberger (2010)

High TOC and elevated radioactivity in basal Marcellus Shale

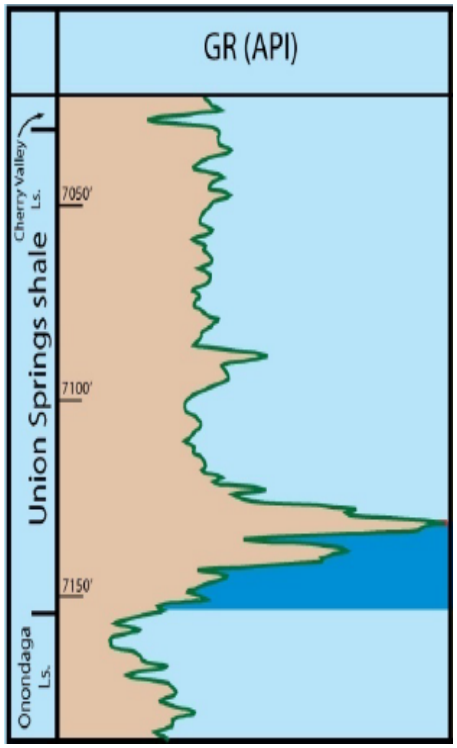
Location of the Core	Uranium Content (ppm)
Allegheny, NY	8.9 – 67.7
Tompkins County, NY	25 – 53
Livingston County, NY	16.6 – 83.7

Levanthal and others (1981)

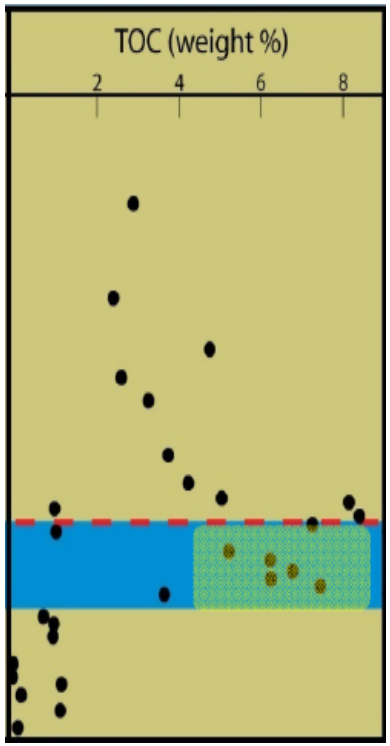


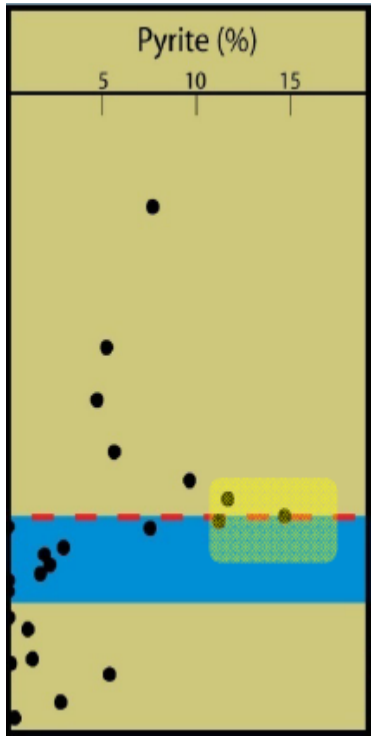
High TOC and abundant pyrite in basal Marcellus Shale

Gamma Log



Drill Core Sample Analysis

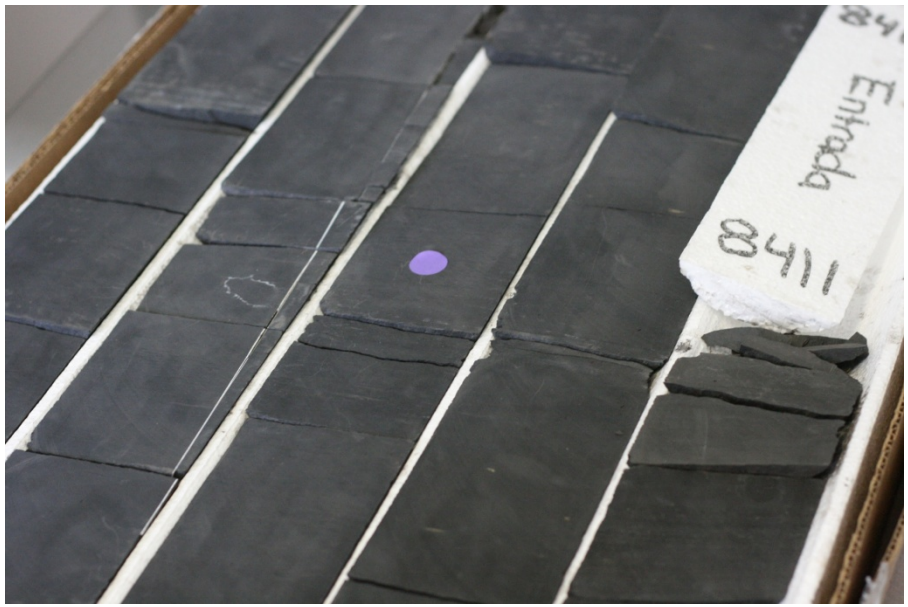




Lash and Engelder (2009)

Drill Cuttings

- **Elevated uranium and abundant pyrite in high-TOC black shale**
- **Multi-horizontal well site will generate more than 500 times the volume of shale cuttings than single-vertical well site**



Core of target interval

Drill cuttings

Drilling Fluids and Cuttings

Lined pit

Closed-loop system

Mixed with sawdust

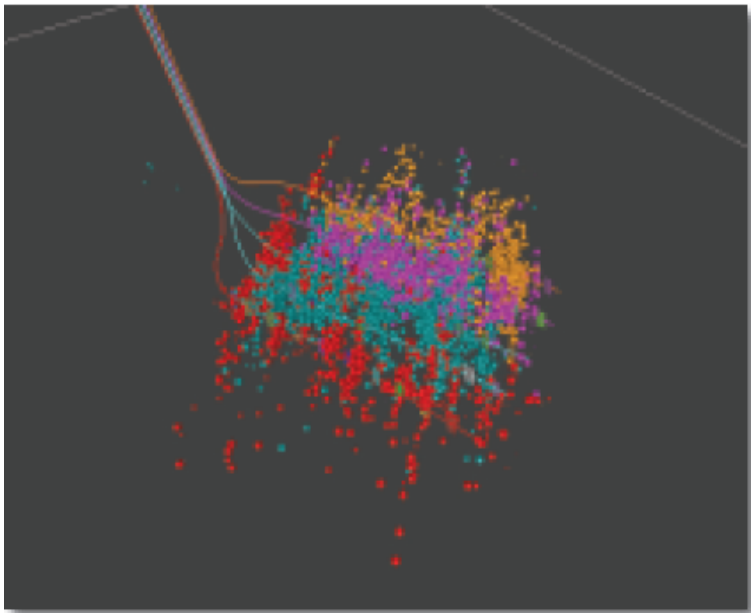
Offsite disposal in landfill

Hydraulic Fracturing

Marcellus Hydraulic Fracturing

- Produces readily detectable microseismic events (400 per frac)
- Frac half lengths greater than 1,000 feet
- Frac azimuths typically east-northeast parallel to J1 joint sets
- Reactivation of pre-existing joints by strike-slip failure

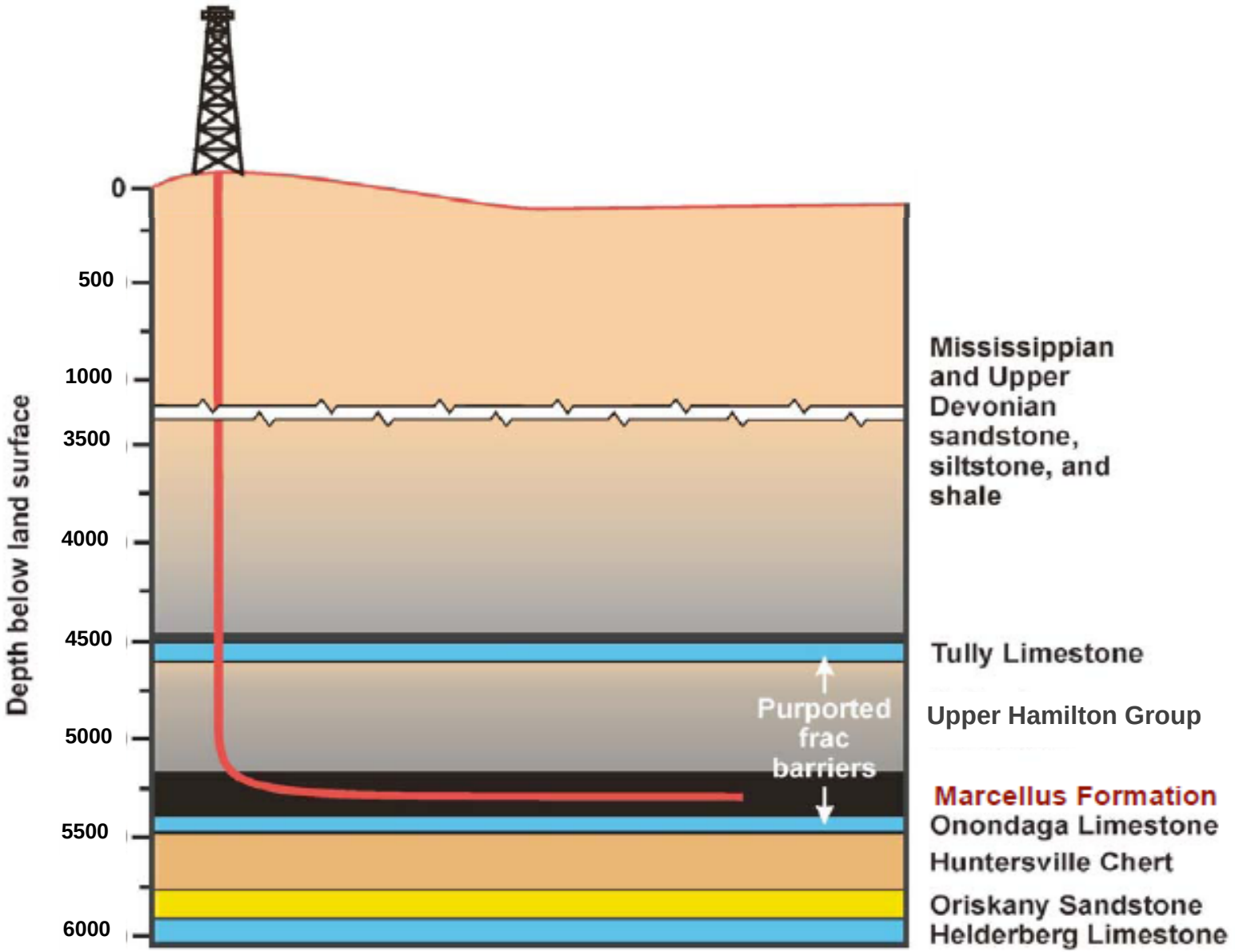
Duncan and Williams-Stroud (2009)



Microseismic for five Marcellus laterals

Joint sets in the Appalachian Basin

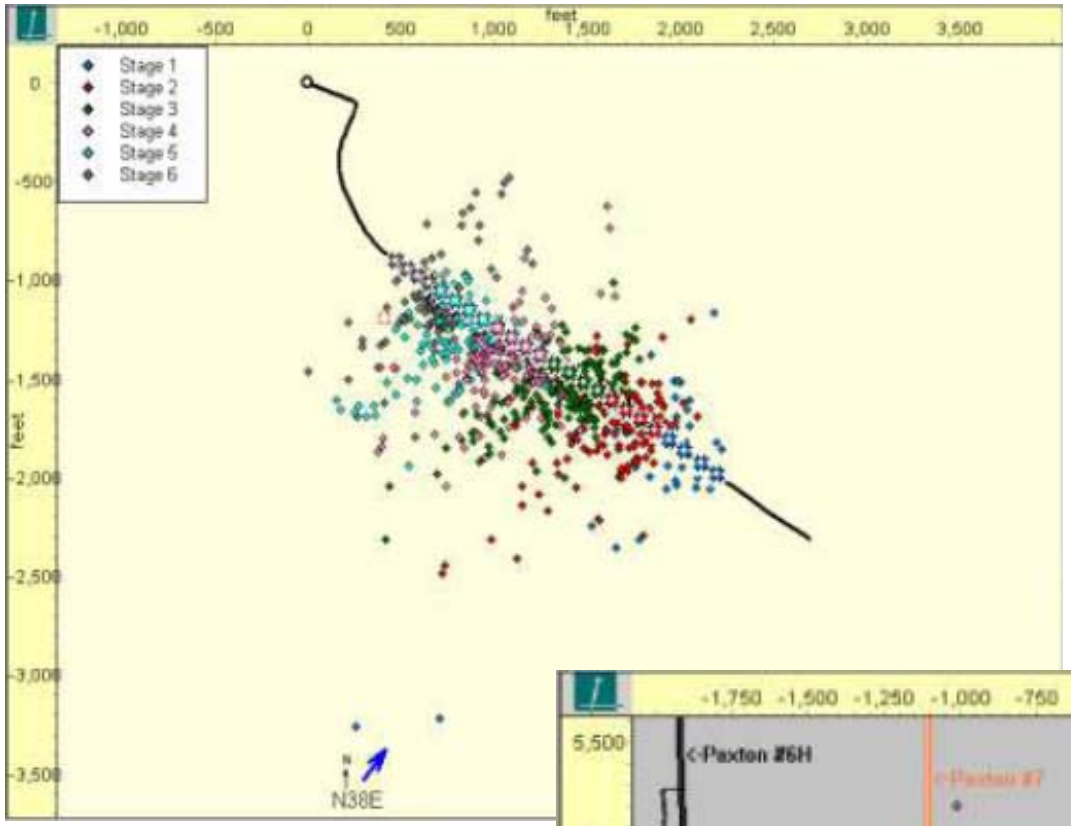
Stratigraphy and Barriers to Fracture Propagation

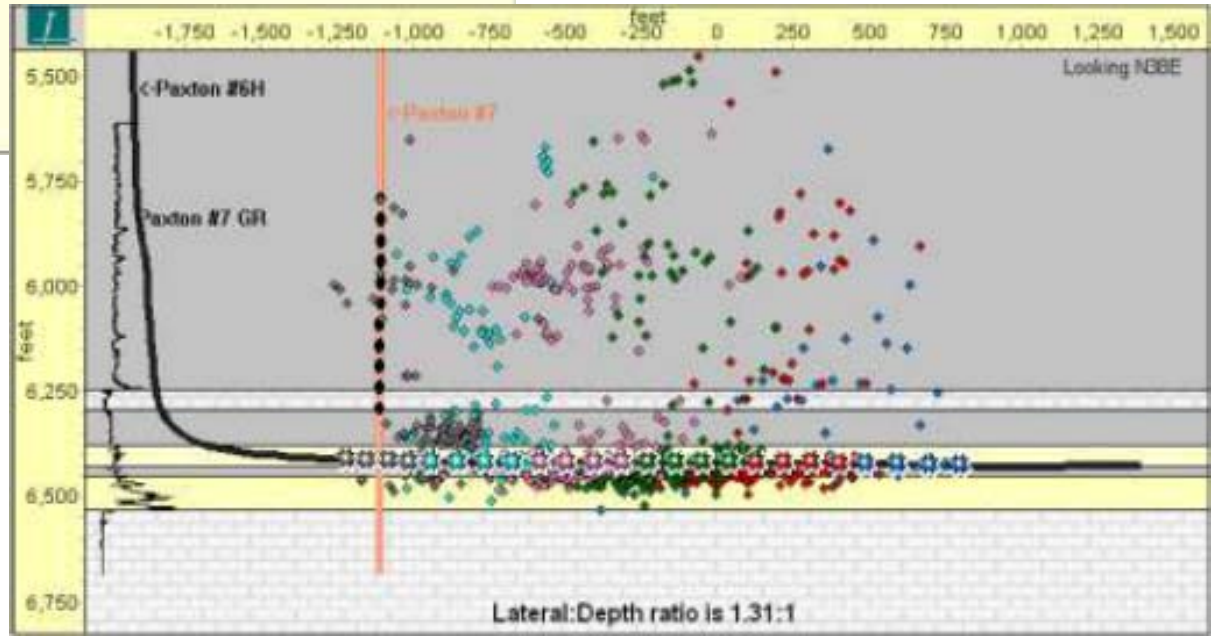


Modified from Kostelnick (2010)

Microseismic Monitoring of Marcellus Fracs

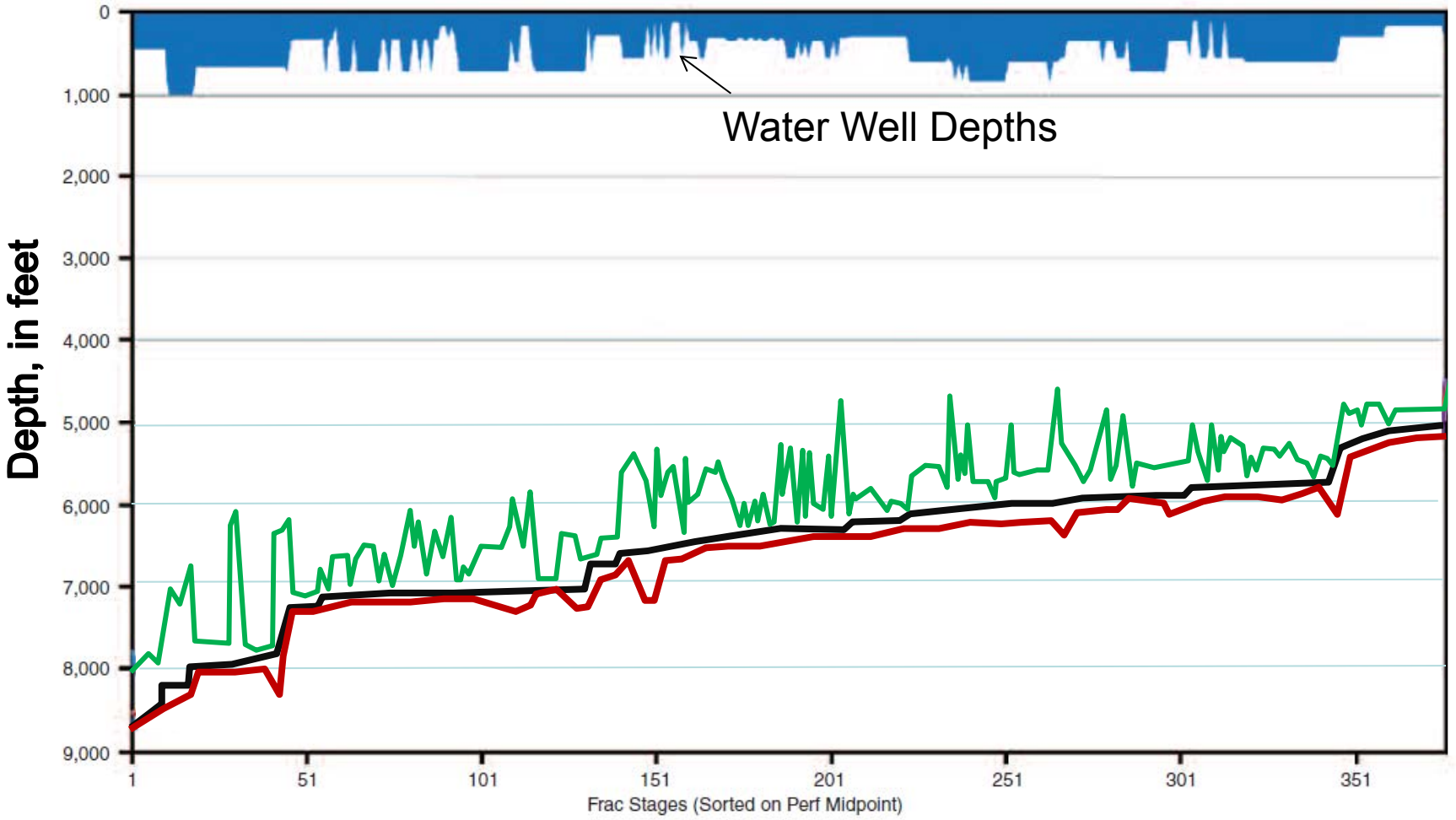
(Marcellus SPE 131783)





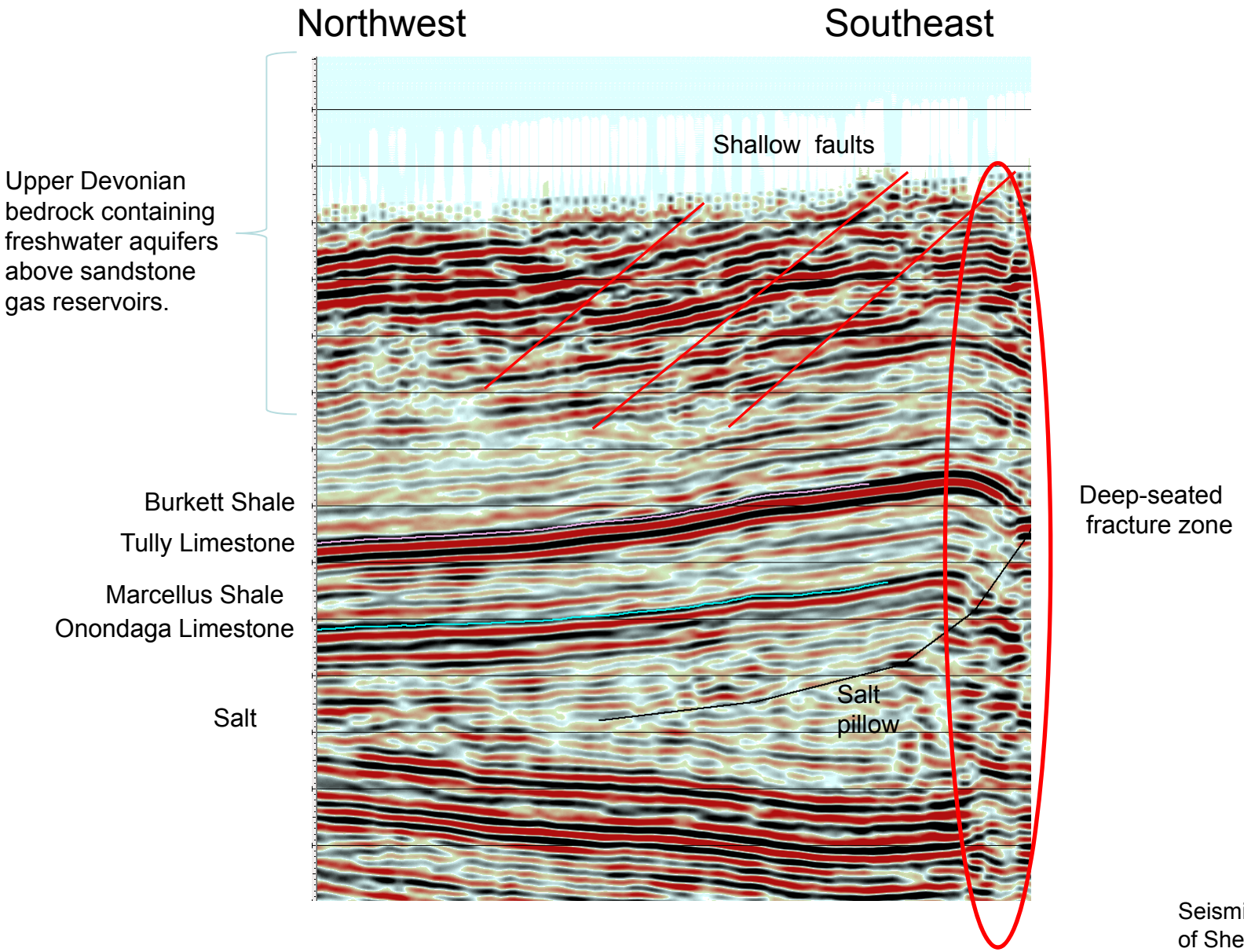
Microseismic Mapped Fracture Treatments

Marcellus Shale



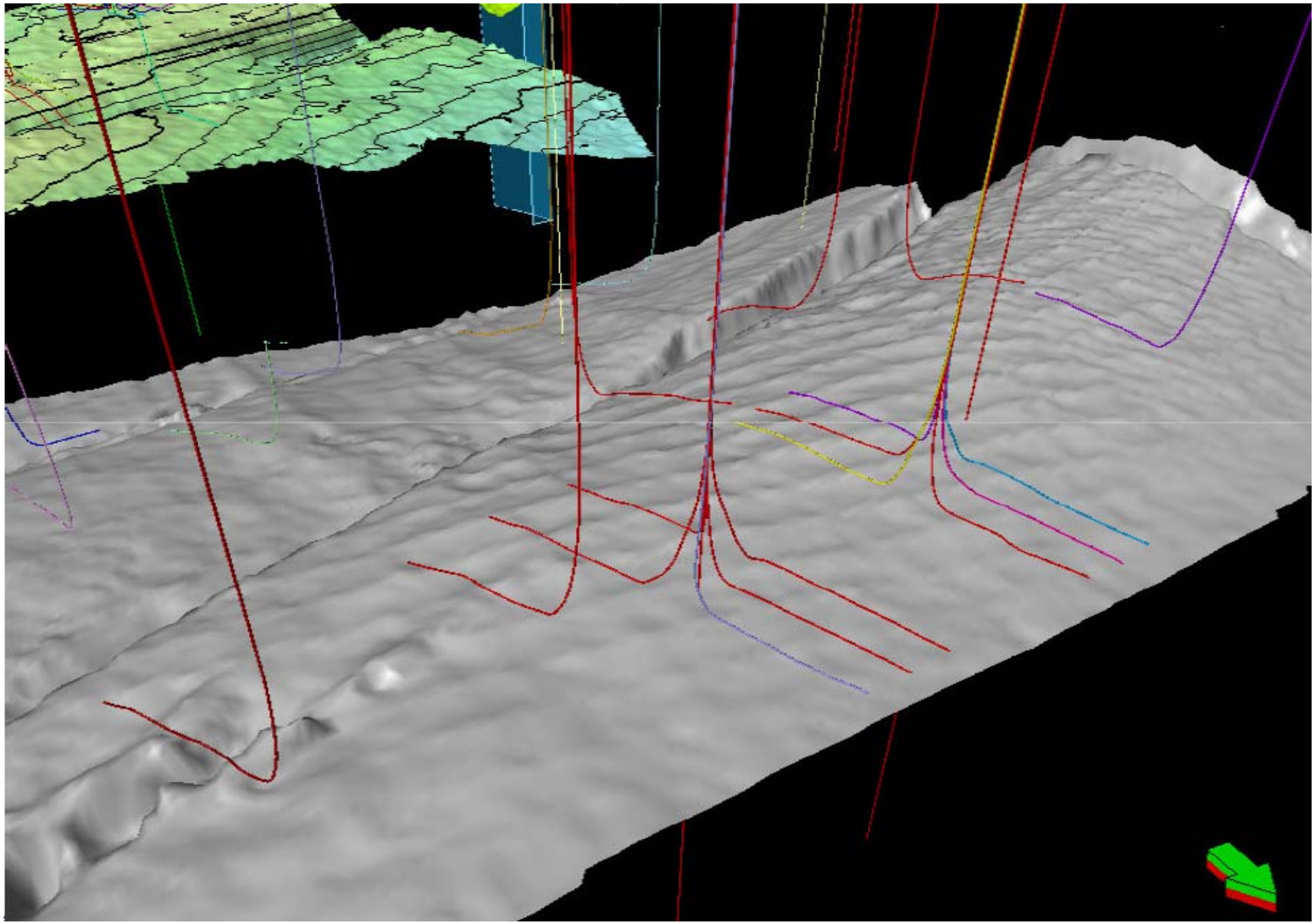
Source: Fisher, July 2010, The American Oil and Gas Reporter

Seismic Line from North-Central Pennsylvania



Seismic data courtesy of Shell Appalachia

Avoid Structures



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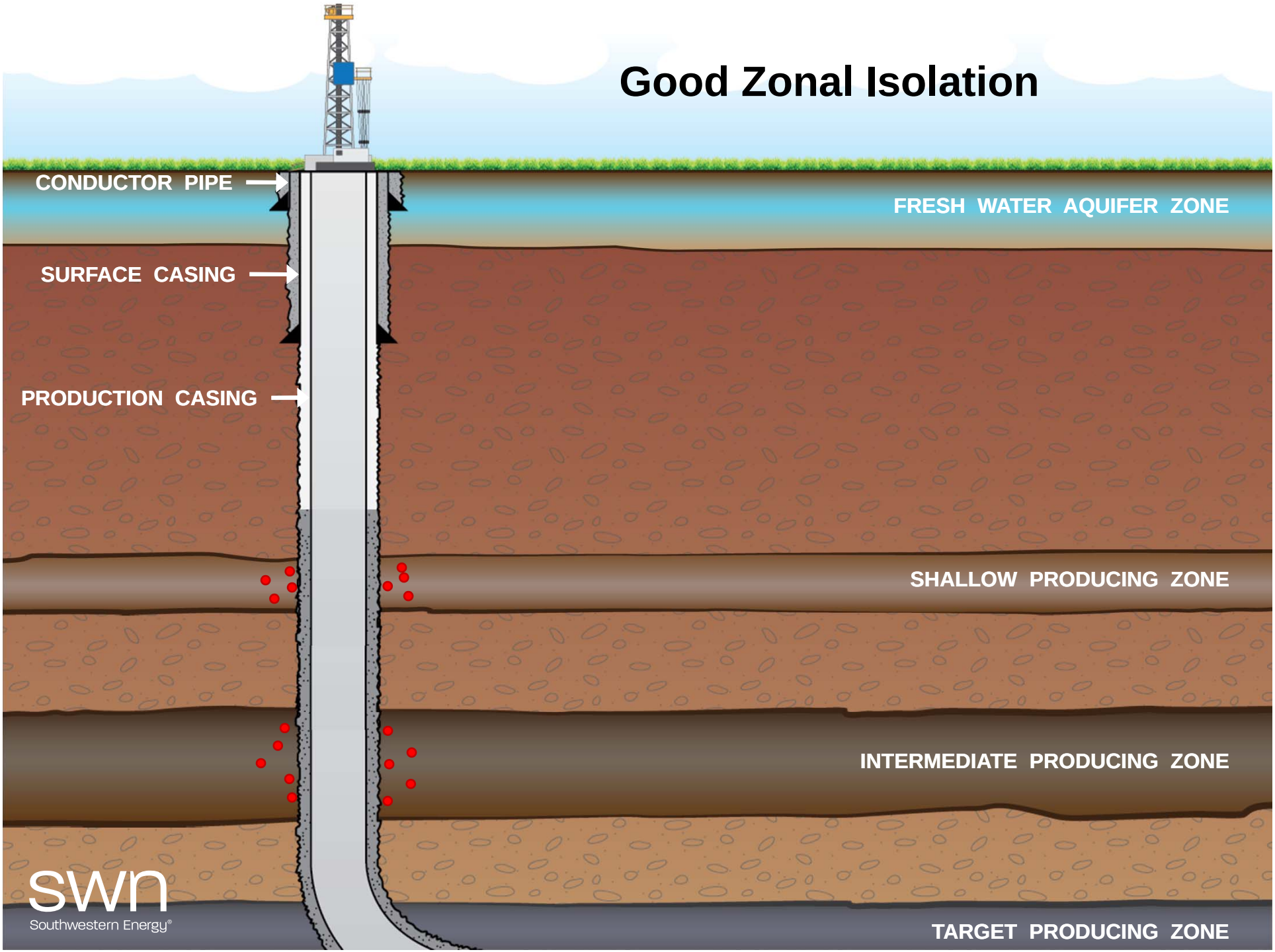
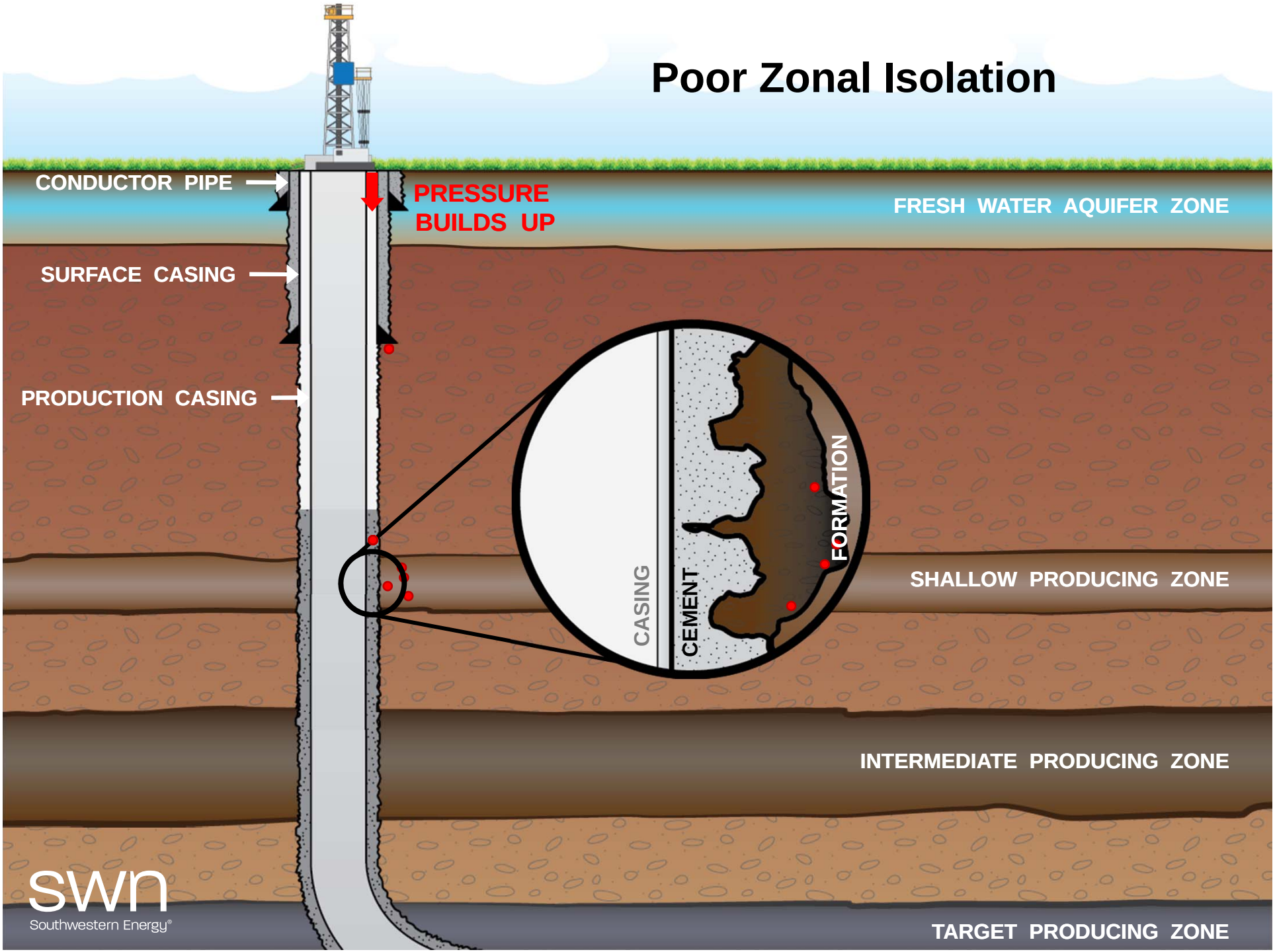

Good Zonal Isolation
CONDUCTOR PIPE
SURFACE CASING
PRODUCTION CASING
FRESH WATER AQUIFER ZONE
SHALLOW PRODUCING ZONE
INTERMEDIATE PRODUCING ZONE
TARGET PRODUCING ZONE
swn
Southwestern Energy®


Poor Zonal Isolation
CONDUCTOR PIPE
PRESSURE BUILDS UP
FRESH WATER AQUIFER ZONE
SURFACE CASING
PRODUCTION CASING
CASING
CEMENT
FORMATION
SHALLOW PRODUCING ZONE
INTERMEDIATE PRODUCING ZONE
TARGET PRODUCING ZONE
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Air & Waste Management
A s s o c i a t i o n
Mid-Atlantic States Section

Marcellus Shale Gas Air Quality Issues

MASS-A&WMA Conference

Environmental Aspects of Shale Gas Development

Trenton, N.J.

Spring 2012

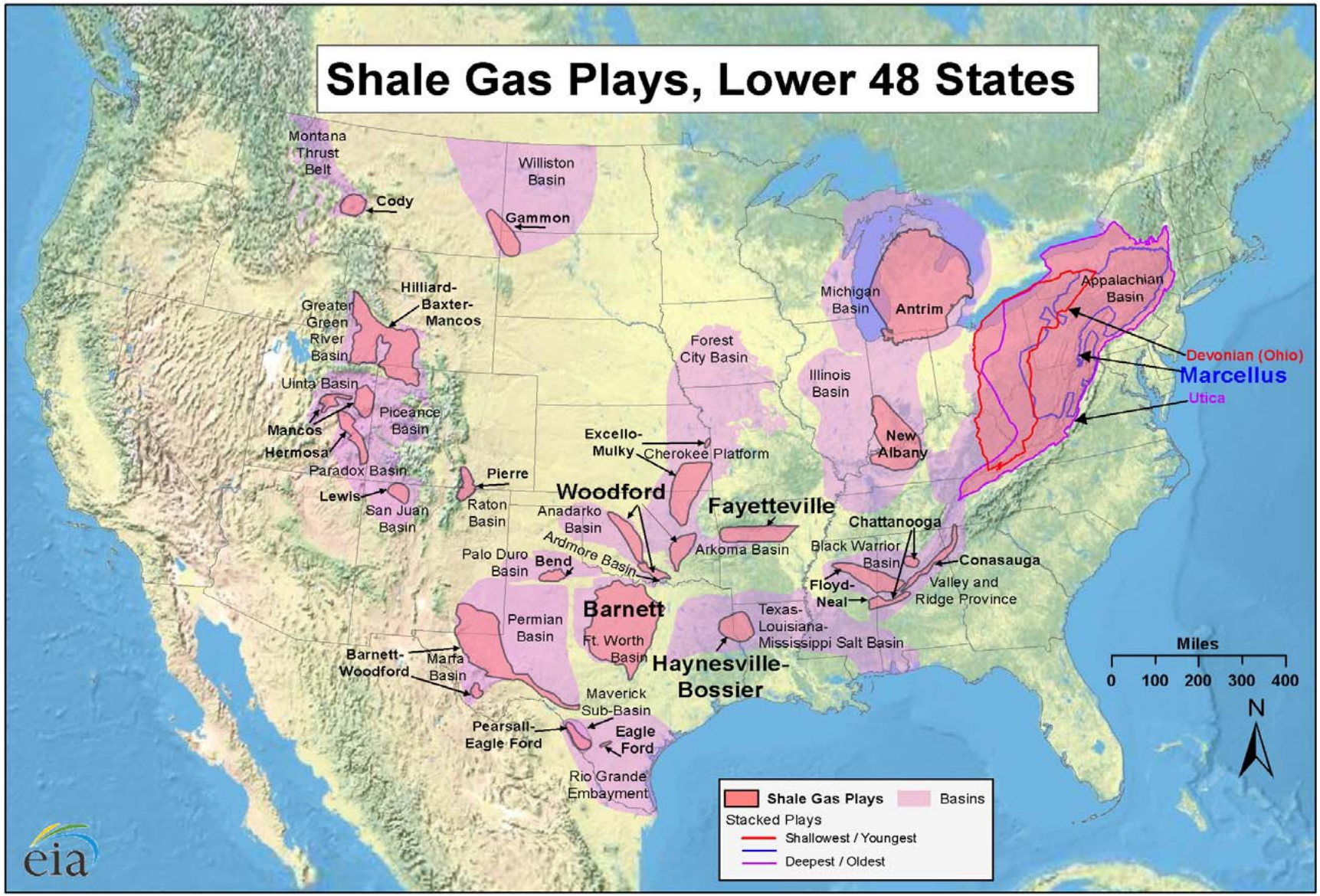
Presented by:
John Slade, Senior Consultant, All4 Inc.

ALL4

Air & Waste Management
Association
Mid-Atlantic States Section

Overview

- Extent of Shale Gas Formations
- Sources of Air Emissions
- Pollutants Emitted
- Air Quality Permitting
- Source Definition - Aggregation
- GHG Tailoring Rule
- Federal Regulations

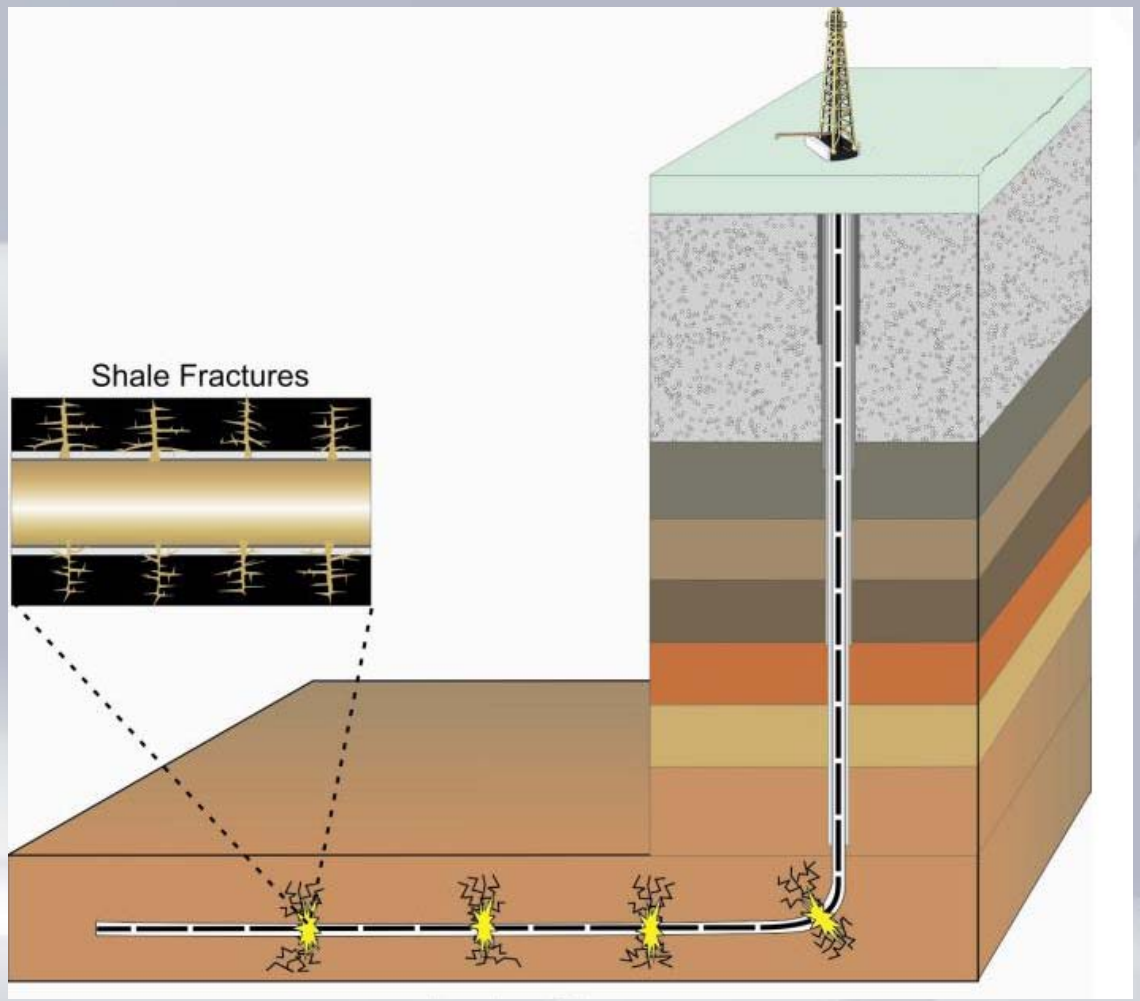


Source: Energy Information Administration based on data from various published studies.
Updated: March 10, 2010

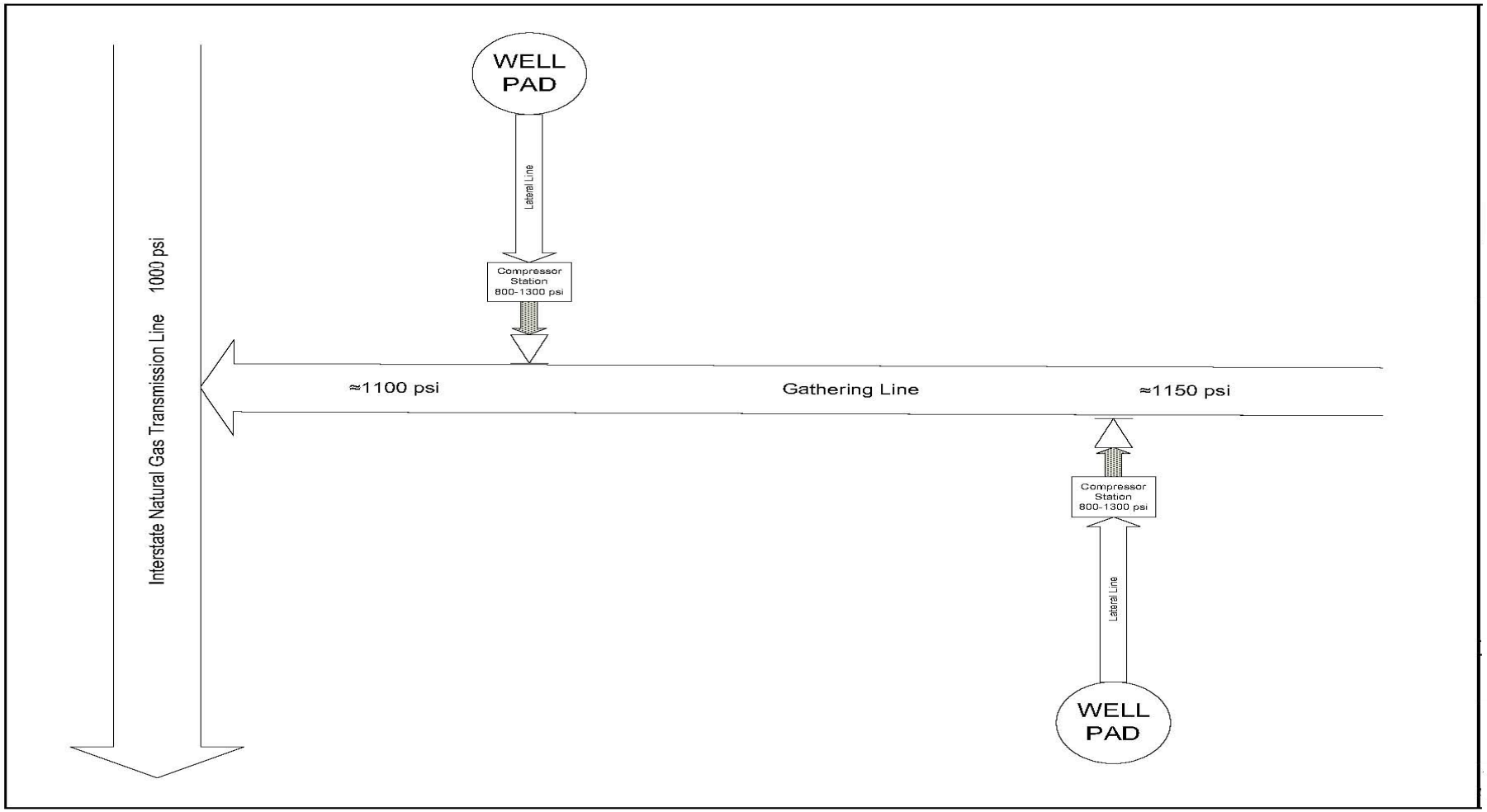
Sources of Air Emissions

- Sources of emissions
  - Well Development
    - Drilling
    - Fracturing shale formations
    - Initial well completions
  - Gas Compression Stations
    - Reciprocating internal combustion engines
    - Dehydration units
    - Separators
    - Re-boilers

Shale Gas Wells



Gas Collection & Transmission



Pollutants Emitted

- Emission Profiles
  - Combustion products
    - Nitrogen oxides (NO_X)
    - Carbon monoxide (CO)
    - Particulate matter ($PM/PM_{10}/PM_{2.5}$)
    - Sulfur dioxide (SO_2)
    - Total Hydrocarbons (THC/VOCs)
  - Process Emissions
    - Methane (GHGs)
    - Total hydrocarbons (THC/VOCs)
    - Hazardous Air Pollutants (HAPs)

Air Quality Permitting

- Permits and Rules
  - State “pre-construction” air permitting requirements
  - Federal “pre-construction” air permitting requirements
  - State/Federal operating permit requirements
  - State implementation plan (SIP) rules
  - Federal rules (e.g., NSPS and NESHAP)

Air Permitting Process

- Individual air permit construction applications and operating permits
- General Operating Permits
- Public Notices
- Public Hearing
- Municipal Notifications

Pennsylvania Permitting

- List of exempt activities (subject to change)
- General permits (limits on application – 30 day issuance)
  - GP-5 (Natural Gas Production Facilities) – Proposed revisions out for public comment
  - GP-9 (Diesel IC Engines)
  - GP-11 (Non-road engines for drilling and temporary generators)
- State Minor Source Permit (Not subject to Title V)
- Nonattainment areas
  - Ozone (Pennsylvania part of Ozone Transport Region)
  - $PM_{2.5}$
- State BAT for Minor Source Permits

West Virginia Permitting

- List of exempt activities (subject to change)
- General permits (limits on application – 45 day issuance)
  - G30-D (Natural Gas Production Facilities - NGPF)
  - G33-A (NGPF – adds engines subject to Part 60, Subpart JJJJ)
  - G35-A (NGPF - with glycol dehydration units)
- Rule 13 , Minor Source Permit (no State BAT)
- Nonattainment areas
  - Ozone (NOT part of the Ozone Transport Region)
  - $PM_{2.5}$

Ohio Permitting

- List of exempt equipment and activities (subject to change)
- General permits (typical issuance less than 30 days)
  - GP 5.1 and 5.2 (Unpaved Roads and Parking Lots)
  - GP 12 (Oil and Gas Well-Site Production Operations)
- State Minor Source Permit (Not subject to Title V or NSR)
- Nonattainment areas
  - Ozone (NOT part of the Ozone Transport Region)
  - $PM_{2.5}$
- State BAT for Minor Source Permits
  - Established in general permit for affected sources

Ozone Nonattainment

- Northeast Ozone Transport Region (OTR)
  - Established by § 7511c (a) of the Clean Air Act (CAA)
  - Includes Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Maryland, Delaware, the northern counties of Virginia, and the District of Columbia
  - Entire area is minimally considered as a moderate ozone nonattainment area

Ozone Nonattainment

- OTR Requirements
  - §7511c (b)(1)(A): enhanced vehicle inspection and maintenance
  - §7511c (b)(1)(B): Reasonably Available Control Technology (RACT) for major (> 50 ton) VOC sources
  - §7511a (b)(1)(A)(ii)(II): RACT for major (>100 to) NO_X sources
  - §7511c (b)(2):
    - Any stationary source that emits or has the potential to emit at least 50 tons per year of VOC shall be considered a major stationary source
    - Such sources shall be subject to the requirements which would be applicable to major stationary sources if the area were classified as a moderate nonattainment area.

Ozone Nonattainment

- Nonattainment New Source Review (NSR)Requirements
  - 100 tpy major source threshold for NO_X nonattainment NSR (NNSR)permitting vs. 250 tpy in “attainment areas”
  - 50 tpy major source threshold for VOC NNSR permitting vs. 250 tpy in “attainment areas”
  - For existing facilities, aggregation of contemporaneous VOC or NO_X emission increases
  - Lowest Achievable Emission Rate (LAER) and emission offset requirements

$PM_{2.5}$ Nonattainment

- Scattered fine particulate matter ($PM_{2.5}$) non-attainment areas throughout state
  - Major modification threshold is 10 tpy and includes condensable PM
  - $PM_{2.5}$ NNSR rules include aggregation of contemporaneous $PM_{2.5}$ emission increases
  - Sulfur dioxide (SO_2) is a $PM_{2.5}$ precursor
  - NO_X is a precursor pollutant for $PM_{2.5}$ emissions

$PM_{2.5}$ Nonattainment

- Significant increase in $PM_{2.5}$ precursors (NO_X and SO_2) in $PM_{2.5}$ nonattainment area triggers NNSR
- $PM_{2.5}$ Emission Reduction Credits (ERCs) are generally not available
- Direct $PM_{2.5}$ ERCs and $PM_{2.5}$ precursor ERCs must be in the vicinity of the project

Prevention of Significant Deterioration

- Best Available Control Technology (BACT)
- Ambient air quality impacts analysis
- "Double Jeopardy" for ozone and $PM_{2.5}$ precursor pollutants NO_2 and SO_2
- Stringent new National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$, NO_2, and SO_2

Source Definition for Permitting

- Source Aggregation
  - Why is aggregation important?
    - PTE of "source" defines air permitting requirements (and schedule)
    - The definition of "source" under NSR and Title V has it roots in the case of *Alabama Power v. Costle*, 636 F.2d 323 (D.C. Cir. 1979)
    - Source was limited by the four statutory terms, "structure, building, facility or installation"
    - U.S. EPA can treat contiguous and commonly owned units as a single source if they fit within these terms

Source Definition for Permitting

- The U.S. EPA defined “stationary source” facility to mean any building, structure, or facility which meets three criteria:
  - (1) belong to the same two-digit SIC Code;
  - (2) are under the control of the same company; and
  - (3) are located on one or more contiguous or adjacent properties

Source Definition for Permitting

- U.S. EPA issued source aggregation guidance for oil and gas activities (Jan. 2007)
  - Guidance indicated that well sites and other production activities occurring over large geographical distances should be treated as separate sources
  - U.S. EPA withdrew the January 2007 guidance (Sept. 2009)
- Pennsylvania issued aggregation guidance document in 2011 that included a “distance” test

GHG Tailoring Rule

- PSD for GHJGs is triggered for new construction projects that result in GHG emissions of at least 100,000 tpy regardless of any other pollutant
- Modifications at existing major facilities that result in GHG emissions increases of 75,000 tpy
- Facilities that emit at least 100,000 tpy of GHG as CO2e will be subject to Title V permitting

Federal Regulations

- Standards of Performance for New Stationary sources (NSPS) requirements
  - 40 CFR Part 60 Subpart KKK – Standards of Performance of Equipment Leak VOC from Onshore Natural Gas Processing Plants
  - 40 CFR Part 60 Subpart LLL- Standards of Performance for Onshore Natural Gas Processing: SO2 Emissions
  - 40 CFR Part 60 Subpart JJJJ– Standards of Performance for Stationary Spark Ignition Internal Combustion Engines
  - 40 CFR Part 60 Subpart IIII – Standards of Performance for Compression Ignition Internal Combustion Engines
  - 40 CFR Part 60 Subpart KKKK—Standards of Performance for Stationary Combustion Turbines

Federal Regulations

- NESHAP requirements – major and possibly area sources of HAP
  - 40 CFR Part 63 Subpart HH – National Emission Standards for Hazardous Air Pollutants from Oil and Natural Gas Production Facilities
  - 40 CFR Part 63 Subpart HHH – National Emission Standards for Hazardous Air Pollutants: Oil and Natural Gas Production and Natural Gas Transmission and Storage
  - 40 CFR Part 63 Subpart ZZZZ - National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion engines

Proposed Federal Regulations

- Part 60, Subpart OOOO
  - VOC emissions from all oil and gas operations not already covered under Subpart KKK which include:
    - Well completions - “green completions”
    - Compressors
    - Pneumatic Controllers
    - Condensate and Crude Oil Storage Tanks

Proposed Federal Regulations

- Centrifugal compressors would have to be equipped with dry seal systems.
- Owners/operators of reciprocating compressors would have to replace rod packing systems every 26,000 hours of operation
- Pneumatic Controllers – new and replacement controllers cannot be gas driven

Proposed Federal Regulations

- Condensate and Crude Oil Storage Tanks
  - Tanks with greater than 1 barrels per day throughput must reduce VOC emissions by 95 percent
- Additional leak detection and repair requirements

Air Permitting Timing Issues

- General permits and applicability
- Air permitting “exemptions”
- Components of processing plants and compressor stations are air emission sources
- Major/minor sources are subject to differing requirements and timelines
- Air permits must be obtained prior to “beginning actual construction”

Air Permitting Timing Issues

- Typical “minor source” permitting timeline:
  - Application Preparation (source) is 2 to 3 months (typical)
    - Best Available Technology (BAT) for new sources
  - Agency review is typically 4 months, but can be up to 6 months
  - PSD permitting could take 18 months

Air Permitting Timing Issues

- Typical “major” source permitting timeline (PSD and/or NNSR)
  - Application Preparation (source) typically 4 months
    - BACT in attainment areas
    - LAER in non-attainment areas
    - Dispersion modeling (PSD)
    - Emission offsets (NNSR)
  - Technical review can be up to 12 months (or longer)
  - Public comment period and possible hearing = 30 days
  - U.S. EPA review and comment = 45 days
  - Total timeline = 18 months

Summary

- State and federal agencies are reviewing the environmental impact of shale gas development for air, water and waste, and proposing new and revised rules.
- New state and federal regulations will likely slow the pace of completion of new wells.
- There will be a continuing debate over the relative benefit/harm of shale gas development.

Thank You

Speaker Contact Information

John Slade

jslade@all4inc.com

Air & Waste Management
A s s o c i a t i o n
Mid-Atlantic States Section

Environmental Aspects of

Shale Gas Development

Air & Waste Management
Association
Mid-Atlantic States Section

Groundwater Issues

Presented by:

Louis F. Vittorio, Jr., P.G.

EarthRes Group, Inc.

President, PCPG

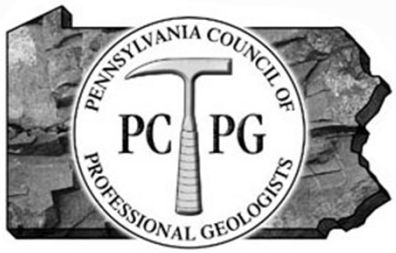
March 27, 2012

Pennsylvania Council of Professional Geologists
PC PG

ERG
EarthRes Group

Today's Presenter:

Louis F. Vittorio, Jr., P.G. - Mr. Vittorio is the Vice President and Principal Hydrogeologist at EarthRes Group, Inc. in Pipersville, PA, and has more than twenty-six years of experience in the industry. He is currently President of the Pennsylvania Council of Professional Geologists (PCPG) serving through 2012. Mr. Vittorio received his BS Degree in Geology/Geophysics from the University of Pittsburgh in 1984 and his MS Degree in Geology from Lehigh University in 1988. In his capacity at PCPG, Mr. Vittorio has organized and taught courses on hydrogeology and water sampling has provided talks to schools and industry groups. He has written articles, position papers and comments on pending regulations that affect groundwater resources.



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Talk Development and PCPG Outreach

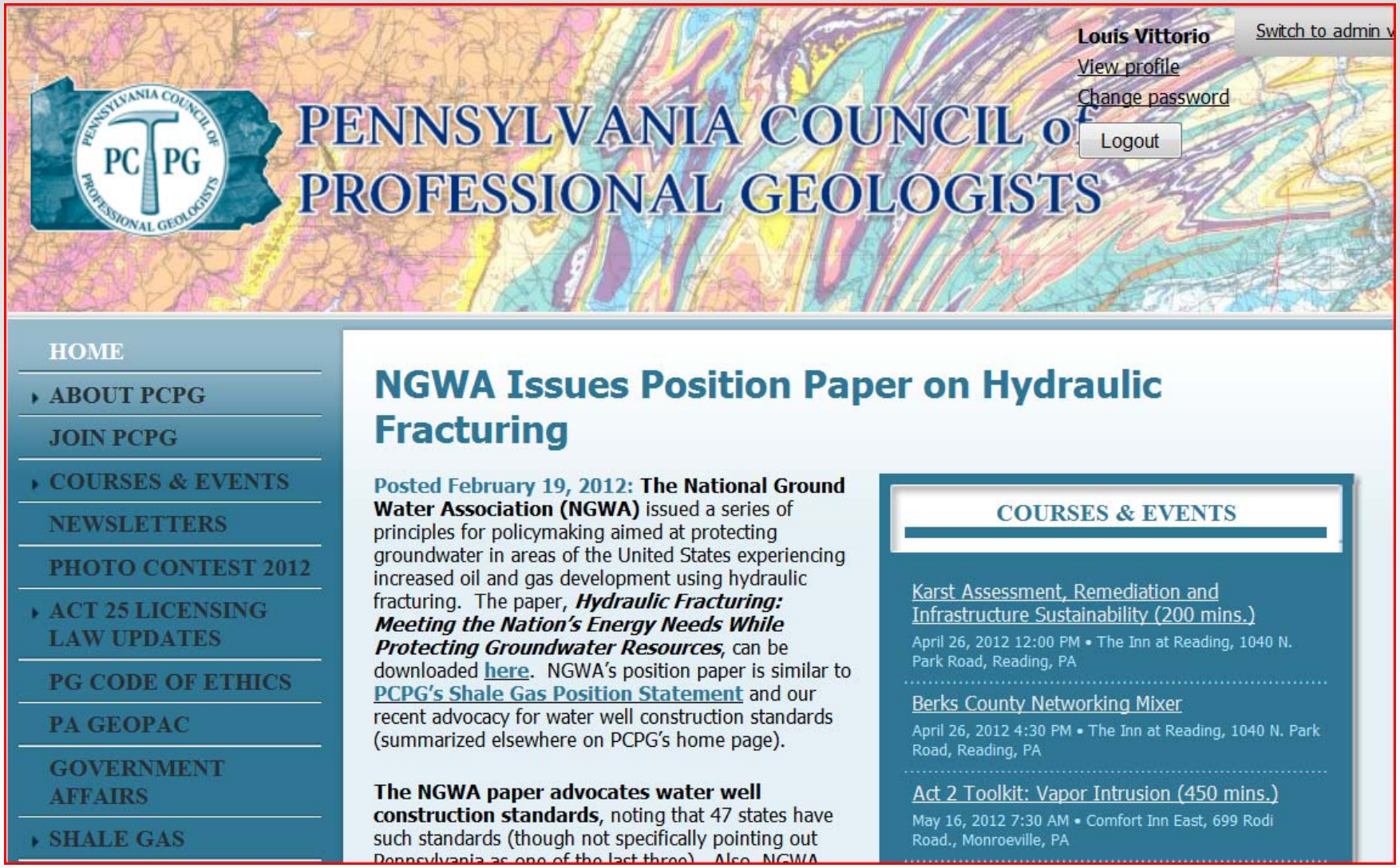
The Core of this presentation was developed by PCPG Board Members over Several Years. Special Thanks to:

Dan Billman, PG, CPG

Billman Geologic

Consultants, Inc.

Valerie Holliday, PG, CPG
GeoLogos, LLC



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PCPG Testifies in Support of Water Well Construction Standards

Posted January 11, 2012: The Chair of PCPG's Government Affairs Committee, Donald R. Wagner, PG, provided testimony to the House Consumer Affairs Committee on January 10, 2012 in support of House Bill 1855 (Miller-R), concerning water well construction standards.

PCPG has long recognized the need for private water well construction regulations to protect human health and safety and Pennsylvania's valuable water resources, and accordingly, PCPG recommends that House Bill 1855 apply to all water wells drilled or constructed in the Commonwealth, excluding those water wells for which well construction standards are already established under the authority of existing legislation (such as the Oil and Gas Act or the Safe Drinking Water Act).

As part of its testimony, **PCPG offered five general comments** regarding the proposed legislative text:

1) PCPG recommends that the scope of HB 1855 cover **all private water wells**, the construction or decommissioning of which are not otherwise regulated under the authority of existing legislation.

2) HB 1855 currently defines a **"water well owner"** as the person who owns the land on which the water well is located. PCPG notes that in some circumstances, such as off-site monitoring or remediation wells, the well owner may not be the owner of the land on which the well is located, and the owner of the well would more reasonably be the person responsible for the investigation and/or remediation.

PCPG Marcellus Shale Gas Position Statement

PCPG supports the responsible development of Pennsylvania's natural resources and has prepared a statement to provide a balanced review and discussion of Marcellus shale gas development issues. You can review and download PCPG's position statement on our Shale Gas page.

Also available on the Shale Gas page is a copy of **Gas Shale Occurrence & Impacts in the Delaware River Basin: A Geologic Perspective**. This presentation was prepared and given by PCPG board members Dan Billman, P.G. and Valerie Holliday, P.G. to the Water Resources Association of the Delaware River Basin in October 2010 and to PCPG membership in January 2011 during our Annual Meeting.

DRBC Posts Revised Draft Natural Gas Development Regulations; Postpones November 21, 2011 Special Meeting

On November 8, 2011, **the Delaware River Basin Commission (DRBC) posted revised Draft Natural Gas Development Regulations on its website at** http://www.state.nj.us/drbc/notice_naturalgas-draftregs.htm. This revised draft addresses extensive testimony and public comments to the draft regulations that were proposed in December 2010. As stated by DRBC, "The revised draft regulations apply to all 'natural gas development projects', ...including the construction and operation of all natural gas wells in the basin, regardless of the target geologic formation, whether a well is for production or exploration, and whether high-

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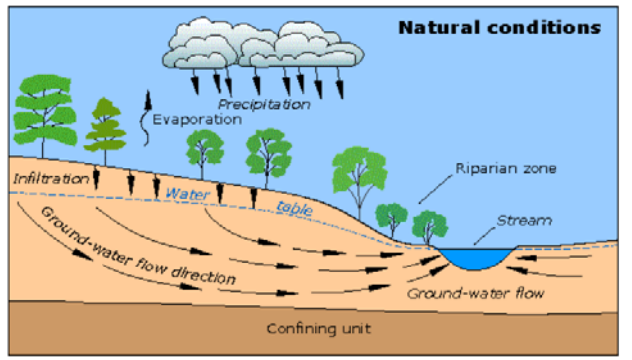
Here Today to Speak About Groundwater Issues

- Shale Gas Overview: How did we get Here?
- Water Budget of the Delaware River Basin
- Water Resource Use - SRBC
- Water Resource Protections
- Conclusions



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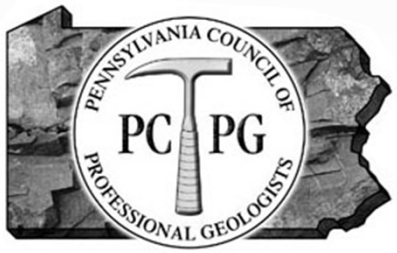
“Bottom Up” – Deep Subsurface: the Petroleum Geologist’s Perspective (Overview)

vs.

“Top Down” – Shallow Subsurface: the Hydrogeologist’s Perspective



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So What Changed (in the early 2000s?)

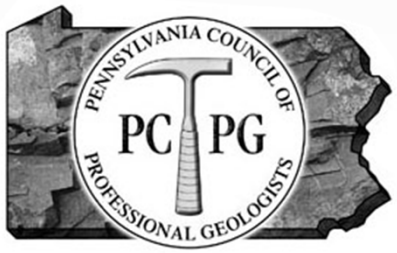
• A geologic mind shift (Paradigm Shift) from viewing shales as source and seal to viewing as a source, seal and RESERVOIR!!

• Technologic advances in horizontal drilling.

• Technologic advances in hydraulic fracturing of shales.

• Natural gas demand coupled with high energy prices. (This is what started the play...no longer the case!)

• Wall Street's (Paradigm Shift) acceptance of unconventional/continuous plays.



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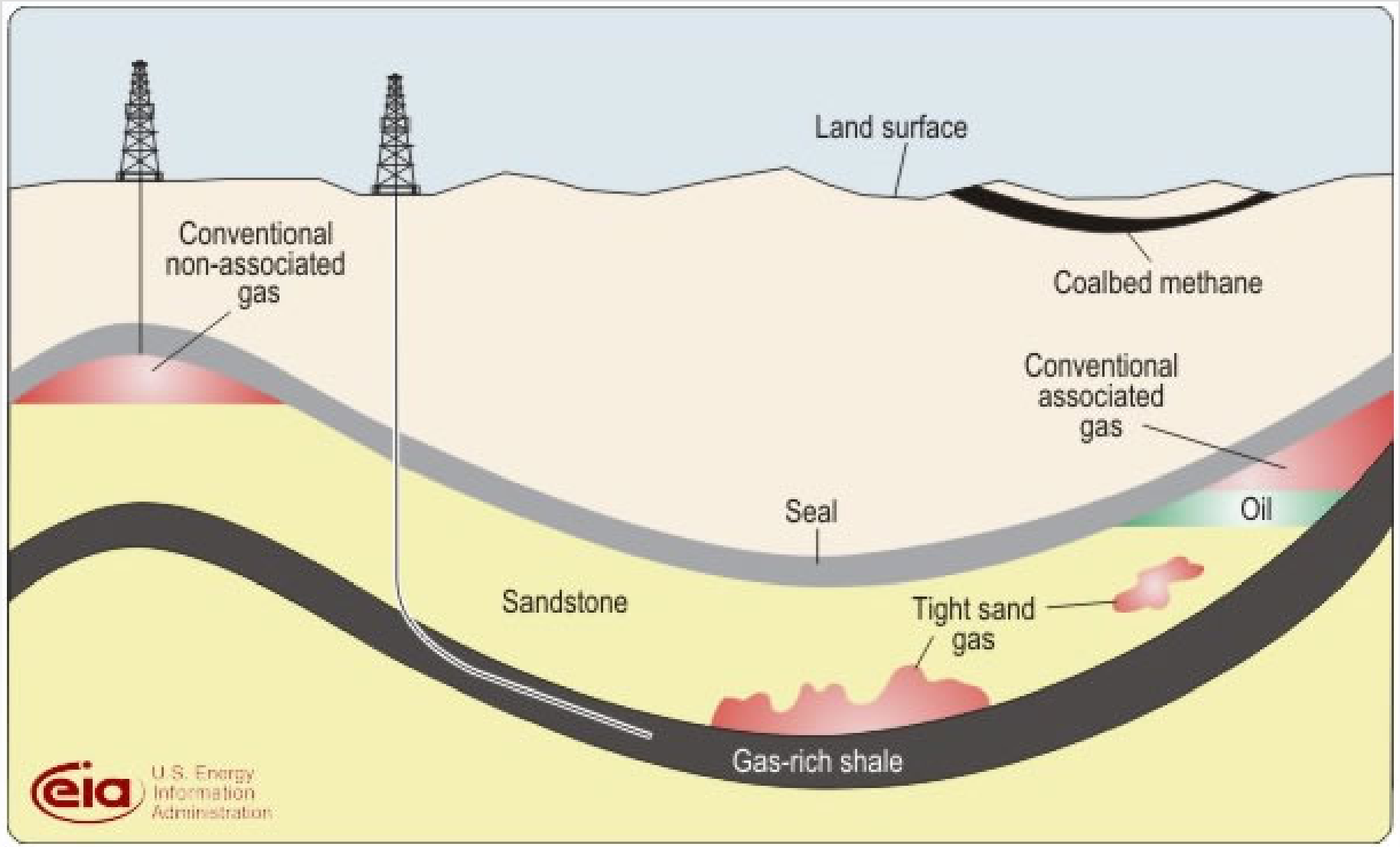
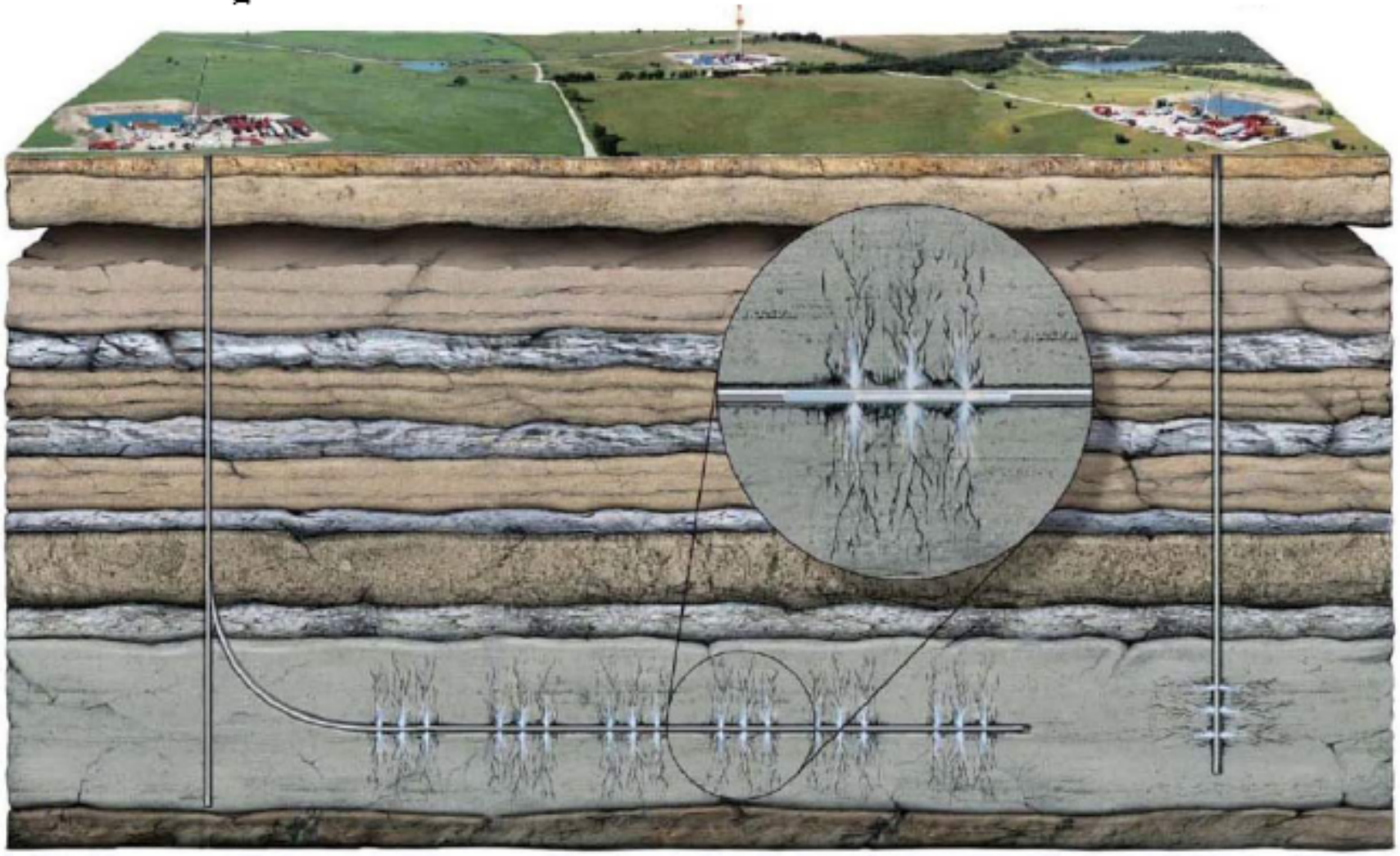


Diagram showing the geometry of conventional and unconventional natural gas resources. Image by EIA.

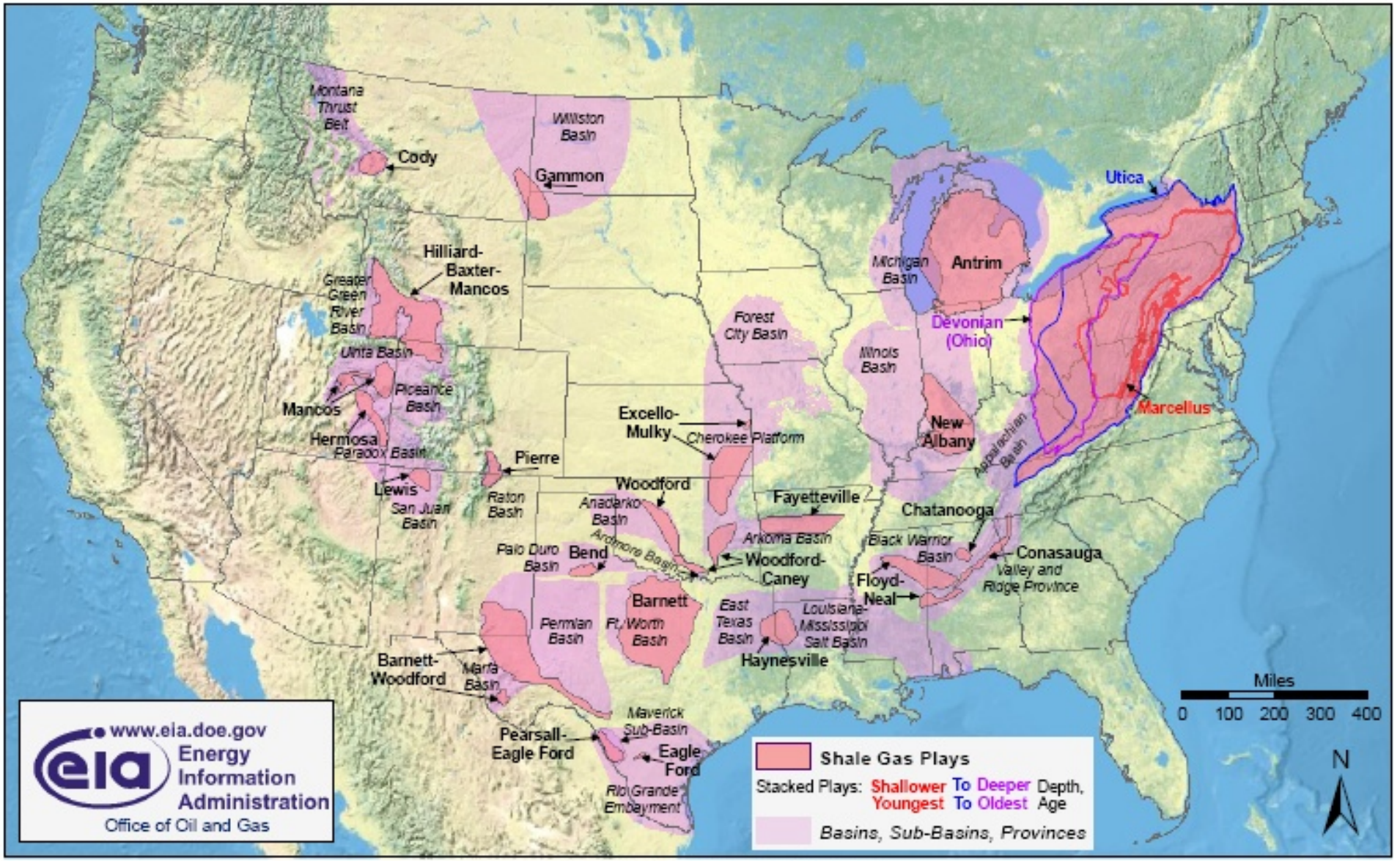
Figure 9: Horizontal versus Vertical Marcellus Shale Wells



Source: Independent Oil and Gas Association of Pennsylvania's Drilling and Developing the Marcellus Shale

From: **The Economic Impact of the Natural Gas Industry and the Marcellus Shale Development in West Virginia in 2009**

Shale Gas Plays, Lower 48 States



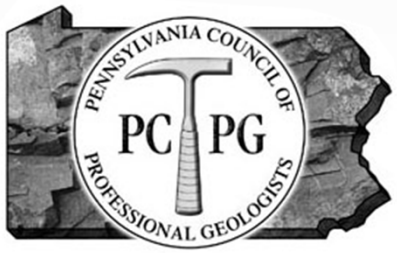
Map Date: March 16, 2009 Data Sources: Published studies

Three Main parts of a Shale play:

#1: Thickness

#2: Depth

#3: Total Organic Carbon and Maturity
Maturity



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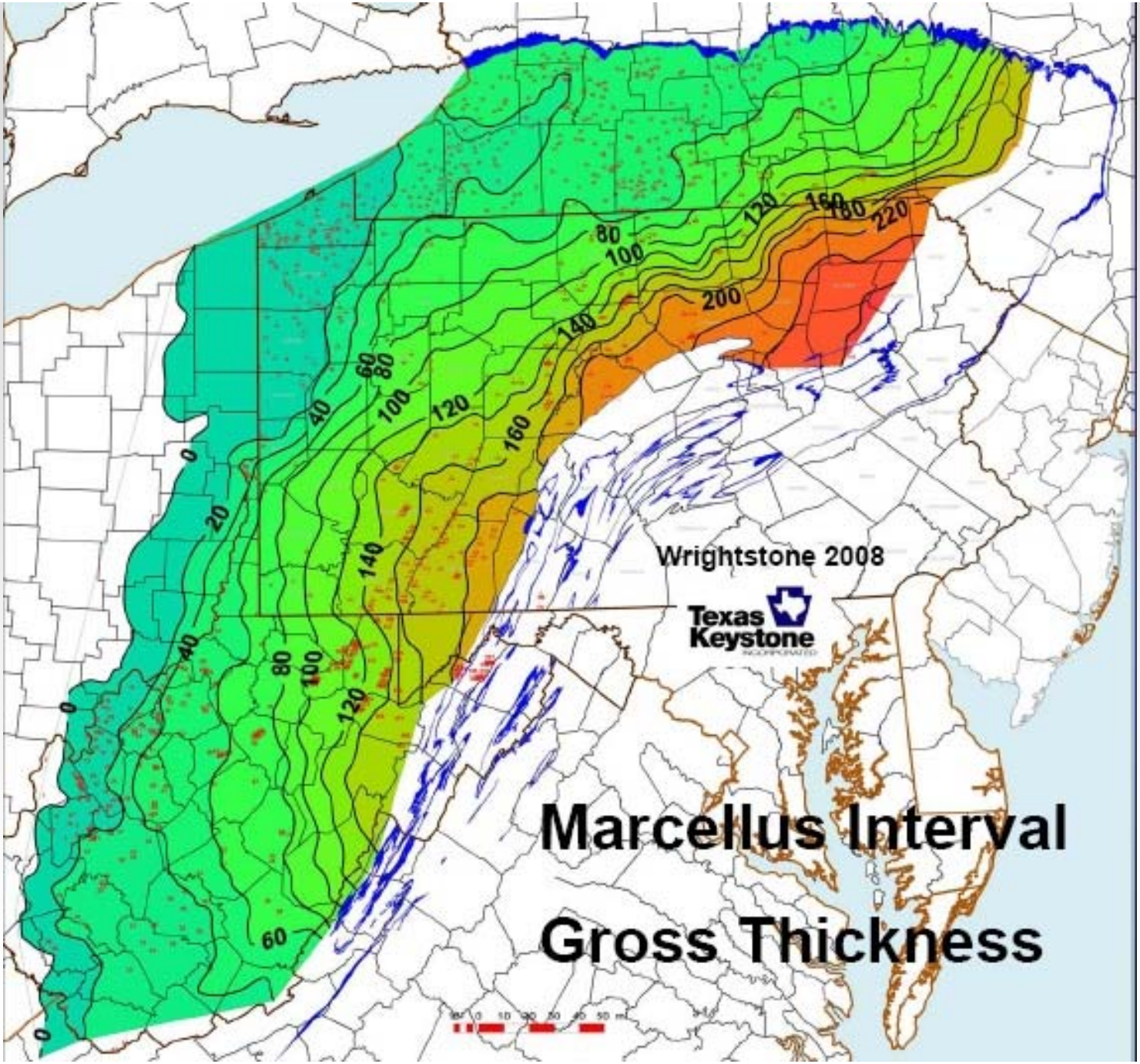
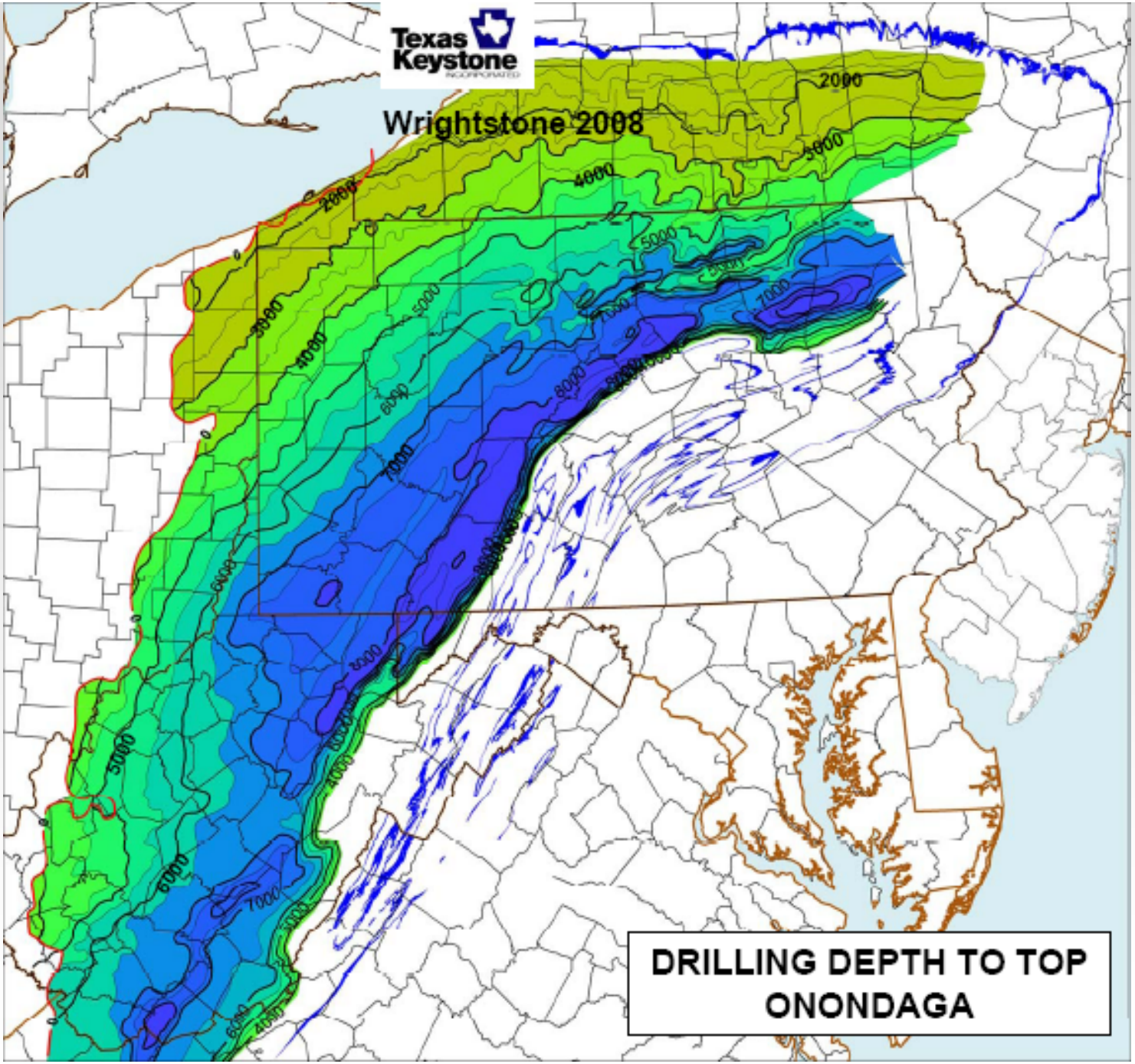


Marcellus Shale Geologic Controls on Production, Wrightstone, 2008



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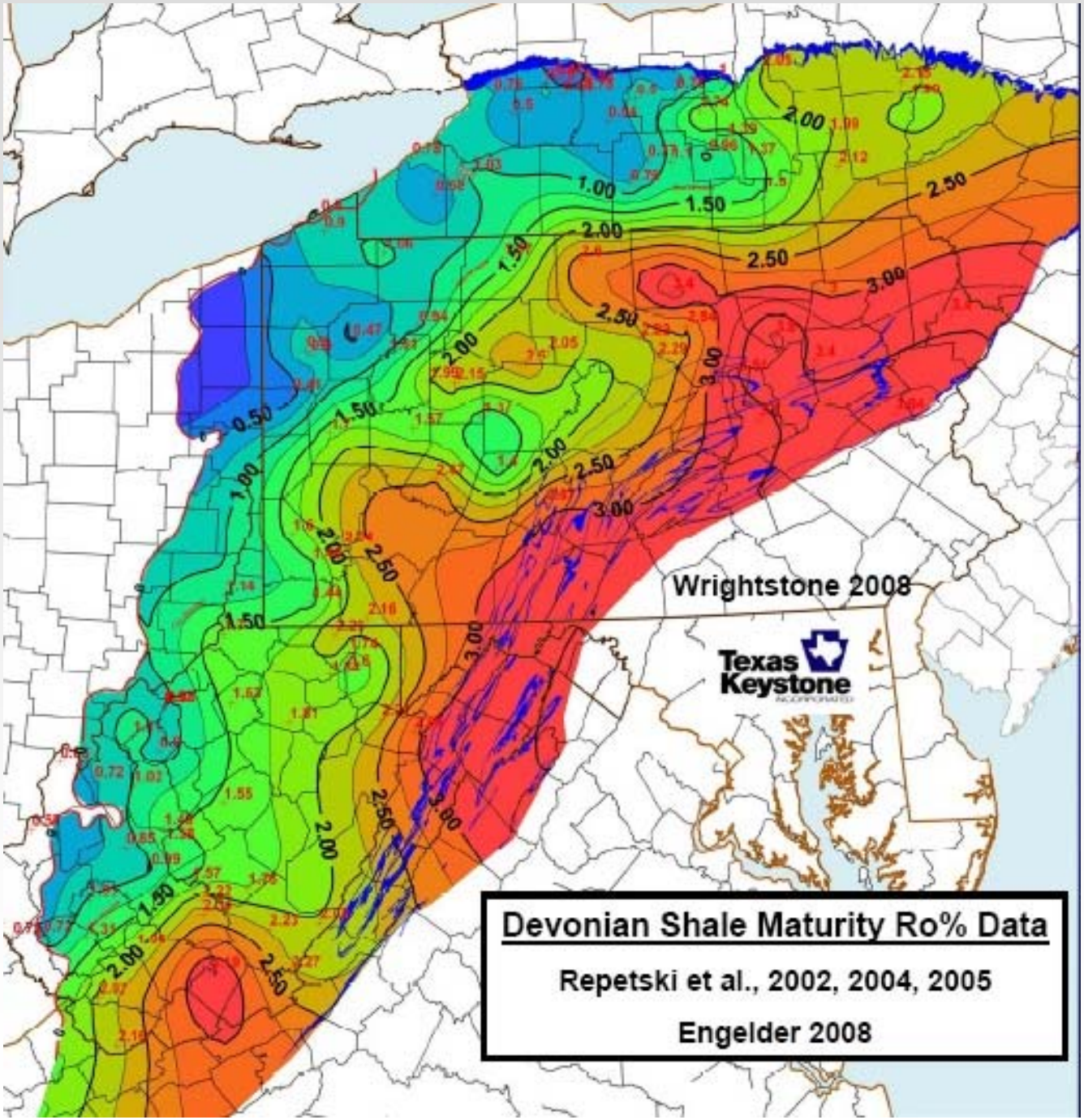
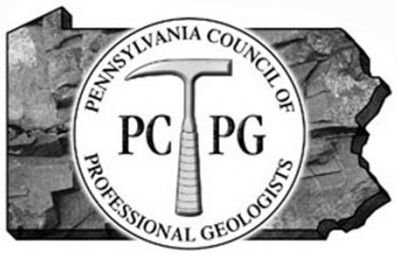


Marcellus Shale Geologic Controls on Production, Wrightstone, 2008

Cookbook Analogy

%TOC = %FAT



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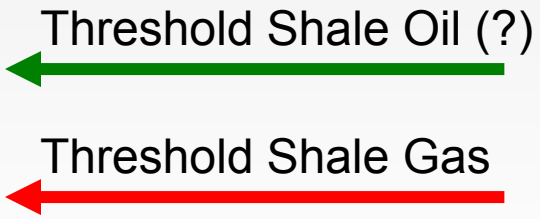
Total Organic Carbon Guidelines

- Present day organic richness of source rock

Quality	TOC (wt%)
Poor	**<0.5**
Fair	**0.5 to 1**
Good	**1 to 2**
Very good	**2 to 4**
Excellent	**>4**



Total Organic Carbon Guidelines

>1% TOC

Minimum Threshold for Hydrocarbon Generation/Expulsion

4% TOC

Excellent Quality Source Rock

e.g. Barnett Shale

15% TOC

High Grade Oil Shale

e.g. Bakken Shale

>50% TOC

Carbonaceous Shale

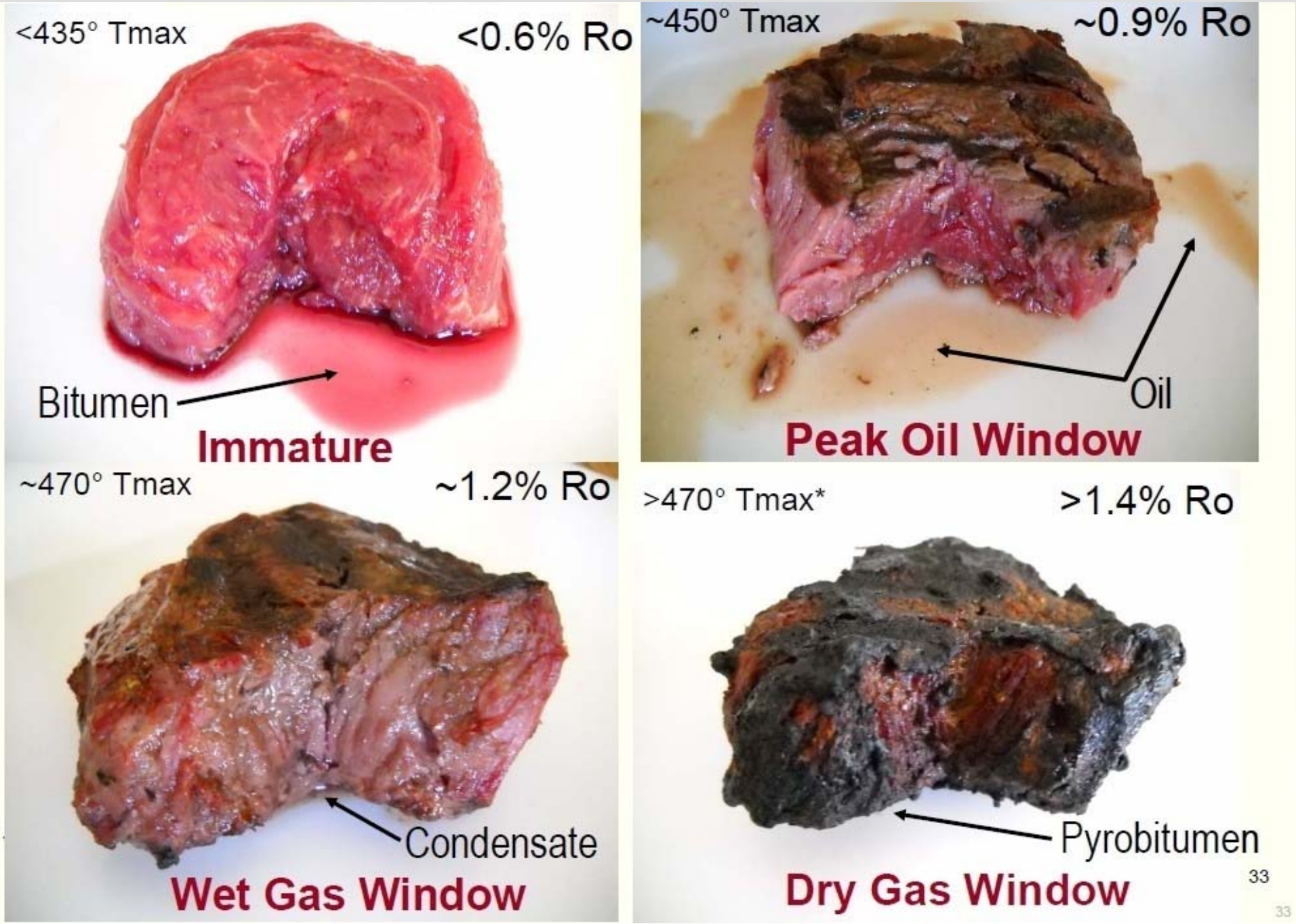
Coal

Thermal Maturity Guidelines

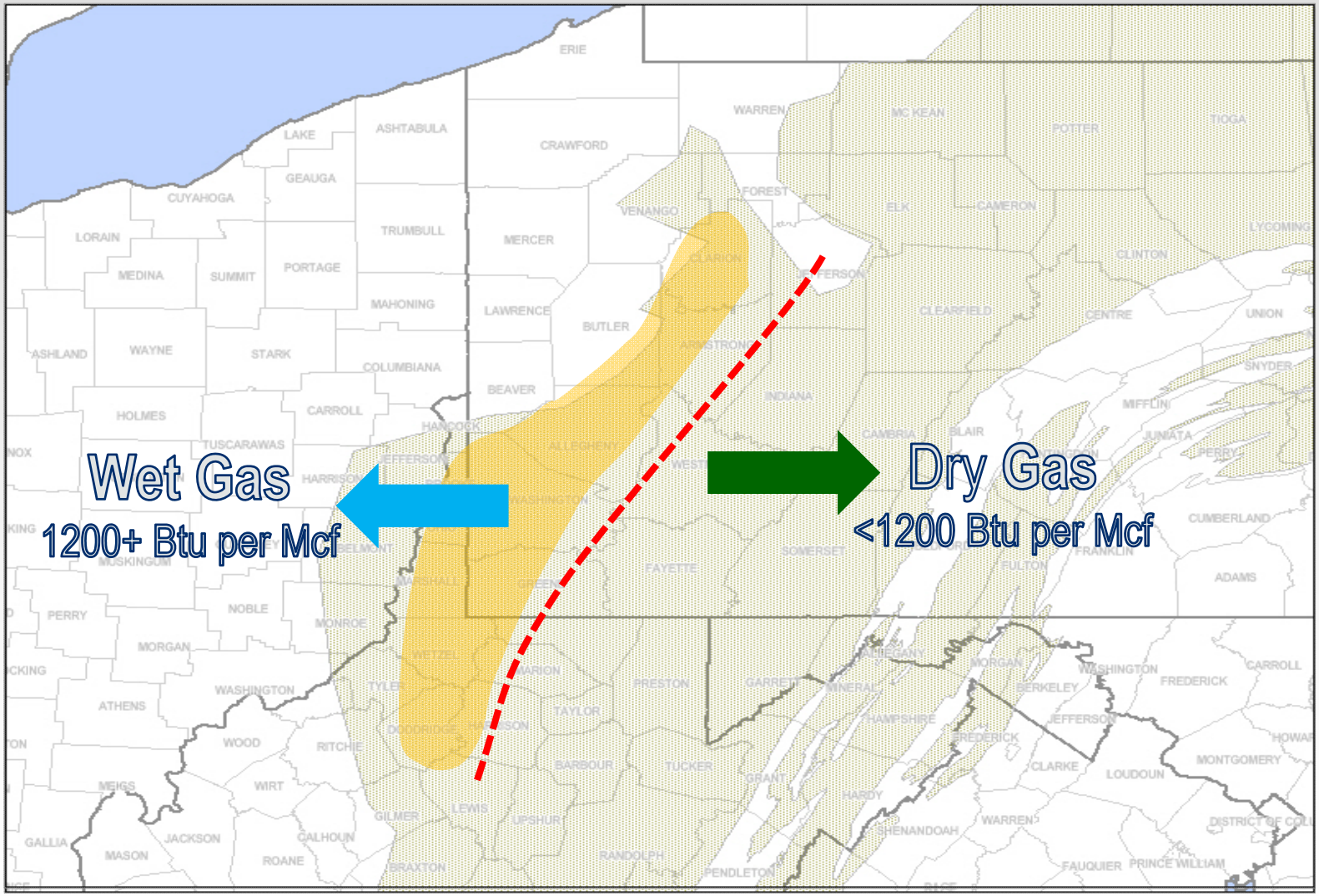
- Vitrinite Reflectance (% Ro) the standard for maturity assessment
  - Measured by organic petrologist via whole rock or kerogen concentrate

Immature	<0.6% Ro
Oil window	0.6-1.1% Ro
Wet gas window	1.1-1.4% Ro
Dry gas window	1.4-~3.2% Ro
Gas destruction	>~3.2% Ro (?)

121


<435° Tmax
<0.6% Ro
Bitumen
Immature
~450° Tmax
~0.9% Ro
Oil
Peak Oil Window
~470° Tmax
~1.2% Ro
Condensate
Wet Gas Window
>470° Tmax*
>1.4% Ro
Pyrobitumen
Dry Gas Window

33



Sources: Pace Global; Equitable Resources, MarkWest, Atlas Energy, Range Resources, and Caiman Energy.

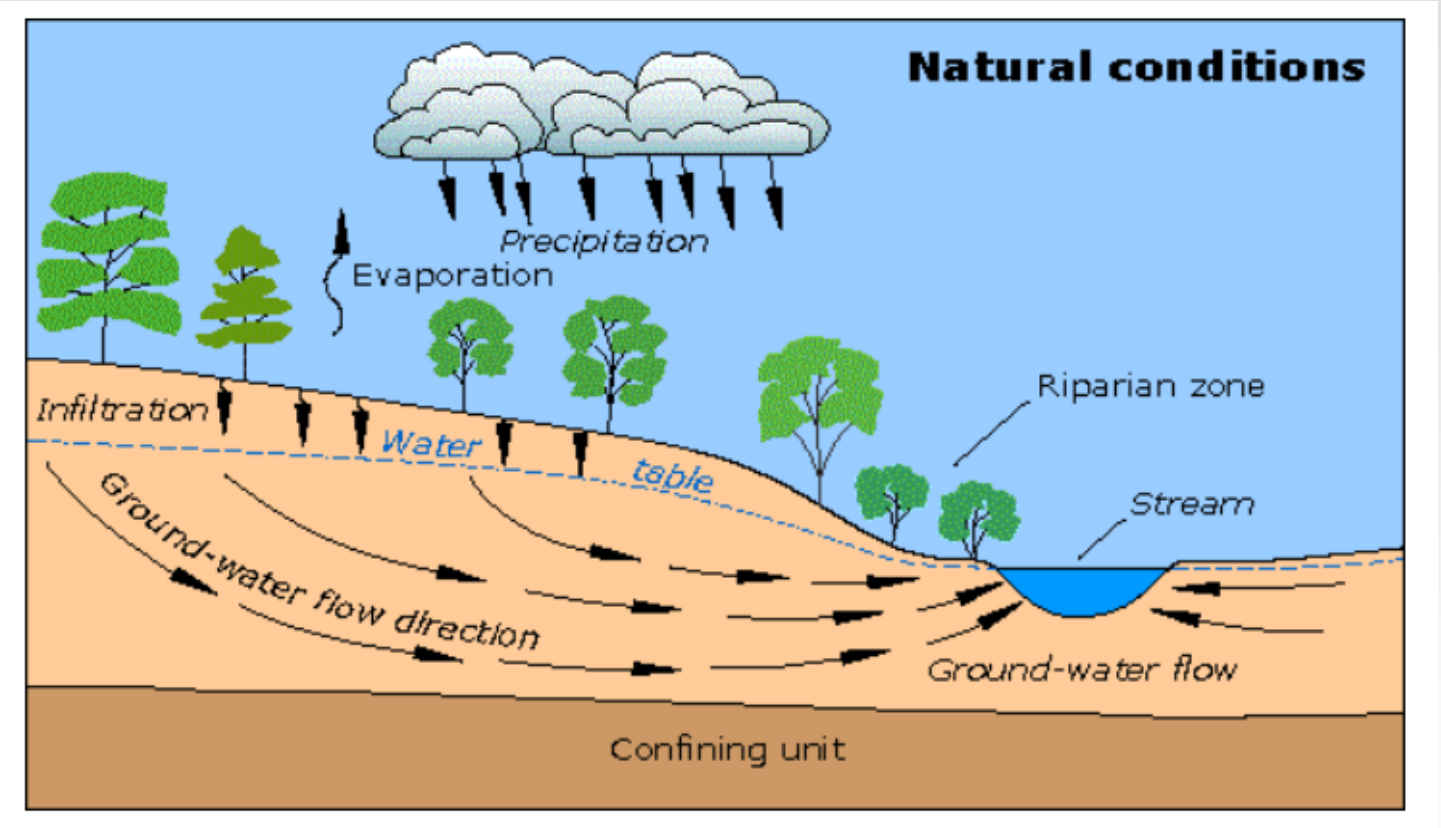
www.naturalgas.org/overview/background.asp

Natural Gas: A Combustible Mixture of Hydrocarbon Gases

Typical Composition of Natural Gas

Wet gas	Methane	CH_4	70-90% (Dry gas)
	Ethane	C_2H_6	0-20%
	Propane	C_3H_8	
	Butane	C_4H_{10}	
	Carbon Dioxide	CO_2	0-8%
	Oxygen	O_2	0-0.2%
	Nitrogen	N_2	0-5%
	Hydrogen sulphide	H_2S	0-5%
	Rare gases	A, He, Ne, Xe	trace

DRBC Quick Water Budget



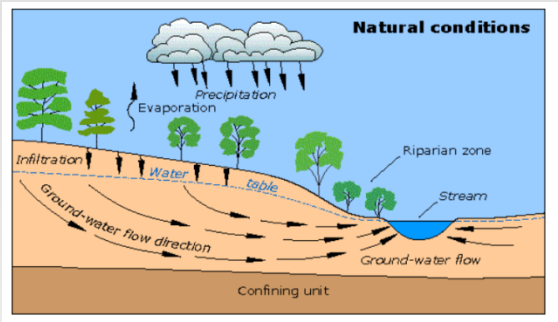
$$P = ET + Qro + Qg + \Delta Sg$$

DRBC Quick Water Budget

12765	sq miles
640	ac/mi
43560	Sq ft / ac
3.75	ft of rain /Yr (=45 in)
1,334,504,160,000	Cu Ft / yr
9,982,091,116,800	Gal/yr
27,348,194,841	gal / day
16,408,916,904	ET / day
10,939,277,936	SW + GW / day

Area of Basin

Average Precip.



P = 10 Trillion Gal / year !

P = 27.3 Billion Gal / day

But wait: ET =16.4 Billion Gal / day

Approx. 11 Billion Gal / day runoff and recharge

$$P = ET + Qro + Qg + \Delta Sg$$

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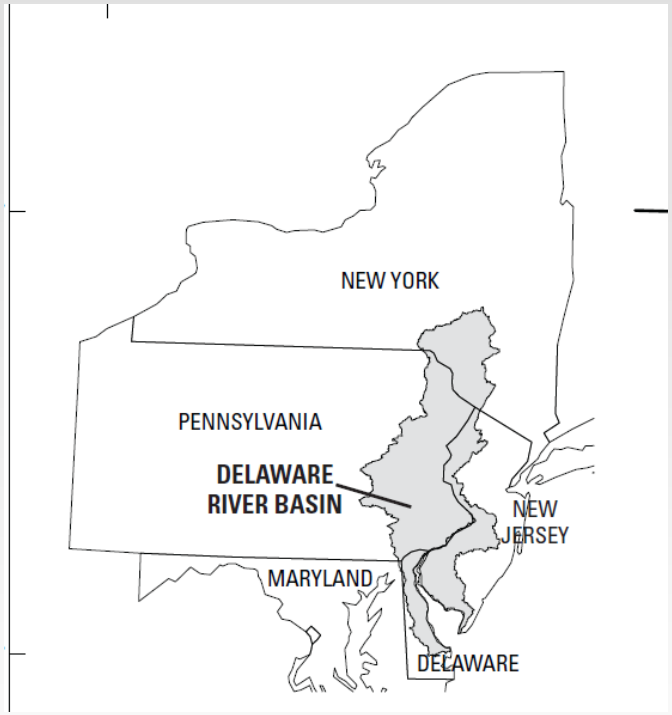
DRBC Quick Water Budget



But not always where and when needed.

Average numbers, more wet years (2009, 2011), Less in Drought (1998-2002)

Still, problem of Supply Management, not absence of supply.

Relied upon water source for approx. 15 million

$$P = ET + Qro + Qg + \Delta Sg$$

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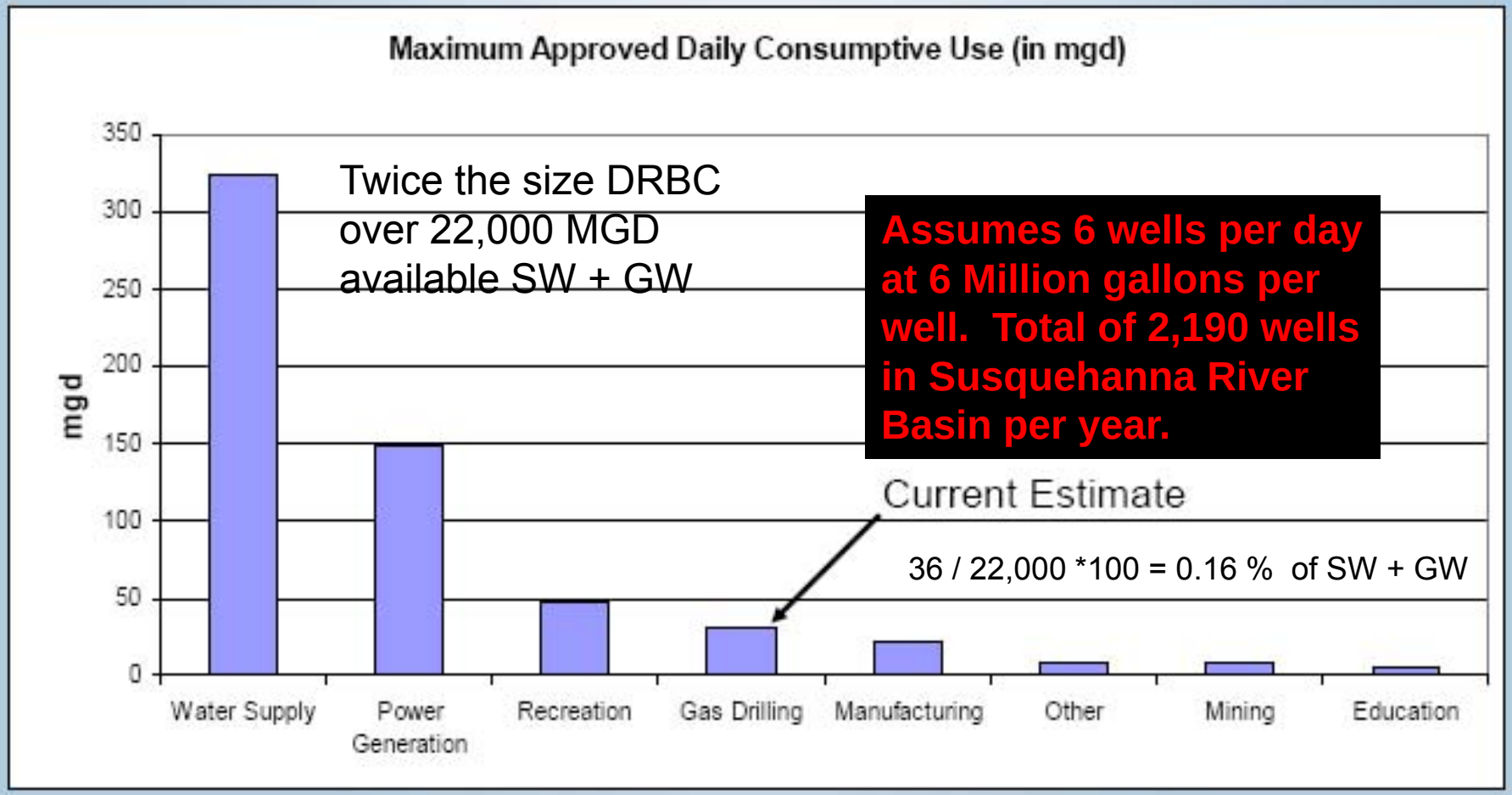
Resource Requirements for Shale Gas

- Approximately 6 million gallons of water for use in drilling, cementing and completion fracturing of a horizontal well.

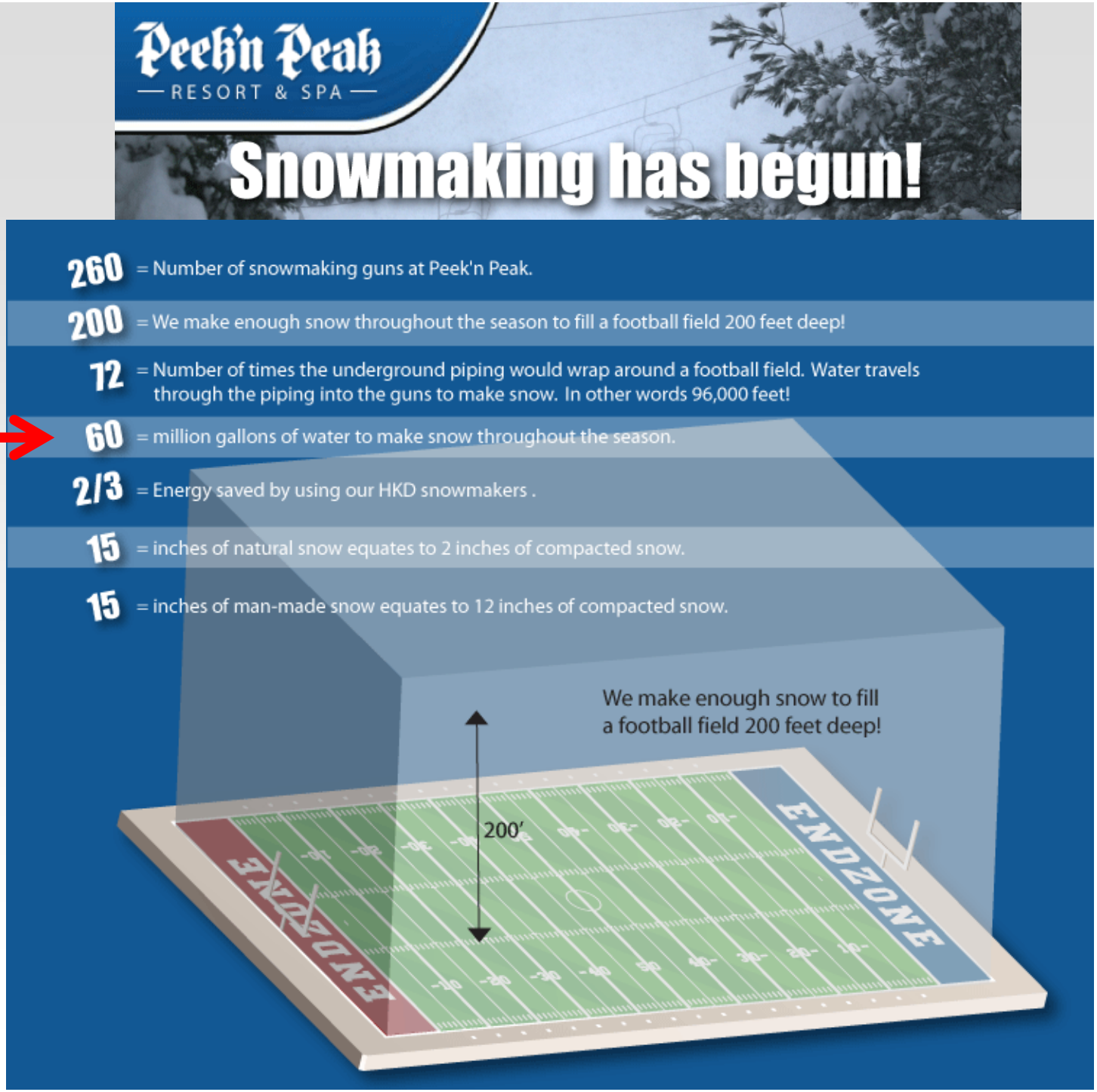
- Drilling pad, typically 3 to 5 acres depending on topography, wellsite design, etc. This is a pad that can support 8 + horizontal wells and requires less land use to recover the same amount of gas from vertical wells (24 or more vertical wells).

- Pipeline lengths vary greatly depending on distance to sales point/transmission pipelines. Rights-of-way acquired by drilling company.

Maximum Daily Consumptive Use



10 Marcellus wells in one winter!

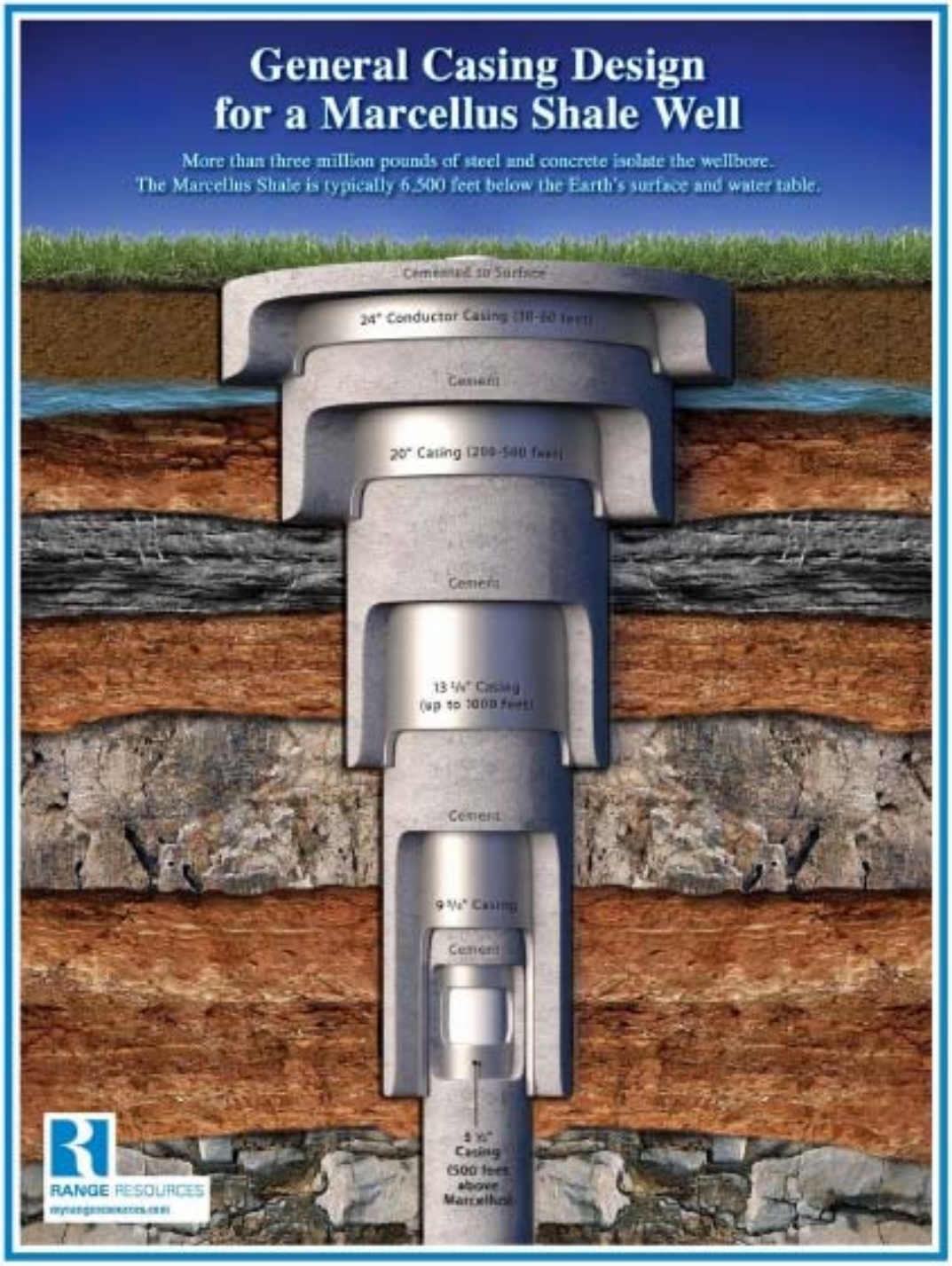


From: "Peek'n Peak is Preparing for a Great Winter", e-newsletter 11/19/08

Water Resource Requirements for Various Energy Resources

Energy Resource	Range of Gallons of Water Used per MMBTU of Energy Produced
Deep Shale Natural Gas	0.84 – 3.70
Coal (no slurry transport)	2 – 8
Coal (slurry transport)	13 – 32
Nuclear	8 – 14
Conventional Oil	8 – 20
Synfuel - Coal Gasification	11 –26
Oil Shale	22 – 56
Tar Sands	27 – 68
Synfuel - Fisher Tropsch (from coal)	41 – 60
Enhanced Oil Recovery	21 – 2,500
Biofuels (irrigated Corn Ethanol, irrigated Soy Biodiesel)	>2,500

Source: *"Deep Shale Natural Gas: Abundant, Affordable, and Still Water Efficient"*, Groundwater Protection Council, 2010.

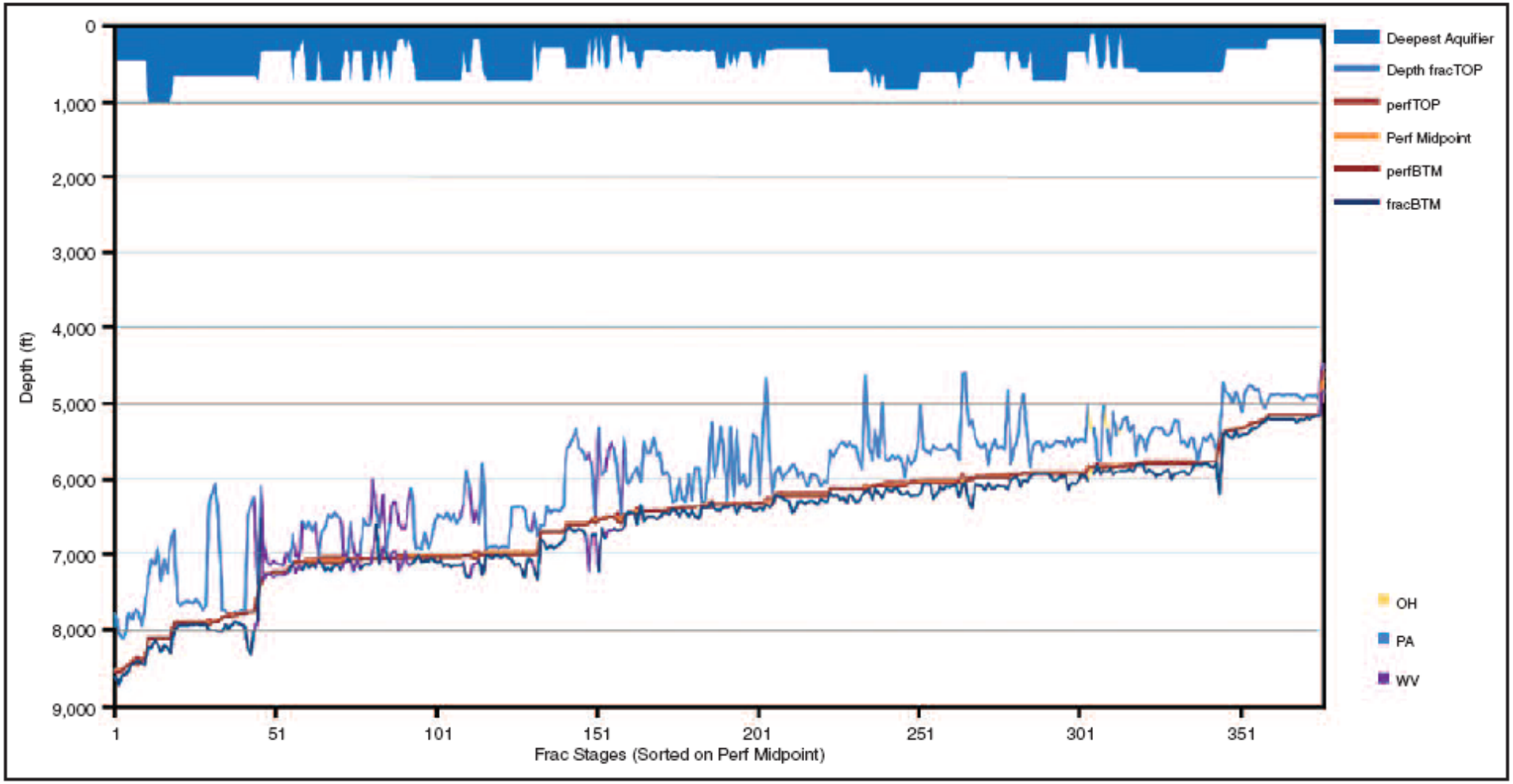


← Casing Design

Designed to keep what is in the hole … in the hole and what is not in the hole … out of the hole.

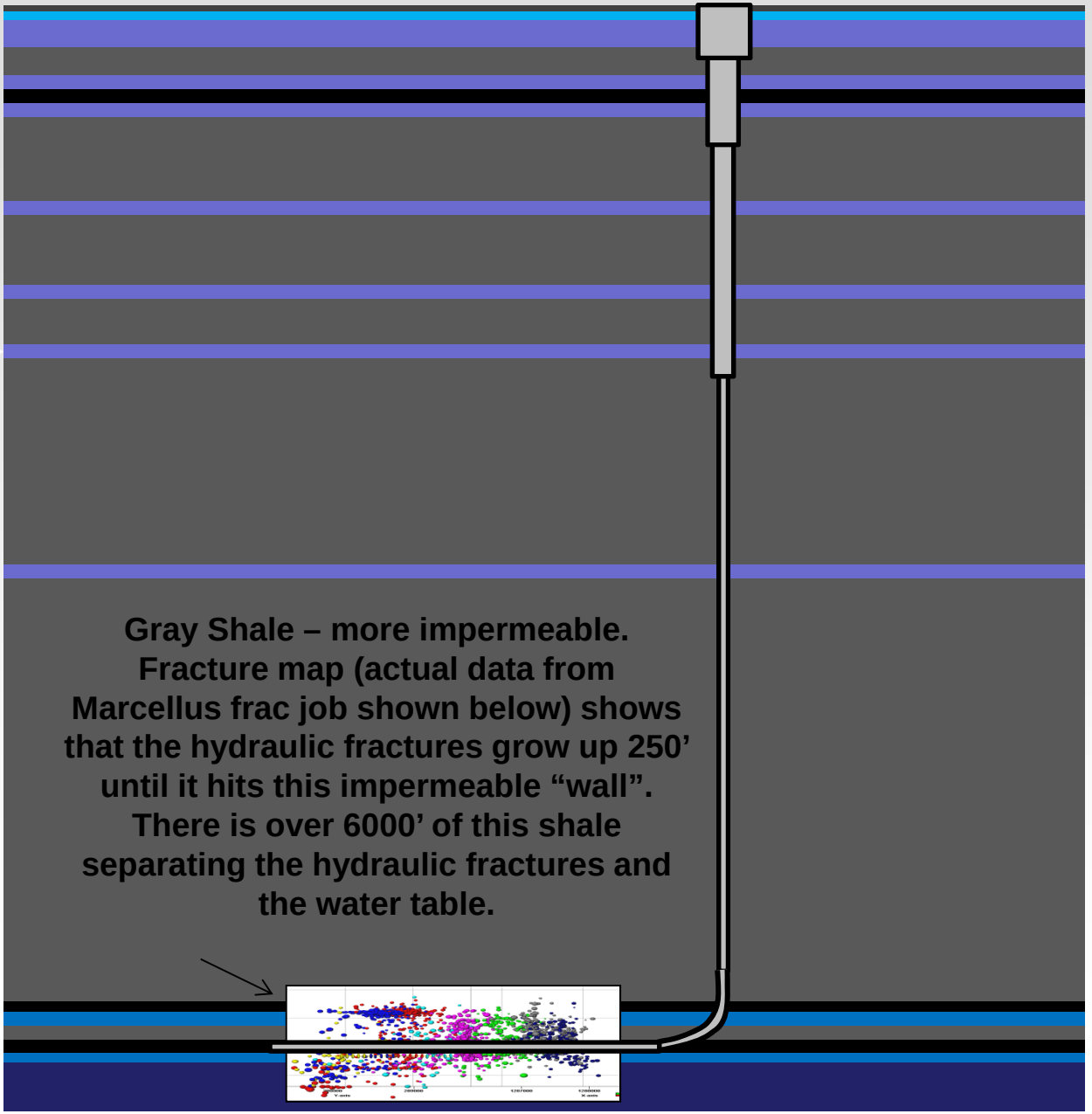
Designed to protect the groundwater from drilling fluids and produced products and designed to keep groundwater and rock material out of the borehole.

Marcellus Shale Mapped Fracture Treatments (TVD)



Data Confirms Safety of Well Fracturing, American Oil & Gas Reporter, July 2010

Western PA Example



Water Table

Coal

Historical shallow gas: closer to water table. (100,000 +/- frac jobs in these formations, no problem)

Gray Shale – more impermeable. Fracture map (actual data from Marcellus frac job shown below) shows that the hydraulic fractures grow up 250’ until it hits this impermeable “wall”. There is over 6000’ of this shale separating the hydraulic fractures and the water table.

Fractures hitting a “wall”

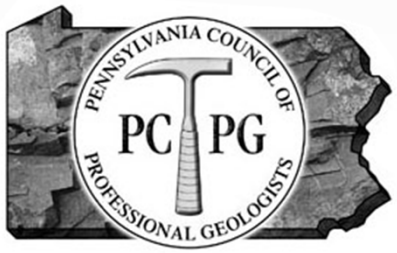
Marcellus

Source: Chesapeake Energy Corporation, 2008

Hydraulic Fracturing of a Marcellus Shale Well, West Virginia

HYDRAULIC FRACTURING AND GROUNDWATER QUALITY

IS THERE A CONNECTION?



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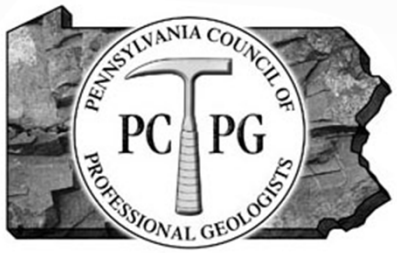
CONCERNS ABOUT FRACING AND IMPACTS TO GROUNDWATER (AND SURFACE WATER)…

Terminology Review

- **Aquifer - A body of rock that contains sufficient saturated permeable material to conduct groundwater and yield significant quantities of water to wells and springs**

- **Potable Water - Water that is suitable and palatable for human use; fresh or treated water with safe levels of pathogenic organisms and toxic constituents and tolerably low in objectionable taste, odor, color or turbidity (after AGI, 2005, Glossary of Geology)**

- **Saline water - Water that generally is considered unsuitable for human consumption or for irrigation because of its high TDS content. (http://or.water.usgs.gov/projs_dir/willgw/glossary.html)**



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Some perspective: not all groundwater is potable…

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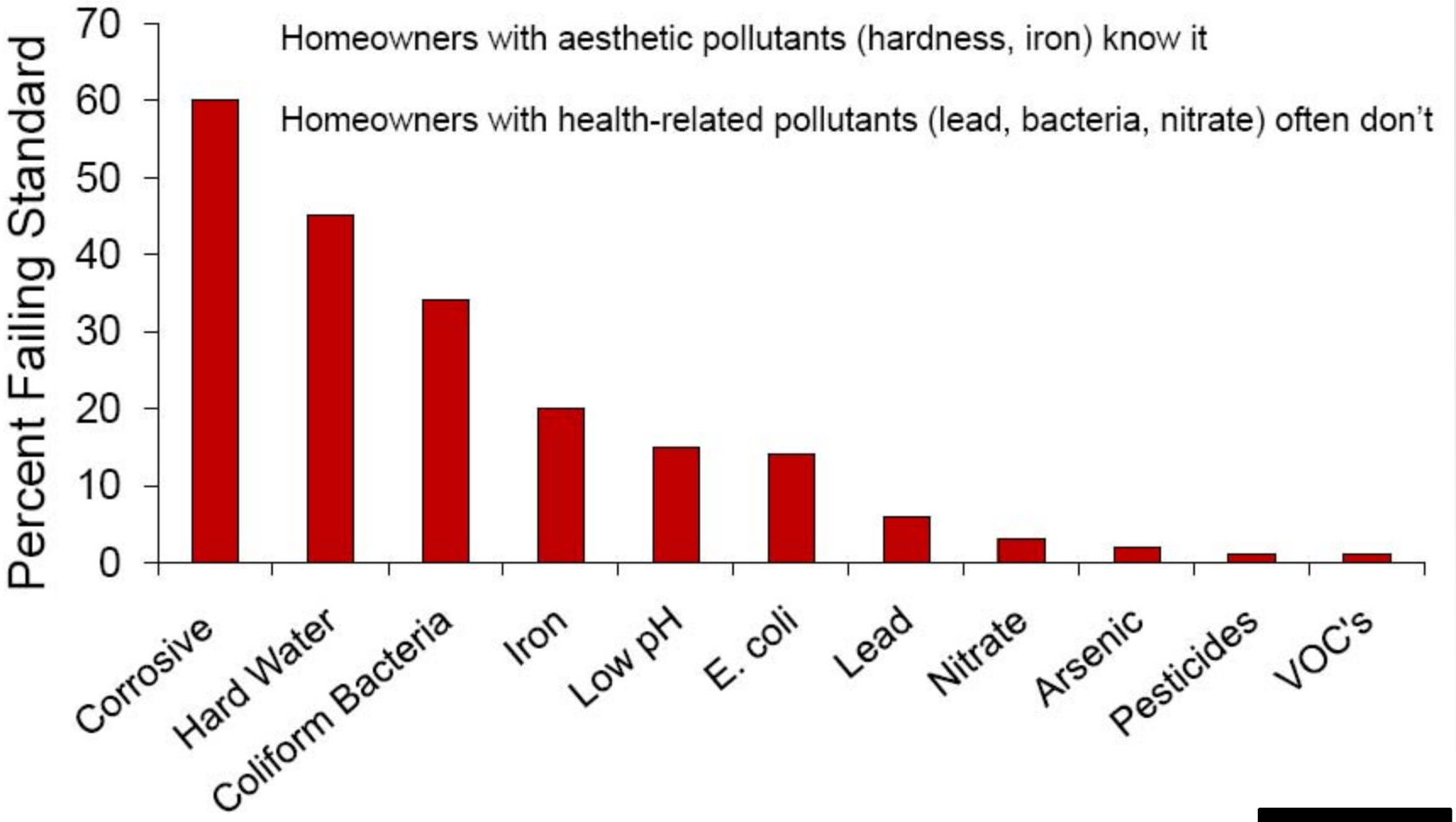
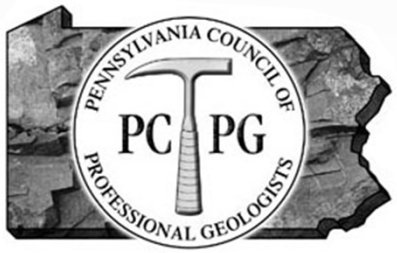
Pre-Drilling Problems are Common



41% fail at least one drinking water standard…

From 9/5/2010 B. Swistock PSU Cooperative Extension webinar

One major indicator of water quality is its Total Dissolved Solids content (TDS)



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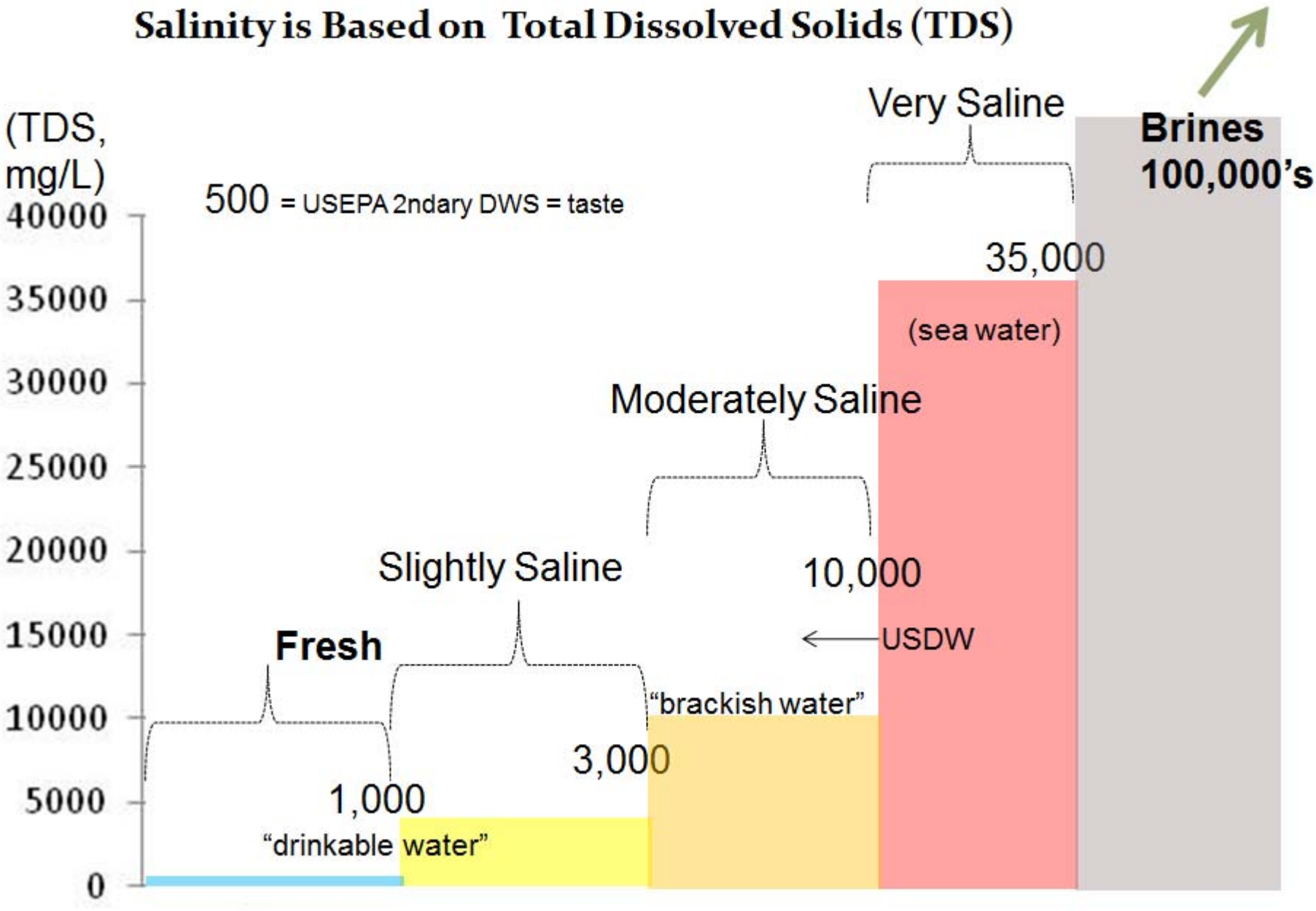
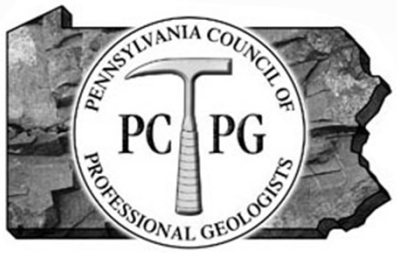


http://or.water.usgs.gov/projs_dir/willgw/glossary.html

Aquifers are not bottomless…

Groundwater Quality & Quantity Degrade With Depth



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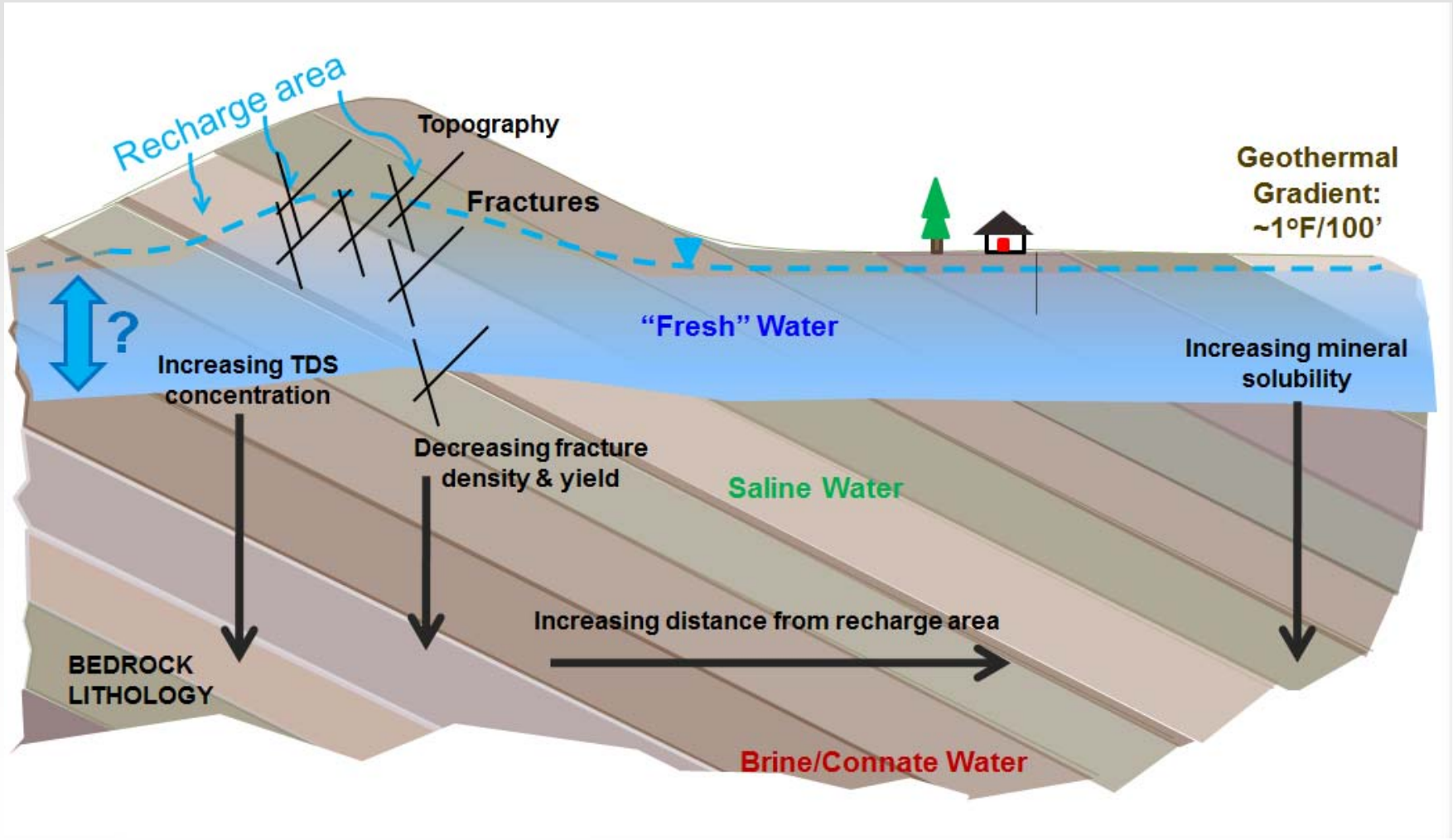
Natural Degradation of Groundwater Quality & Quantity



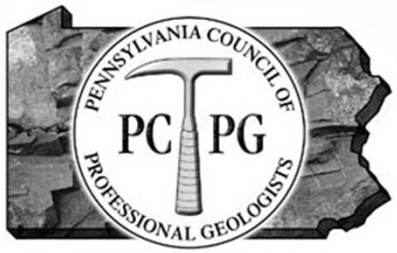
Protection of "Deepest Fresh Groundwater"

- **PA Code § 78.1. Definition:** *"Deepest fresh groundwater*—The deepest fresh groundwater bearing formation penetrated by the wellbore as determined from drillers logs from the well or from other wells in the area surrounding the well or from historical records of the normal surface casing seat depths in the area surrounding the well, whichever is deeper."

- **PA's Oil & Gas Regs - PA Code § 78.83.** Surface and coal protective casing and cementing procedures.
- "**. . . .**the operator shall drill to approximately 50 feet below the deepest fresh groundwater or at least 50 feet into consolidated rock, whichever is deeper, and immediately set and permanently cement a string of surface casing to that depth".

“Deepest fresh groundwater”=
Potable aquifer thickness, or
altitude of fresh/saline interface

But -
Available Data are Sparse…



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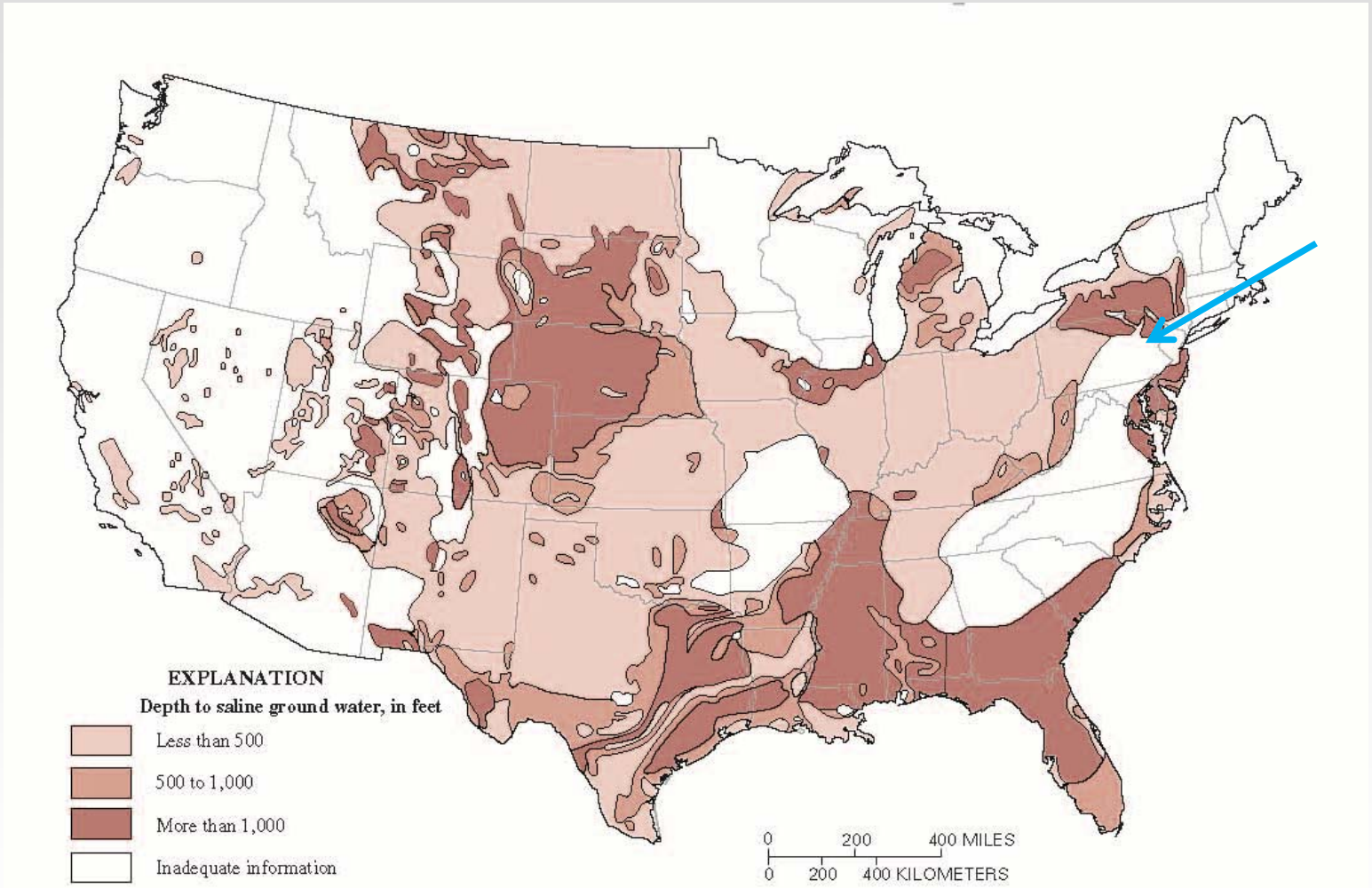
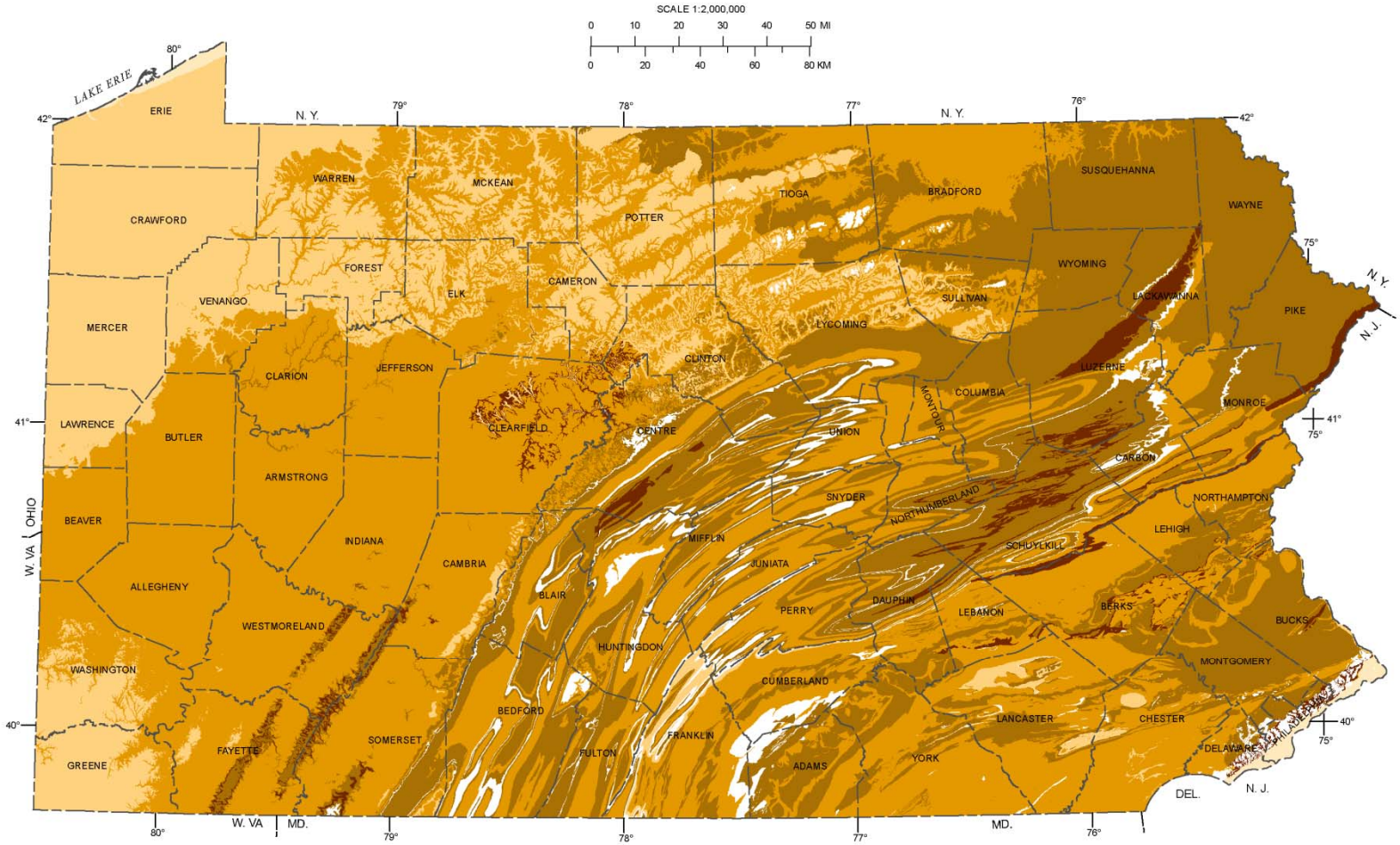


Figure 1. Depth to saline ground water in the United States (generalized from Feth and others, 1965)

USGS Fact Sheet 075-03, 2003

MEDIAN WATER WELL DEPTH BY GEOLOGIC UNIT OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF
CONSERVATION AND NATURAL RESOURCES
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



Median Water Well Depth by Geologic Unit (feet below surface)

<50	100 - 150	>250
50 - 100	150 - 250	No data

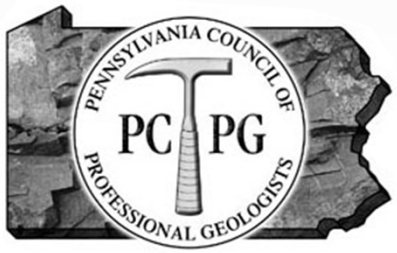
Compiled by S. O. Reese, 2009

This map represents median water well depth by geologic unit. Well depth was extracted by geologic unit and physiographic section from Water Resource Report 69, and joined to the digital bedrock geology of Pennsylvania to create a geographic information system (GIS) layer. The median value is based on a minimum of 10 records and includes all water uses and topographic settings. If a geologic unit did not have enough records for a specific physiographic section, well depth data from an adjacent section were joined to the unit. Approximately 97 percent of the state is covered.

This map is based on the following datasets:

- Fleeger, G. M. McElroy, T. A. and Moore, M. E., 2004, Hydrogeologic and Well-Construction Characteristics of the Rocks of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 69, Database (Microsoft Access 97 and 2000).
- Miles, C. E., and Whitfield, T. G., compilers, 2001, Bedrock geology of Pennsylvania: Pennsylvania Geological Survey, 4th ser., dataset, scale 1:250,000.
- Pennsylvania Geological Survey, 2002, Physiographic provinces of Pennsylvania: 4th ser., digital dataset, scale 1:100,000, unpublished.

CASE STUDY: DEEPEST FRESH WATER IN THE PA DELAWARE RIVER BASIN'S MARCELLUS COUNTIES



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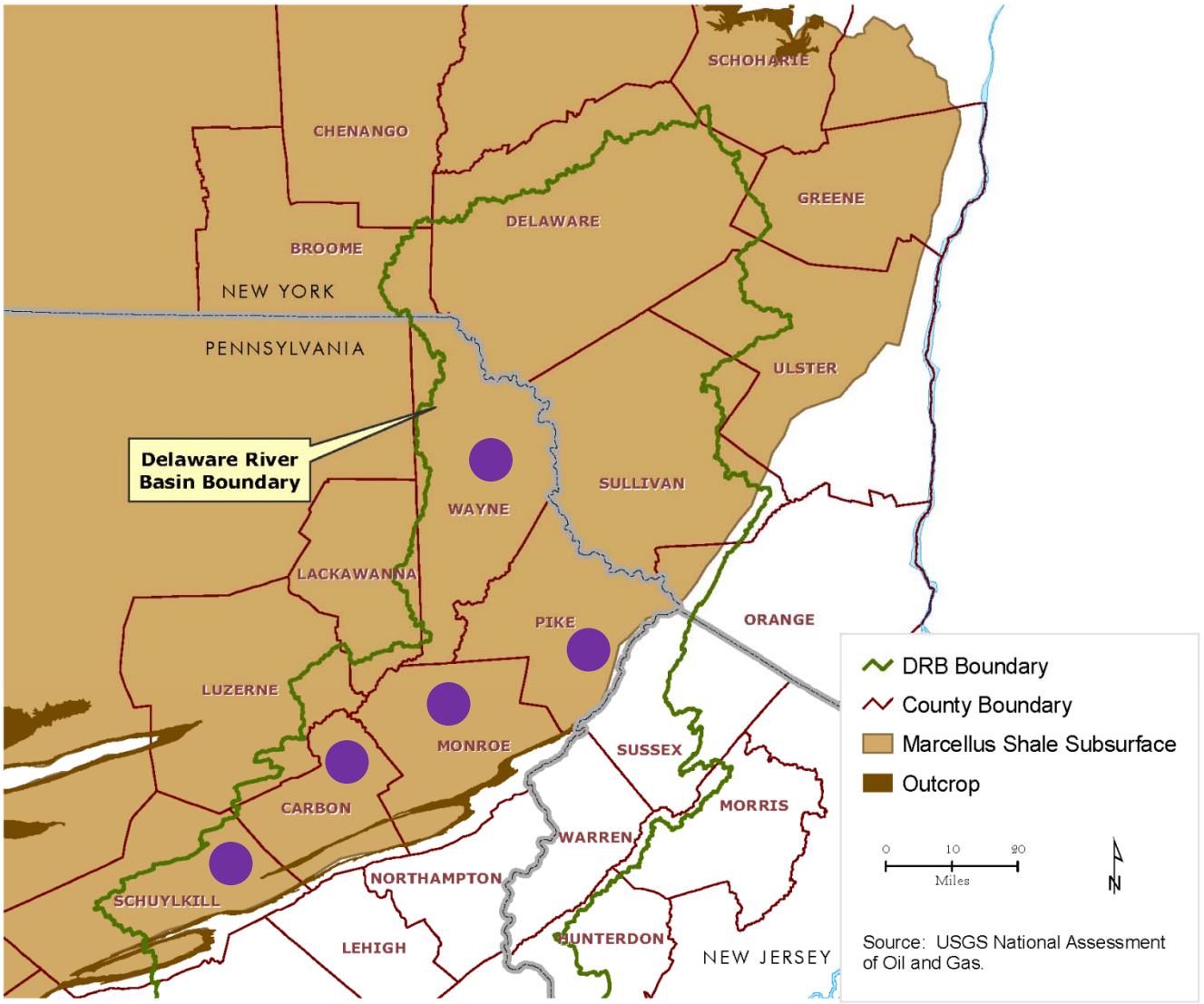
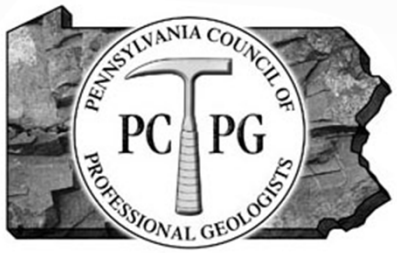


http://www.state.nj.us/drbc/naturalgas.htm

Thickness of Fresh Water System in PA's DRB Marcellus counties?

- Very limited published info:
  - Pike County: >800' (PAGS WR 65);
  - Monroe County: " 800' or more," but "little water is yielded to wells by aquifers more than 500 feet below ground surface" (PAGS WR47)



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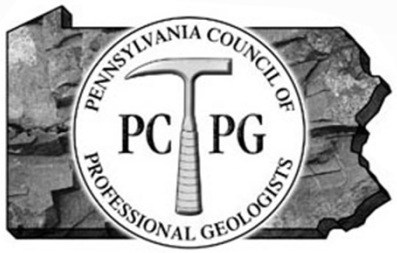
A Proxy for Minimum Depth to Saline Interface:

Water Supply Well Depths



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Water Supply Well Depth Statistics

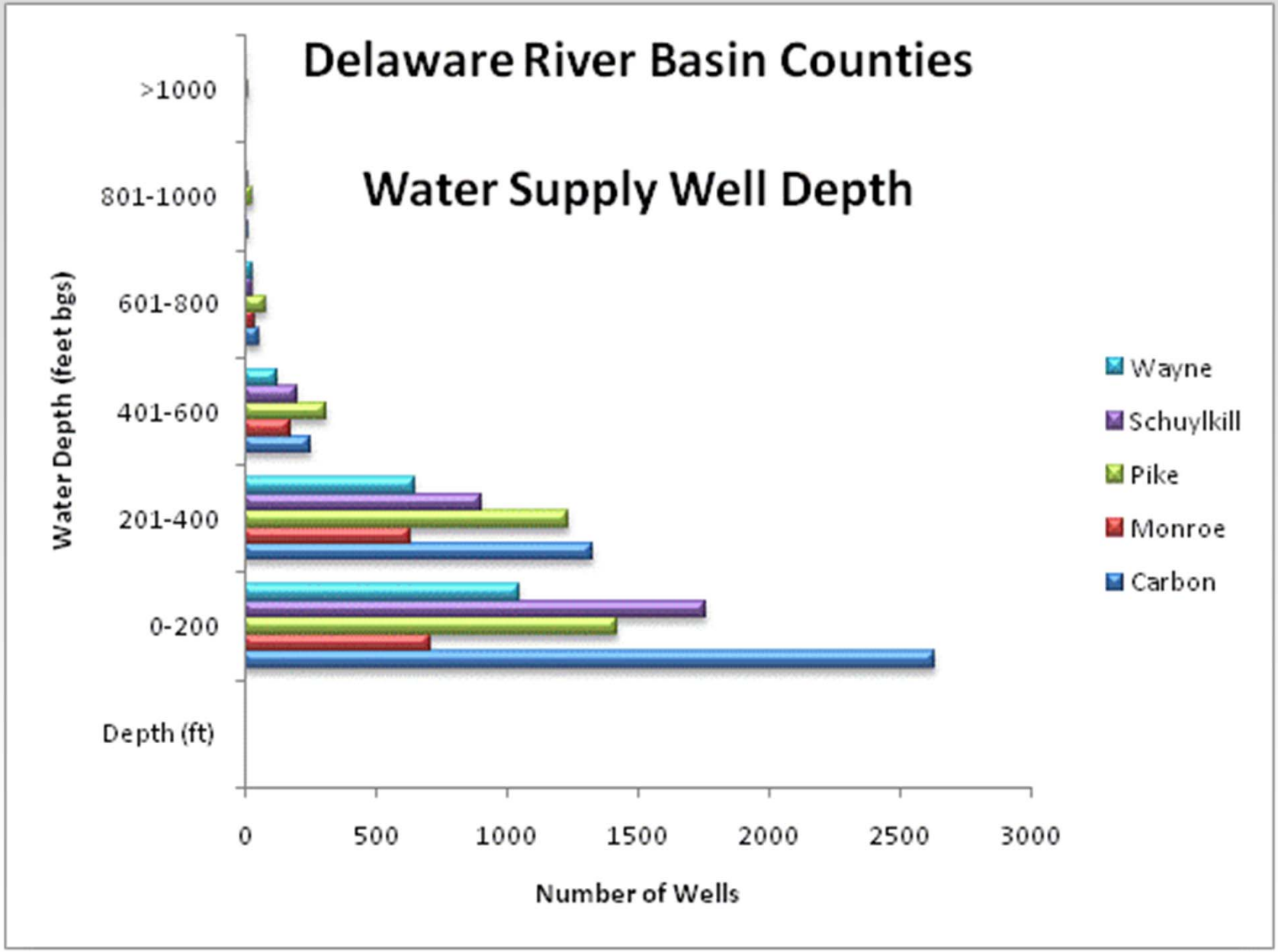
(ft bgs)

	Carbon	*Monroe*	*Pike*	*Schuylkill*	*Wayne*	
MIN	12	15	8	10.8	14.6	
MAX	1,220	1,800	2,300	1,080	1,500	
MEDIAN	180	240	220	180	200	
MEAN	218	263	262	213	229	
# ≥1000'	5	3	13	6	4	
						Total
# of Wells	*4,303*	*1,569*	*3,094*	*2,923*	*1877*	*13,766*

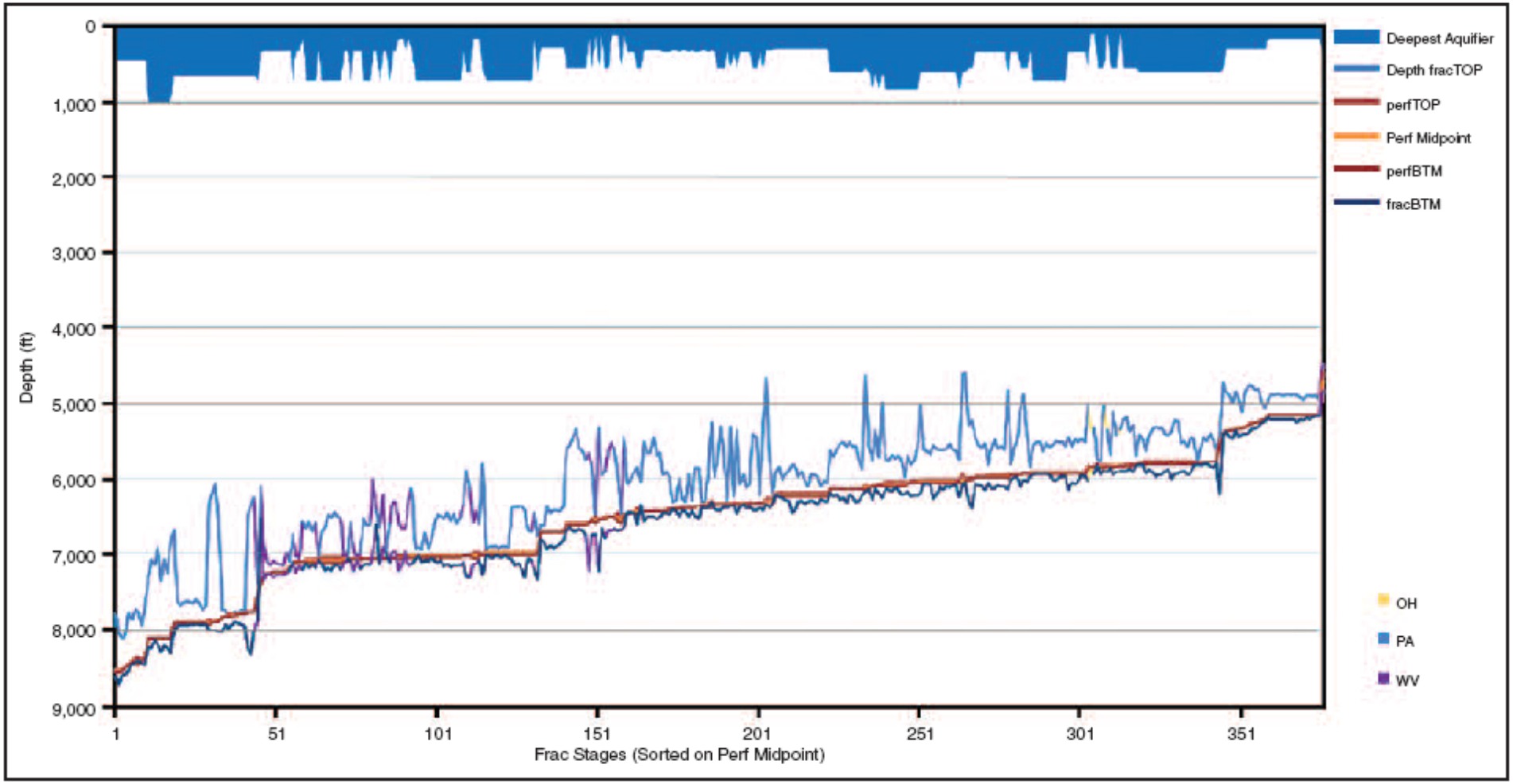
All figures calculated from PaGWIS on-line database:

http://www.dcnr.state.pa.us/topogeo/groundwater/PaGWIS/SelectRecords.asp?Type=All&UserType=

(Oil/gas wells and test borings excluded)


Delaware River Basin Counties
Water Supply Well Depth
Water Depth (feet bgs)
>1000
801-1000
601-800
401-600
201-400
0-200
Depth (ft)
0
500
1000
1500
2000
2500
3000
Number of Wells
Wayne
Schuylkill
Pike
Monroe
Carbon

Marcellus Shale Mapped Fracture Treatments (TVD)

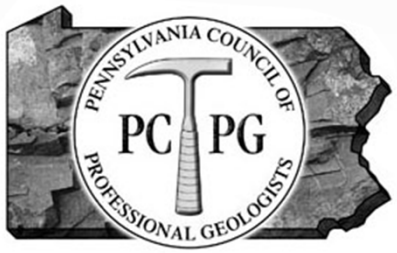


Data Confirms Safety of Well Fracturing, American Oil & Gas Reporter, July 2010

What is known so far about Marcellus gas well surface casing depths in in the PA DRB Marcellus Counties?

- Data are very limited – no Marcellus gas wells drilled to date in Monroe, Pike, Schuylkill*
- Well completion reports = main source of info, few available yet
- Matoushek #1 well in Wayne County

*Recent mine water withdrawal application, for Marcellus well drilling!



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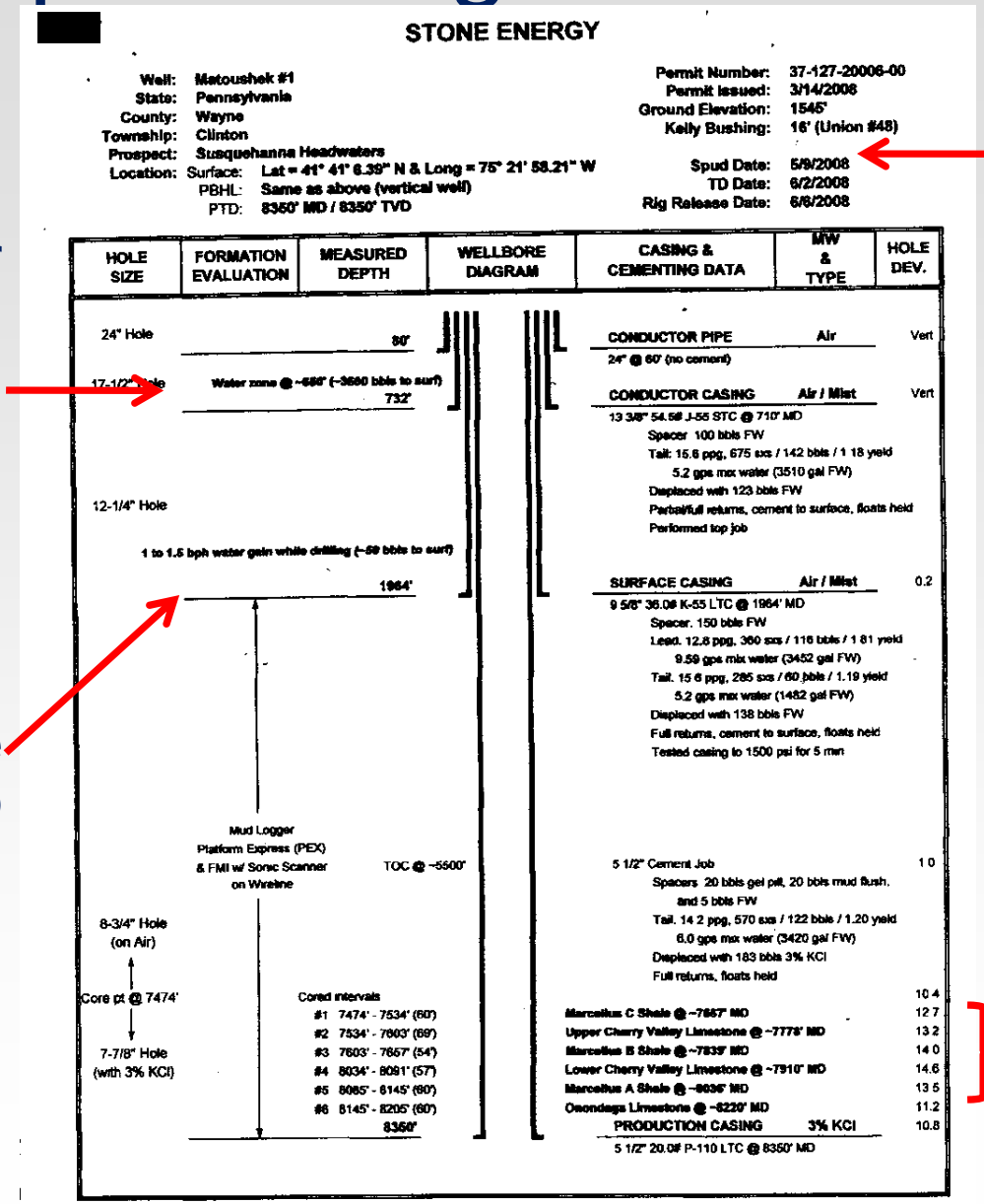
Matoushek 1, Wayne County PA

(from www.wvcpoa.com)

Completion log for Matoushek#1



STONE ENERGY

Well: Matoushek #1
State: Pennsylvania
County: Wayne
Township: Clinton
Prospect: Susquehanna Headwaters
Location: Surface: Lat = 41° 41' 6.39" N & Long = 75° 21' 58.21" W
PBHL: Same as above (vertical well)
PTD: 8350' MD / 8350' TVD

Permit Number: 37-127-20006-00
Permit Issued: 3/14/2008
Ground Elevation: 1545'
Kelly Bushing: 16' (Union #48)
Spud Date: 5/9/2008
TD Date: 6/2/2008
Rig Release Date: 6/6/2008

HOLE SIZE	FORMATION EVALUATION	MEASURED DEPTH	WELLBORE DIAGRAM	CASING & CEMENTING DATA	MW & TYPE	HOLE DEV.
24" Hole		80'		CONDUCTOR PIPE — Air — Vert 24" @ 60' (no cement)		
17-1/2" Hole	Water zone @ ~650' (~3500 bbls to surf)	732'		CONDUCTOR CASING — Air / Mist — Vert 13 3/8" 54.5# J-55 STC @ 710' MD Spacer 100 bbls FW Tail: 15.6 ppg, 675 sxs / 142 bbls / 1.18 yield 5.2 gps mix water (3510 gal FW) Displaced with 123 bbls FW Partial/full returns, cement to surface, floats held Performed top job		
12-1/4" Hole	1 to 1.5 bph water gain while drilling (~50 bbls to surf)	1964'		SURFACE CASING — Air / Mist — 0.2 9 5/8" 36.0# K-55 LTC @ 1964' MD Spacer. 150 bbls FW Lead. 12.8 ppg, 360 sxs / 116 bbls / 1.81 yield 9.59 gps mix water (3452 gal FW) Tail. 15.6 ppg, 285 sxs / 60 bbls / 1.19 yield 5.2 gps mix water (1482 gal FW) Displaced with 138 bbls FW Full returns, cement to surface, floats held Tested casing to 1500 psi for 5 min		
	Mud Logger Platform Express (PEX) & FMI w/ Sonic Scanner on Wireline	TOC @ ~5500'		5 1/2" Cement Job — 1.0 Spacers 20 bbls gel pill, 20 bbls mud flush, and 5 bbls FW Tail. 14.2 ppg, 570 sxs / 122 bbls / 1.20 yield 6.0 gps mix water (3420 gal FW) Displaced with 183 bbls 3% KCl Full returns, floats held		
8-3/4" Hole (on Air) Core pt @ 7474' 7-7/8" Hole (with 3% KCl)	Cored intervals #1 7474' - 7534' (60') #2 7534' - 7603' (69') #3 7603' - 7657' (54') #4 8034' - 8091' (57') #5 8085' - 8145' (60') #6 8145' - 8205' (60')	8350'		Marcellus C Shale @ ~7657' MD — 10.4 Upper Cherry Valley Limestone @ ~7778' MD — 12.7 Marcellus B Shale @ ~7839' MD — 13.2 Lower Cherry Valley Limestone @ ~7910' MD — 14.0 Marcellus A Shale @ ~8036' MD — 14.6 Onondaga Limestone @ ~8220' MD — 13.5 PRODUCTION CASING — 3% KCl — 11.2 5 1/2" 20.0# P-110 LTC @ 8350' MD — 10.8		

"Water Zone @ ~650'"

Surface Casing to 1964'

5/9/2008 spud date, 6/6/2008 completion

Marcellus from 7667' – 8036', production casing to 8350'

Implications for Marcellus Gas Exploration in the PA DRB

- Majority of supply wells are 200-300 feet deep
- With gas well frac depths of ~7000-8000', approximately one mile or more of rock separates frac zone and fresh groundwater; therefore
- With properly constructed gas wells, the groundwater exposure pathway from downhole frac fluids is incomplete

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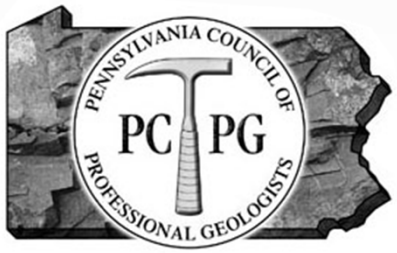
BUT: *THE SHALLOWER THE POTABLE WELL, THE MORE VULNERABLE TO SURFACE RELEASES…*

BEST MANAGEMENT PRACTICES (BMPS) ARE THE KEY TO CONTAINMENT OF FRAC FLUIDS AND FLOWBACK WATER



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BMPS IN ACTION

Pa. investigating Marcellus well blowout

January 26, 2011 | By Andrew Maykuth, Inquirer Staff Writer

Pennsylvania environmental officials said Tuesday that they were investigating a blowout at a Marcellus Shale natural gas well in Tioga State Forest last week.

The state Department of Environmental Protection said specialists regained control over the Talisman Energy Inc. well in Ward Township, Tioga County, after 31/2 hours on Jan. 17, a national holiday. There were no injuries.

The DEP said the incident occurred during a hydraulic-fracturing operation. Talisman reported that 21,000 gallons of fracturing fluids and sand spewed onto the well site. The agency said the fluids appeared to have been contained on the plastic-lined well pad.

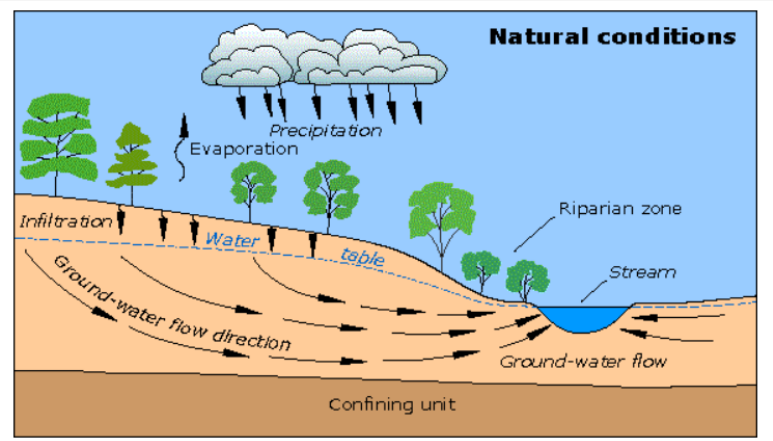
"It does not appear that any significant amount of natural gas was released, and there was no fire or explosion," the DEP said in a news release.

http://articles.philly.com/2011-01-26/business/27049596_1_talisman-energy-blowout-marcellus-shale

Lined Marcellus Location – Southwestern Pennsylvania

Other Protections for Groundwater?

- Chapter 78 Well Casing Requirements
- Pre-Drill Surveys
- Comprehensive Pre Drill Programs
- Stray Gas Investigations Required
- Water Well Casing Regulations



PENNSYLVANIA COUNCIL OF PROFESSIONAL GEOLOGISTS
PC PG

ERG
EARTHRES GROUP

Pre Drill Surveys – Gas Exploration

- **Information Sources**
  - Penn State Cooperative Extension: http://extension.psu.edu/water/marcellus-shale
  - PA DEP: http://www.dep.state.pa.us/dep/deputate/minres/oilgas/factsheets.htm http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_forms/marcellus/marcellus.htm
  - Wilkes University: http://www.water-research.net/

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PA-DEP Recommended Basic Oil & Gas Pre-Drill Parameters

The Pennsylvania Department of Environmental Protection (DEP) has developed the following list of parameters that are recommended for homeowners who wish to have their private well tested. The following list is not an exhaustive list of testing, homeowners may wish to have their water tested for a more extensive list of parameters. Additionally, while it is not recommended, if a homeowner wishes to test for less than the recommended list, the minimum parameters that should be analyzed for are printed in **bold** in the table below. It is recommended that homeowners test their water within one year prior to well drilling. Homeowners can sign up for DEP's e-notice system to receive notice of well permit applications DEP has received for wells in the area they choose. The Web site address is: http://www.ahs2.dep.state.pa.us/eNOTICEWeb/.

Analyte (Inorganic)
Alkalinity
Chloride
Conductivity
Hardness
Oil and Grease
pH*
Sulfate
Total Dissolved Solids*
Residue - Filterable
Total Suspended Solids
Residue – Non Filterable

Analyte (Trace Metal)
Barium
Calcium
Iron*
Magnesium
Manganese*
Potassium
Sodium*
Strontium

Analyte (Organic)
Ethane*
Methane*

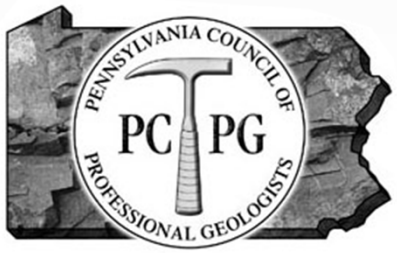
Analyte (Microbiology)
Total Coliform/E.coli

http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-82193/5500-FS-DEP4300.pdf

EARTHRES GROUP

Pre Drill Surveys
Who? Where ?

- Most gas well operators will collect the necessary pre-drilling water quality information from all drinking water supplies within 1,000 feet of their drilling operation.
- The gas well company is required to hire an independent state-certified water testing laboratory.



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Elements of A Stray Gas Investigation Survey

- Complete Pre-Drill Water Sampling Survey. If methane found, complete assessment
- Interviews with area homeowners, businesses, officials, etc.
- Identify all potential sources/pathways in the immediate area of investigation.
- Collect samples of the stray gas, and potential sources for molecular and isotopic analyses

Modified from: Fred Baldassare, Nov. 2009

EARTHRES GROUP

Elements of A Stray Gas Investigation Survey

- Identify and evaluate each potential source for potential mechanisms of migration
- Soil Gas Surveys
- Focus investigation on the basis of molecular and isotopic analyses.
- Assess sources, pathways and mitigation techniques

Modified from: Fred Baldassare, Nov. 2009

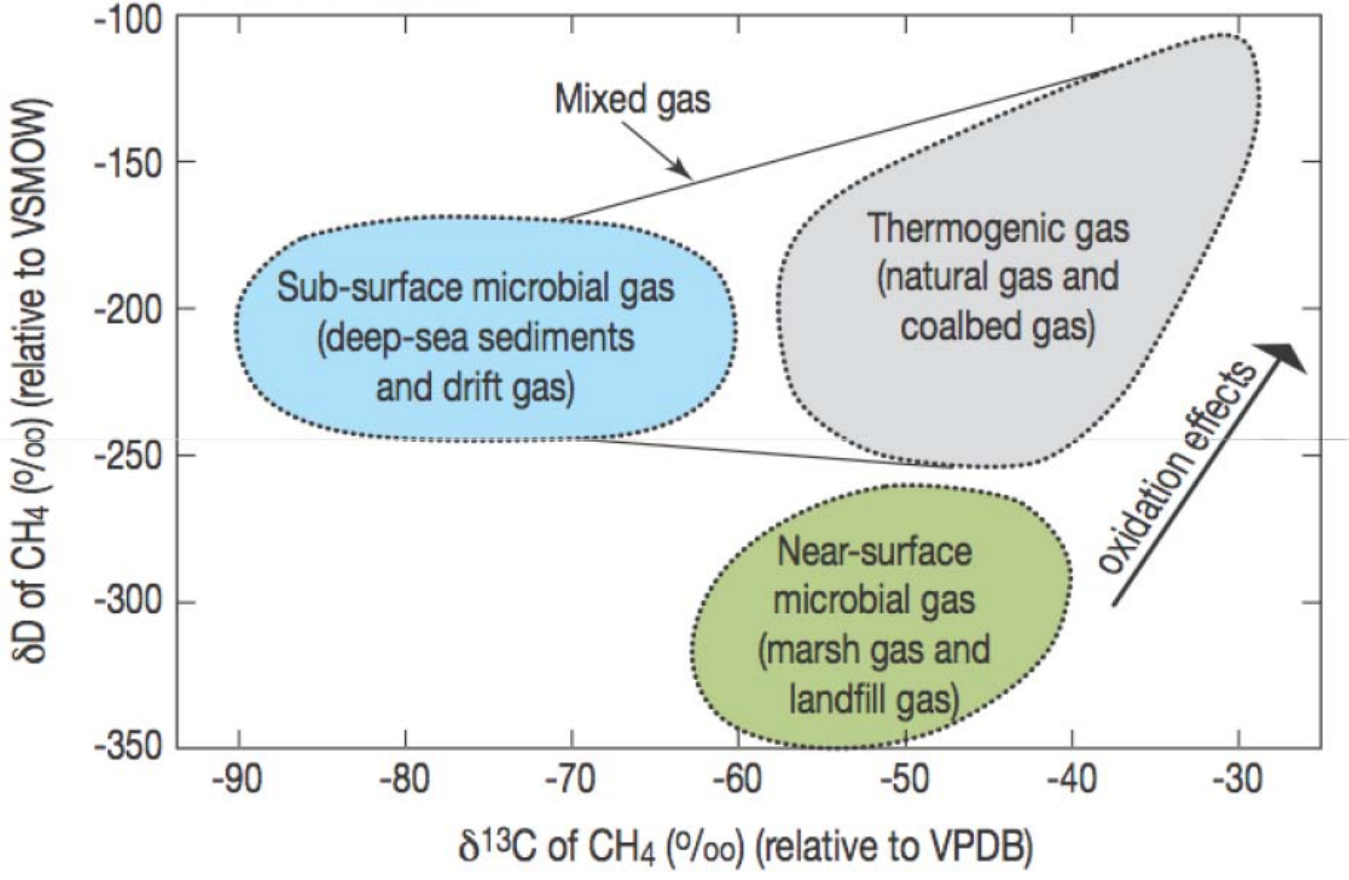
Potential Sources of Stray Gas

- Gas wells
- Coal mining
- Old Landfills / Dumps
- Swamps
- Utilities (gas lines, and migration pathways)
- Shallow Geological Formations (i.e. glacial drift gas, peat, etc.)
- Geologic Features (faults, lineaments, fractures,

Modified from: Fred Baldassare, Nov. 2009

EARTHRES GROUP

Stable carbon and hydrogen isotopic compositional ranges of methanes from different sources.

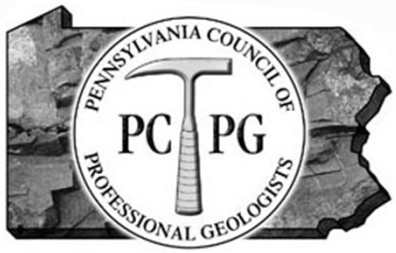


After Coleman and others (1993) based on the data set of Schoell (1980)

Water Well Construction Stds.

House Bill 1855 (Miller-R)

- More than 3 million rural and suburban residents in Pennsylvania rely on a private well for drinking water and about 20,000 new wells are drilled each year in the Commonwealth
- Among our sister states, only Michigan has a larger population served by private water supplies.
- Yet Pennsylvania is one of only two states (Alaska the other) that do not have statewide well construction standards.
- Some local governments in Pennsylvania (county or municipal) have developed and implemented well permitting, construction and/or testing requirements, but no uniform statewide standards exist.
- Poorly constructed water wells pose a human health and safety risk not only to those persons that rely on them for water supply, but to others as well.



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Water Well Construction Stds.

House Bill 1855 (Miller-R)

- Poorly constructed wells can be pathways for the introduction and spread of contaminants to human and ecological receptors through local aquifers, surface waters and other valuable water resources of the Commonwealth.
- PCPG has consistently advocated for the development of private water well construction standards in the Commonwealth and strongly supports House Bill 1855 (Miller-R), and has provided testimony in support (see www.pcpg.org)

- We urge to support the Bill!

PENNSYLVANIA COUNCIL OF PROFESSIONAL GEOLOGISTS
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Environmental Aspects of

Shale Gas Development

Air & Waste Management
Association
Mid-Atlantic States Section

THANK YOU !!

Presented by:

Louis F. Vittorio, Jr., P.G.

EarthRes Group, Inc.

President, PCPG

March 27, 2012

Pennsylvania Council of Professional Geologists
PC PG

ERG
EarthRes Group

Air & Waste Management
A s s o c i a t i o n
Mid-Atlantic States Section

MID-ATLANTIC STATES SECTION AIR AND WATER MANAGEMENT ASSOCIATION

ENVIRONMENTAL ASPECTS OF SHALE GAS DEVELOPMENT
MARCH 27, 2012

Wastewater Produced by Shale Gas Production
Some Regulatory and Management Issues

Tracy Carluccio
Delaware Riverkeeper Network

DELAWARE RIVERKEEPER®

Air & Waste Management
Association
Mid-Atlantic States Section

United States Government Accountability Office

GAO

Report to the Ranking Member, Committee on Science, Space, and Technology, House of Representatives

January 2012

ENERGY-WATER NEXUS

Information on the Quantity, Quality, and Management of Water Produced during Oil and Gas Production

G A O

Accountability * Integrity * Reliability

GAO-12-156

According to EPA records, in 2010 there were 150,855 injection wells authorized for the injection of fluids brought to the surface during oil and gas production, including produced water, although EPA officials told us that not all are currently operating.[18] About four-fifths of the wells—124,837—are located in the nine states we reviewed (see table 1).

Table 1: Number of Injection Wells in Selected States

State	Number of injection wells
Texas	52,016
California	29,505
Kansas	16,658
Oklahoma	10,629
Wyoming	4,978
New Mexico	4,585
Louisiana	3,731
Pennsylvania	1,861
Colorado	874
Total in selected states	**124,837**

Source: GAO analysis of EPA data.

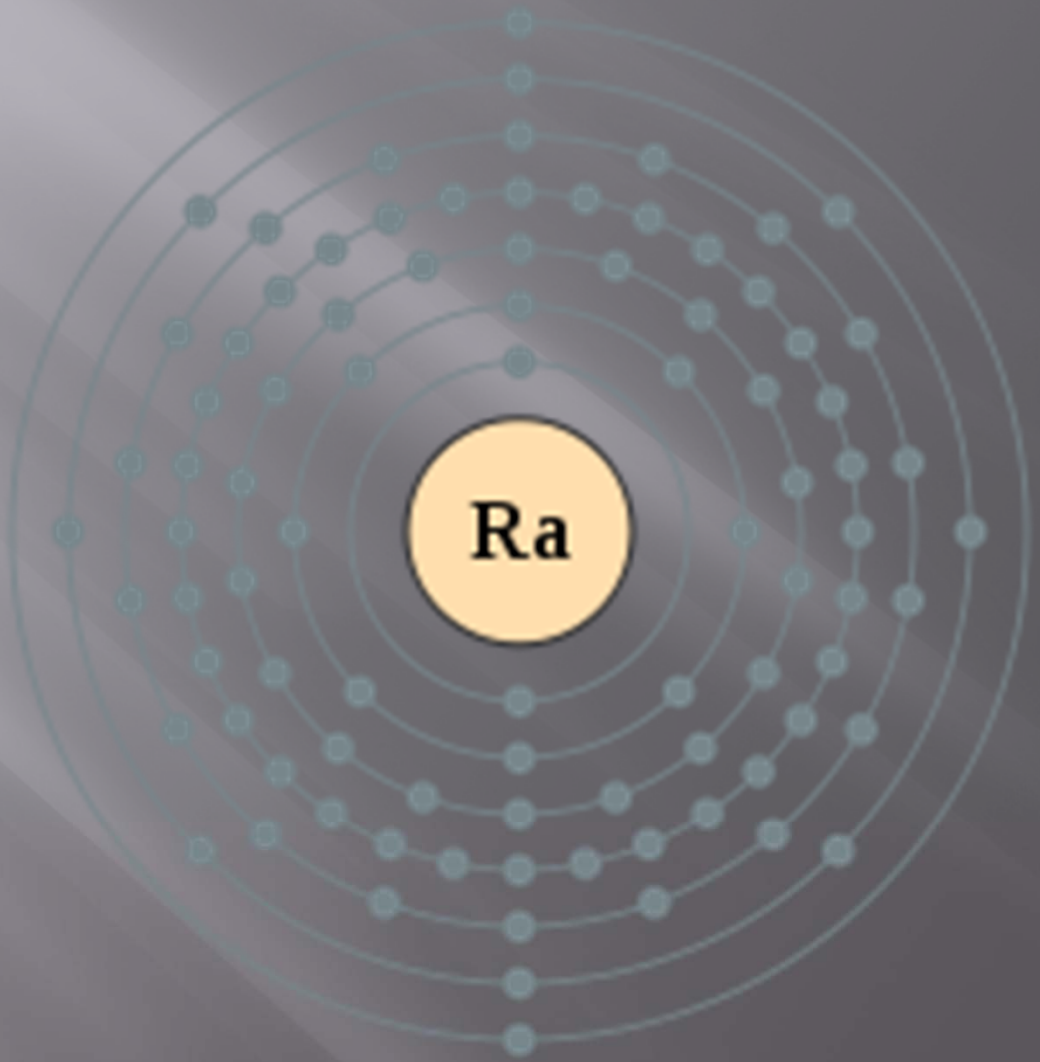
According to state regulators we interviewed in the nine states, underground injection is common in most, but not all, of their states. Specifically, regulators in five states told us that all or almost all of the produced water is managed through underground injection, and in three other states, most of the produced water is managed this way. In the ninth state—Pennsylvania—many producers use underground injection for enhanced recovery, but the practice is not widely used for disposal, according to EPA officials.[19]

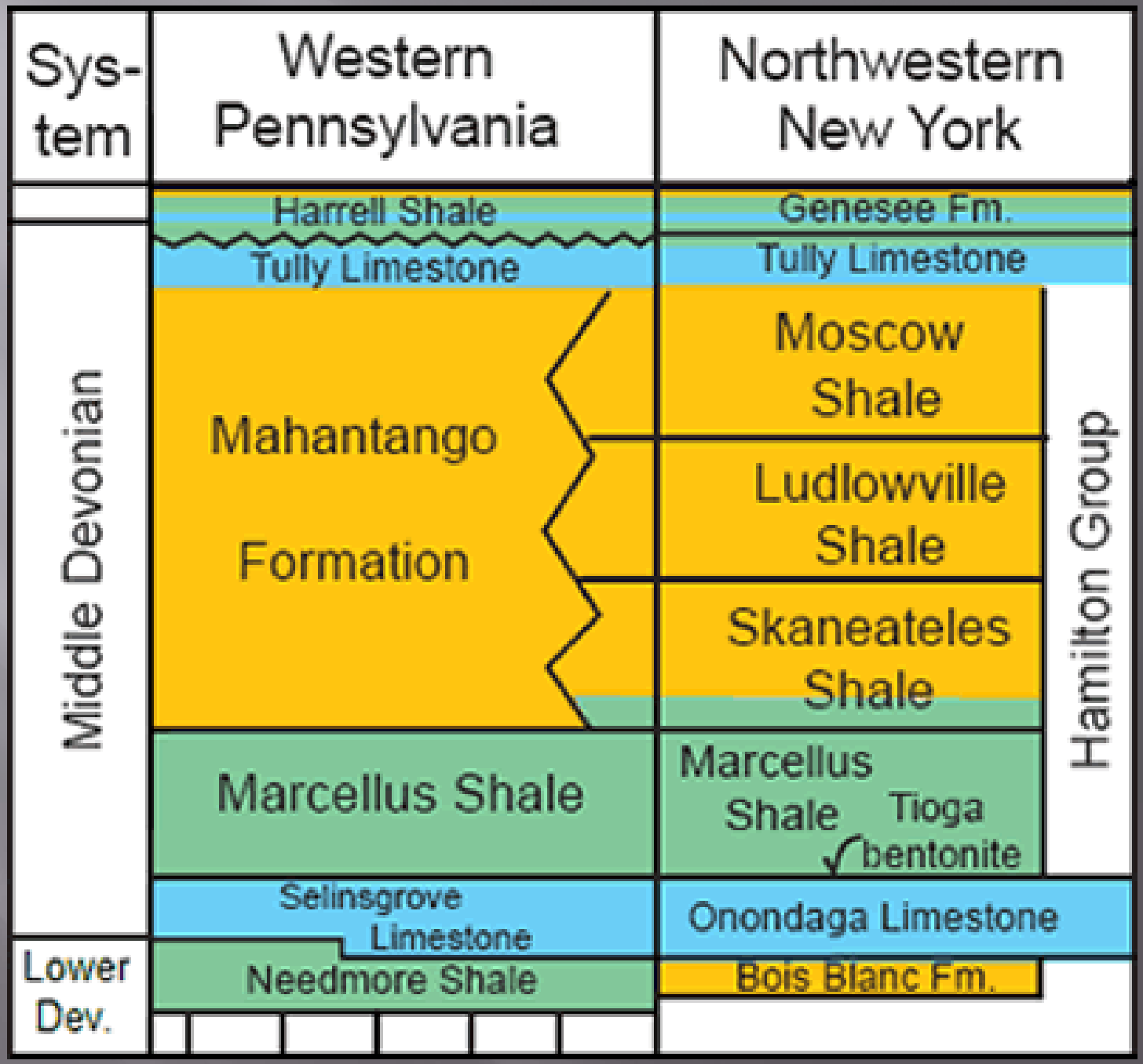
[18]Although approximately 80 percent of these injection wells are used for enhanced recovery and the remaining 20 percent are used for disposal, only about 59 percent of produced water is injected into these wells for enhanced recovery, and about 40 percent is injected for disposal.

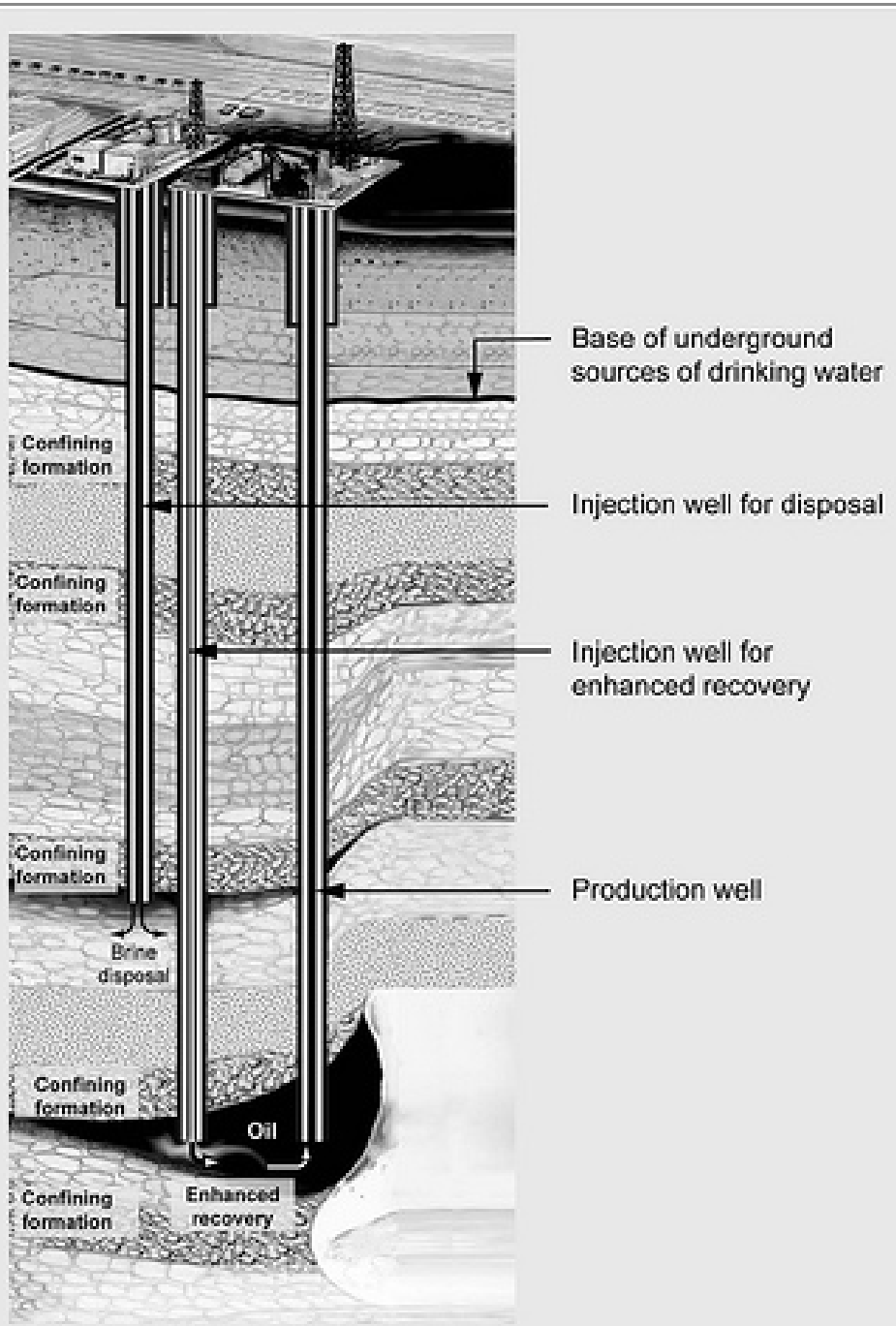
[19]According to EPA officials, there are currently only six active injection wells for produced water disposal in Pennsylvania. As a result, producers that want to dispose of produced water through underground injection would generally have to transport the water to authorized injection wells in Ohio or West Virginia, and trucking can be expensive. However, EPA officials we interviewed said that in the past 2 years producers have shown interest in drilling additional injection wells for disposal in Pennsylvania, and EPA has received permit applications for new wells.

88: Radium

2,8,18,32,18,8,2




Sys-
tem
Western
Pennsylvania
Northwestern
New York
Harrell Shale
Tully Limestone
Genesee Fm.
Tully Limestone
Middle Devonian
Mahantango
Formation
Moscow
Shale
Ludlowville
Shale
Skaneateles
Shale
Hamilton Group
Marcellus Shale
Marcellus
Shale
Tioga
bentonite
Selinsgrove
Limestone
Onondaga Limestone
Lower
Dev.
Needmore Shale
Bois Blanc Fm.


Base of underground sources of drinking water
Confining formation
Injection well for disposal
Confining formation
Injection well for enhanced recovery
Confining formation
Production well
Brine disposal
Confining formation
Oil
Confining formation
Enhanced recovery

Source: EPA

DELAWARE RIVERKEEPER®

Frac Fluid Spill at Cabot Gas Well, Dimock, PA, 9.09

DELAWARE RIVERKEEPER®

Air & Waste Management
A s s o c i a t i o n
Mid-Atlantic States Section

ENVIRONMENTAL ASPECT OF SHALE GAS DEVELOPMENT

MASS-AWMA CONFERENCE
March 27, 2012

INDUSTRY PERSPECTIVE

Air & Waste Management
Association
Mid-Atlantic States Section

SOME NUMBERS

0 / 0

1.5 Trillion

3.25 Trillion

CHIEF OIL & GAS LLC

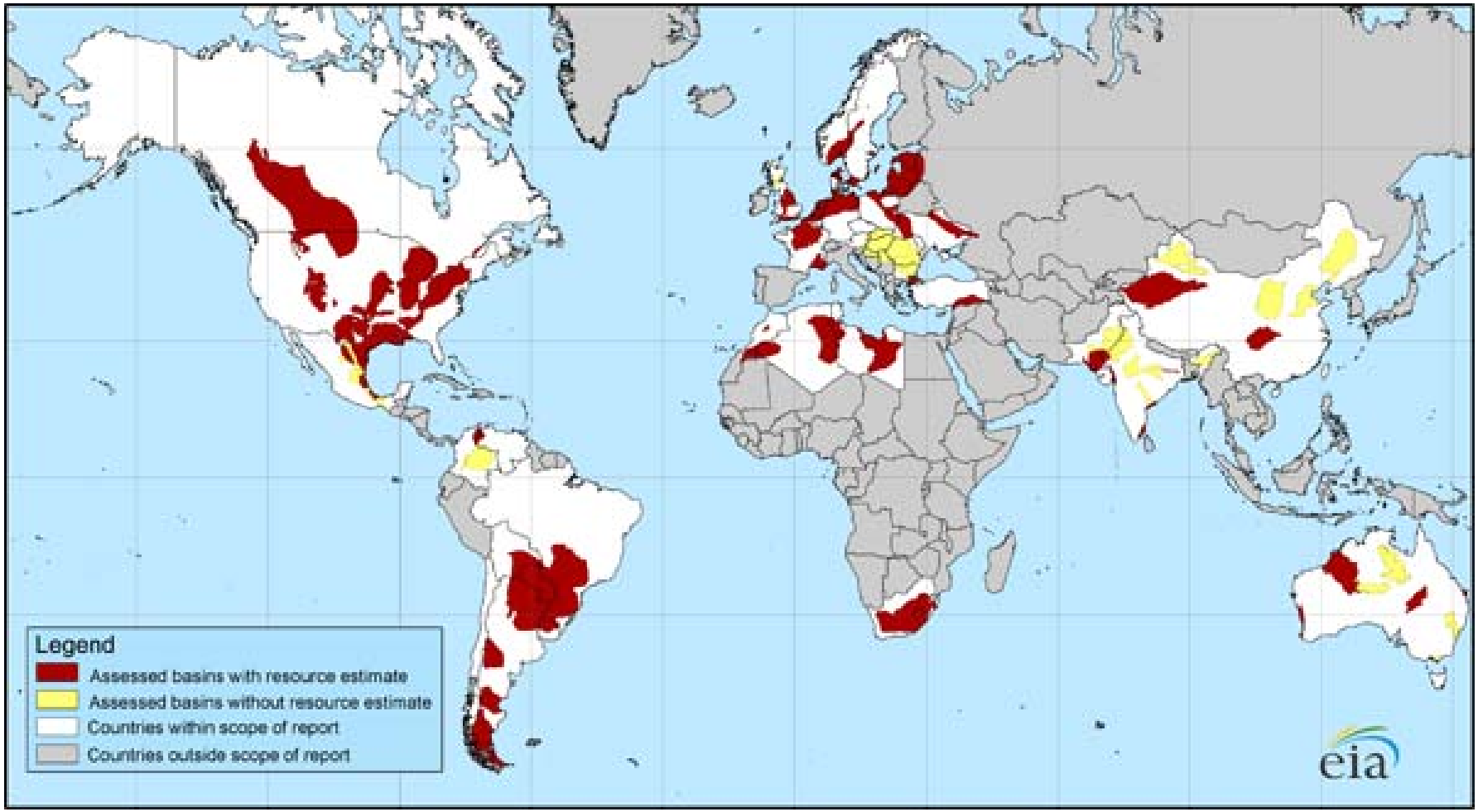
90%

CHIEF OIL & GAS LLC

30%

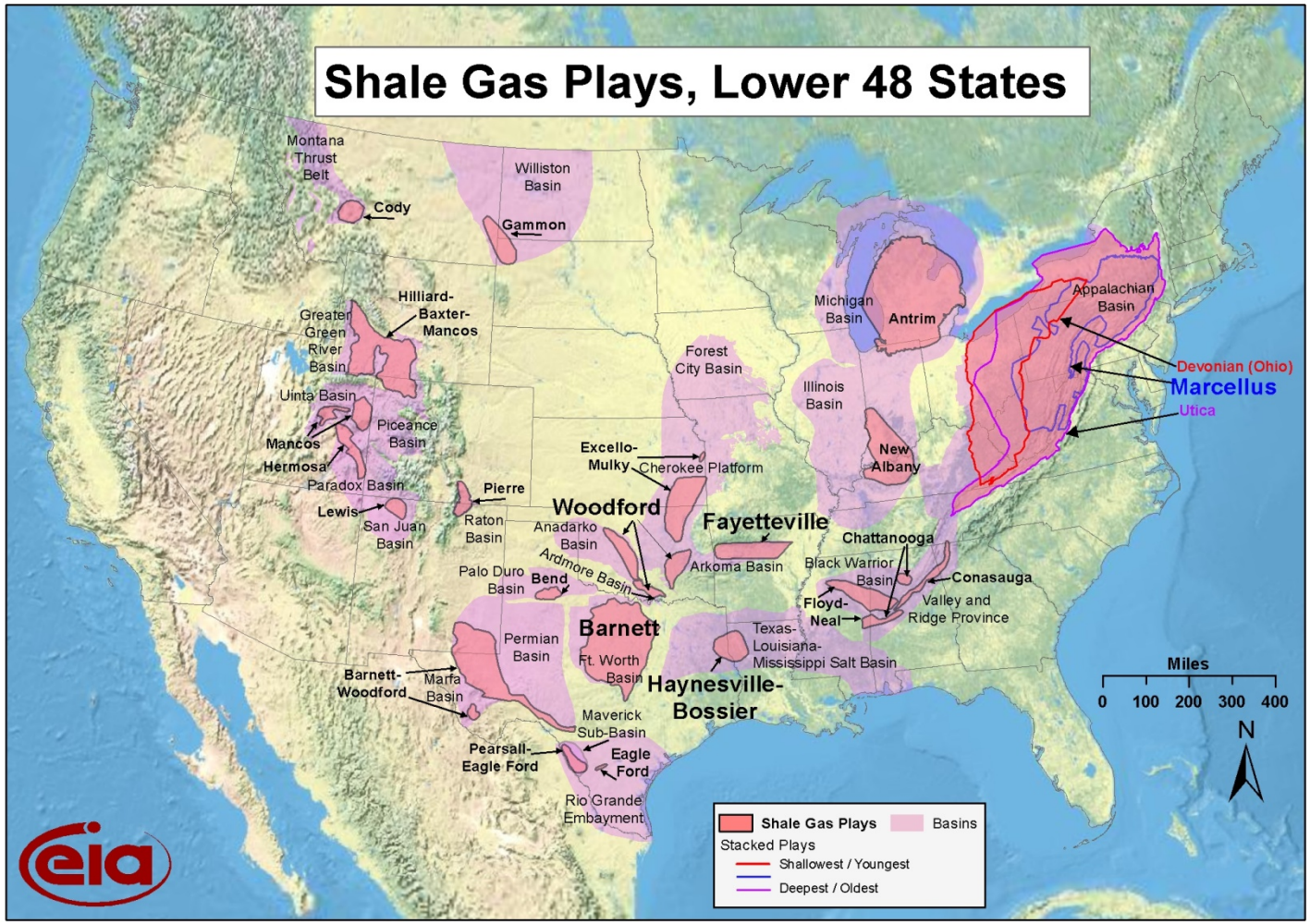
Shale Gas Revolution

Shale Gas: A Global Phenomenon



Source: Energy Information Administration

Shale Gas Revolution Across the U.S.



Source: Energy Information Administration

Economic Benefits

Key Report Findings

- Pennsylvania is self-sufficient in natural gas (net exporter)
- 2020 output levels (17 billion cubic feet per day) could make the Marcellus the single largest producing gas field in the U.S.
- Marcellus could produce a quarter of U.S. natural gas by 2020.
- $1.6 billion in lease and bonus payments in 2010.

Consumer Benefits

- Energy costs dropped by $633 million in 2010 (Penn State, July 2011)
- Electricity rates drop by 50% (Bloomberg News, January 2012)
- Residential gas and electric customers are saving $200 a year (Navigant Consulting, January 2012)
- Major utilities serving Philadelphia area have reduced gas bills by 37% to 52% since 2008 (*Philadelphia Inquirer*, December 2011)

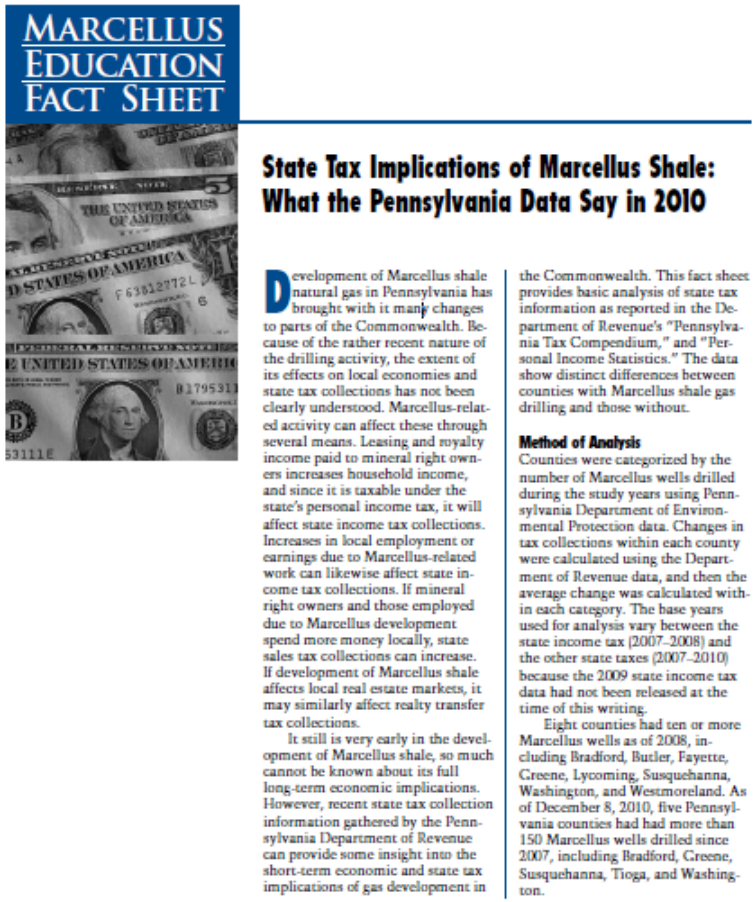
Revenue for Pennsylvania

Paid by Marcellus Industry	
Overall taxes since 2006[1]	$1.1 billion
State and local taxes in 2011[2]	$1.23 billion
Road construction investments since 2008[3]	$411 million
Royalty payments to state in 2011[4]	$107 million
Permitting and enforcement fees to increase DEP personnel	$11 million

[1] – Pennsylvania Department of Revenue, May 2011
[2] – Penn State University, "The Pennsylvania Marcellus Shale Natural Gas Industry: Status, Economic Impacts and Future Potential," July 20, 2011
[3] – Survey of Marcellus Shale Coalition Full Members
[4] – Pennsylvania Department of Conservation and Natural Resources

Revenue for Pennsylvania

- Penn State Analysis of Major Marcellus Counties:
  - 11.36% increase in state sales tax receipts since 2007
  - Stronger realty transfer tax collections vs. remainder of the state
  - 7% more in individual taxable income



MARCELLUS EDUCATION FACT SHEET

State Tax Implications of Marcellus Shale: What the Pennsylvania Data Say in 2010

Development of Marcellus shale natural gas in Pennsylvania has brought with it many changes to parts of the Commonwealth. Because of the rather recent nature of the drilling activity, the extent of its effects on local economies and state tax collections has not been clearly understood. Marcellus-related activity can affect these through several means. Leasing and royalty income paid to mineral right owners increases household income, and since it is taxable under the state's personal income tax, it will affect state income tax collections. Increases in local employment or earnings due to Marcellus-related work can likewise affect state income tax collections. If mineral right owners and those employed due to Marcellus development spend more money locally, state sales tax collections can increase. If development of Marcellus shale affects local real estate markets, it may similarly affect realty transfer tax collections.

It still is very early in the development of Marcellus shale, so much cannot be known about its full long-term economic implications. However, recent state tax collection information gathered by the Pennsylvania Department of Revenue can provide some insight into the short-term economic and state tax implications of gas development in the Commonwealth. This fact sheet provides basic analysis of state tax information as reported in the Department of Revenue's "Pennsylvania Tax Compendium," and "Personal Income Statistics." The data show distinct differences between counties with Marcellus shale gas drilling and those without.

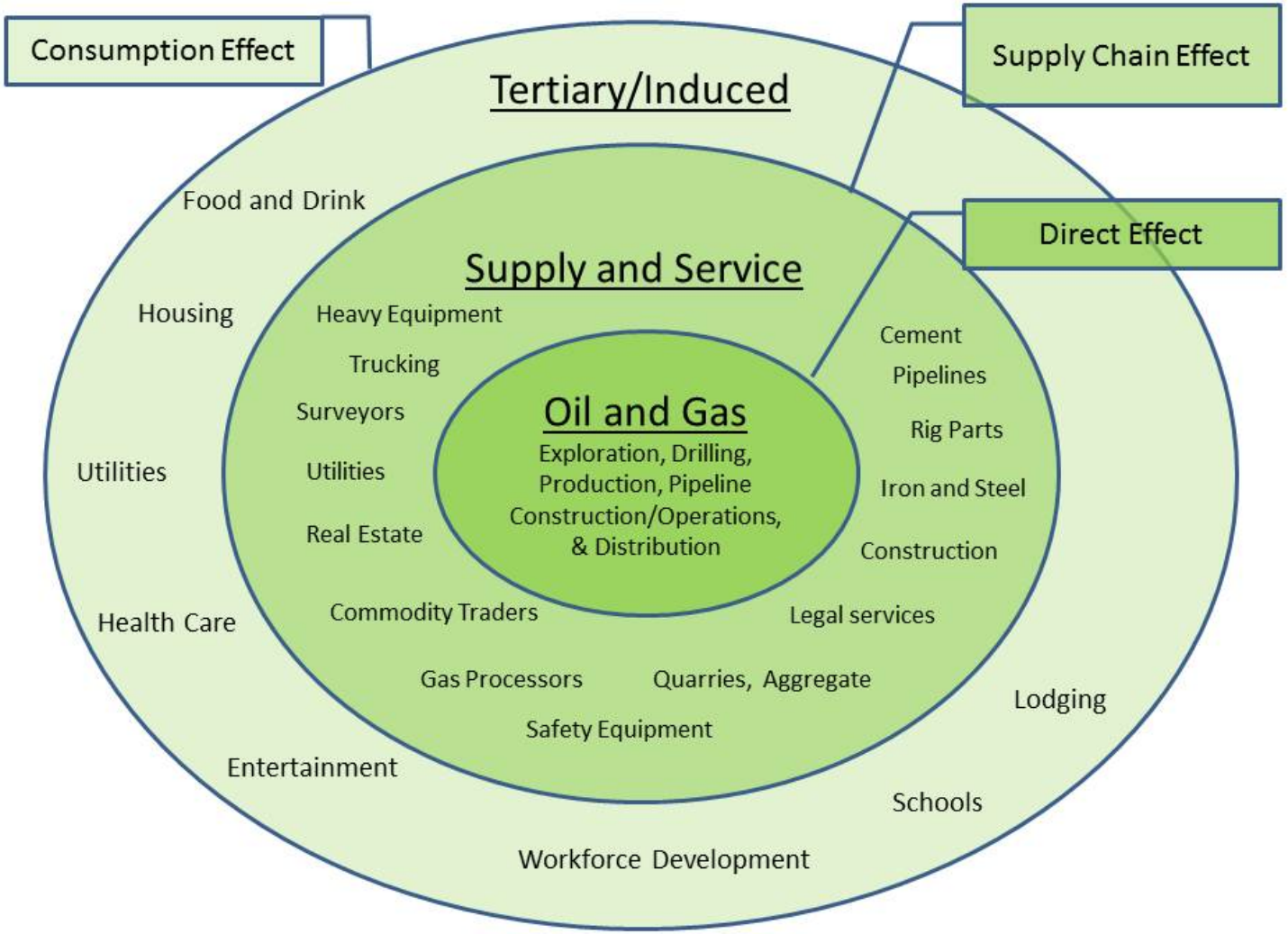
Method of Analysis

Counties were categorized by the number of Marcellus wells drilled during the study years using Pennsylvania Department of Environmental Protection data. Changes in tax collections within each county were calculated using the Department of Revenue data, and then the average change was calculated within each category. The base years used for analysis vary between the state income tax (2007–2008) and the other state taxes (2007–2010) because the 2009 state income tax data had not been released at the time of this writing.

Eight counties had ten or more Marcellus wells as of 2008, including Bradford, Butler, Fayette, Greene, Lycoming, Susquehanna, Washington, and Westmoreland. As of December 8, 2010, five Pennsylvania counties had had more than 150 Marcellus wells drilled since 2007, including Bradford, Greene, Susquehanna, Tioga, and Washington.

Source: Department of Revenue, May 2, 2011; Penn State Marcellus Education Team, February 27, 2011

Shale Economic Spectrum



Shale Gas: Steps in Drilling

Land Acquisition/Site Preparation

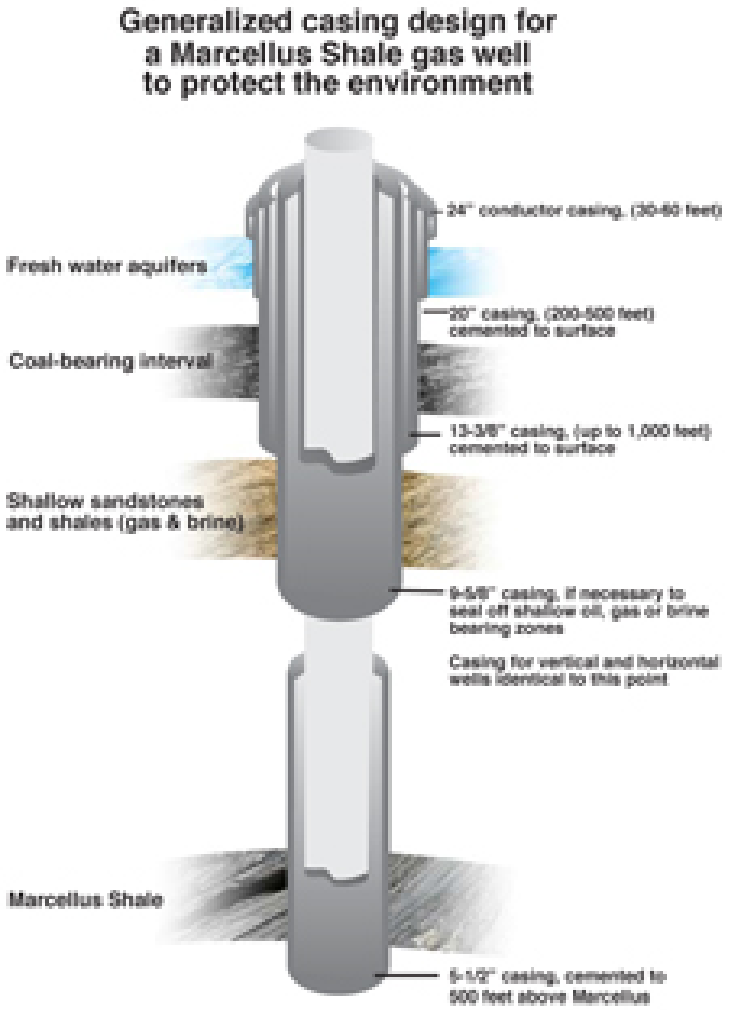
- Obtain rights from landowner.
- Educated landowner is an ideal partner.
- “Production unit” - contiguous parcels of land combined for development.
- Production unit incorporated into a company’s drilling program.
- Site is prepared for drilling activity.

Shale Gas: Environmental Protection in Wells

MARCELLUS SHALE COALITION

Well Casing

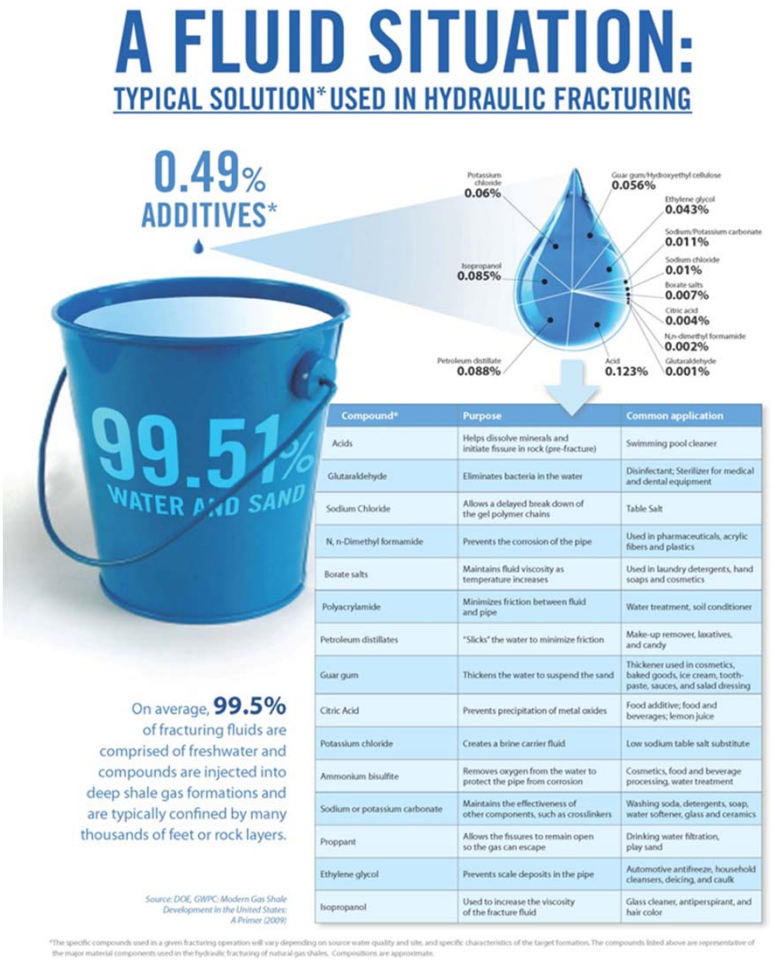
- Multiple layers of steel and cement to ensure redundant protection
  - 1 – through fresh water aquifer
  - 2 – to depths of ~1,500 feet
  - 3 – to final depths
- Cementing to surface at each layer provides stability and protection, preventing the crossflow of hydrocarbons
- 25 PA Code, Chapter 78 rules have further strengthened standards



Shale Gas: Steps in Completion

Hydraulic Fracturing (HF)

- > 60 years: more than 1 million wells in 27 states
- 90 percent of oil and gas wells use HF technology
- 99.5 percent water/sand mix
- 3 to 5 million gallons of water fractures the shale.
- Well casing protects water supply
- PA Chapter 78 upgrades reflect best practices in well casing



Compound*	Purpose	Common application
Acids	Helps dissolve minerals and initiate fissure in rock (pre-fracture)	Swimming pool cleaner
Glutaraldehyde	Eliminates bacteria in the water	Disinfectant; Sterilizer for medical and dental equipment
Sodium Chloride	Allows a delayed break down of the gel polymer chains	Table Salt
N, n-Dimethyl formamide	Prevents the corrosion of the pipe	Used in pharmaceuticals, acrylic fibers and plastics
Borate salts	Maintains fluid viscosity as temperature increases	Used in laundry detergents, hand soaps and cosmetics
Polyacrylamide	Minimizes friction between fluid and pipe	Water treatment, soil conditioner
Petroleum distillates	"Slicks" the water to minimize friction	Make-up remover, laxatives, and candy
Guar gum	Thickens the water to suspend the sand	Thickener used in cosmetics, baked goods, ice cream, tooth-paste, sauces, and salad dressing
Citric Acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice
Potassium chloride	Creates a brine carrier fluid	Low sodium table salt substitute
Ammonium bisulfite	Removes oxygen from the water to protect the pipe from corrosion	Cosmetics, food and beverage processing, water treatment
Sodium or potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Washing soda, detergents, soap, water softener, glass and ceramics
Proppant	Allows the fissures to remain open so the gas can escape	Drinking water filtration, play sand
Ethylene glycol	Prevents scale deposits in the pipe	Automotive antifreeze, household cleansers, deicing, and caulk
Isopropanol	Used to increase the viscosity of the fracture fluid	Glass cleaner, antiperspirant, and hair color

Shale Gas: Steps in Completion

Hydraulic Fracturing

- Permits from state regulatory agencies for water withdrawal.
- New technologies allow producers to recycle most water
- 1,000’ rebuttable presumption rule/ 2500’ as of 4/16/12
- 30 State and federal agencies monitor hydraulic fracturing

Shale Gas: Steps in Completion

Hydraulic Fracturing

- Industrial process; properly encased well, along with proper containment at the surface is critical.

- DEP: 80 orders to repair or replace water supplies in past 15 years;
  - 32,000 oil and gas wells drilled; 0.25% incident rate

- Legislature's Center for Rural PA: 2011 study
  - >40% of 1.2 million private water wells fail drinking water standards

Shale Gas: Steps in Completion

What Federal, State Regulators Say About Hydraulic Fracturing

U.S. EPA Administrator Lisa Jackson: "I'm not aware of any proven case where the fracking process itself has affected water." *(U.S. House Oversight & Government Reform Committee, May 24, 2011)*

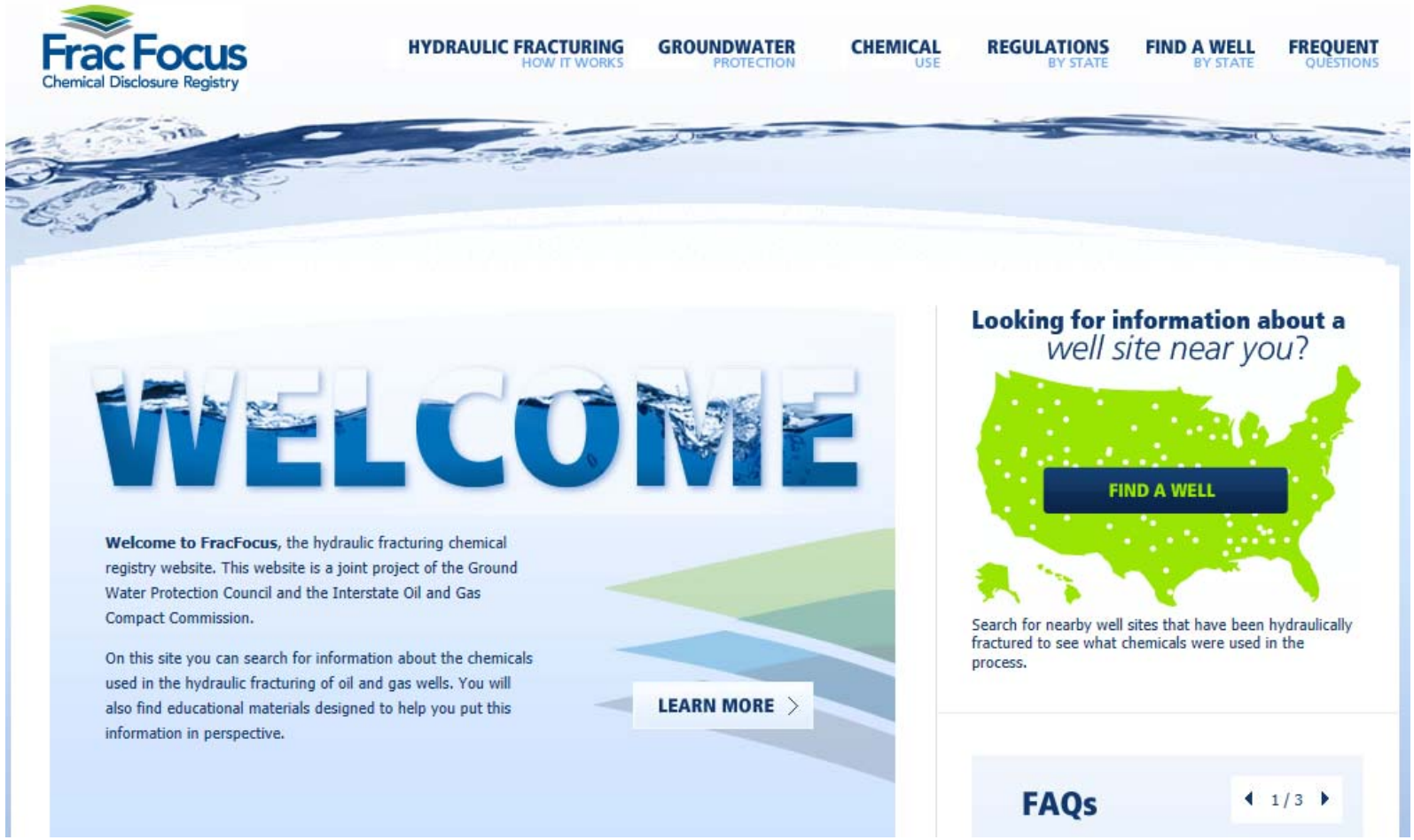
PENNSYLVANIA: "There has never been any evidence of fracking ever causing direct contamination of fresh groundwater in Pennsylvania or anywhere else." *(PA DEP's Scott Perry, Scranton Times-Tribune, 4/2/10)*

OHIO: "After 25 years of investigating citizen complaints of contamination, [our] geologists have not documented a single incident involving contamination of ground water attributed to hydraulic fracturing." *(Scott Kell, deputy chief of Ohio DNR, 5/27/09)*

ALABAMA: "I can state with authority that there have been no documented cases of drinking water contamination caused by such hydraulic fracturing operations in our state." *(Barry H. "Nick" Tew, Jr., Oil & Gas supervisor for Alabama, 5/27/09)*

Transparency

MSC Commitment to FracFocus.org Bolsters PA Requirements



FracFocus.org is a Project of the Groundwater Protection Council and the Interstate Oil & Gas Compact Commission

Environmental Protection

<u>Highly regulated. Highly sophisticated.</u>

- Transparency in permitting
- Staffing, permit fee increases
- Advances in water recycling and reuse
- Protective well casing standards
- Focus on best practices

Regulatory Framework

Site Construction

12 PA Regulations

Reclaimed/Completed Site

10 PA Regulations

Drilling Phase

18 PA Regulations

Hydraulic Fracturing

18 PA Regulations

Midstream

11 PA Regulations

Site Construction

- **Susquehanna River Basin Commission**
  - Chapter 806: Review and Approval of Projects
  - Water Withdrawal Registration
- **Delaware River Basin Commission**
  - Chapter 901: General Provisions

PA Code, Title 25, Environmental Protection

- Chapter 78: Oil and Gas Wells
- Chapter 79: Oil and Gas Conservation
- Chapter 92a: National Pollutant Discharge Elimination System (NPDES) Permitting, Monitoring and Compliance.
- Chapter 93: Water Quality Standards
- Chapter 102: Erosion and Sediment Control
- Chapter 105: Dam Safety and Waterway Management
- Chapter 106: Floodplain Management
- Chapter 110: Water Resources Planning
- Chapter 210: Blasters' Licenses
- Chapter 211: Storage, Handling and Use of Explosives
- Chapter 271: Municipal Waste Management
- Chapter 285: Storage, Collection and Transportation of Municipal Waste

Drilling Phase

- **Susquehanna River Basin Commission**
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  - Water Withdrawal Registration
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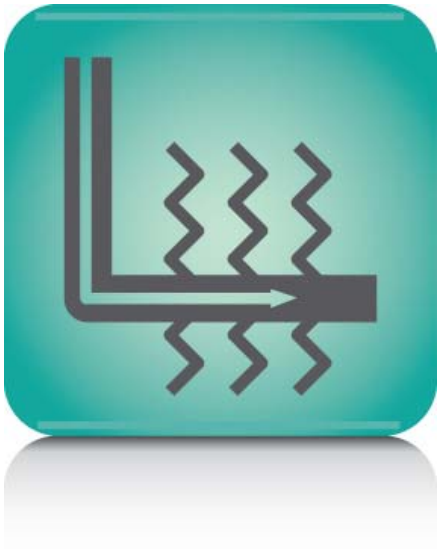
- Chapter 93: Water Quality Standards
- Chapter 105: Dam Safety and Waterway Management
- Chapter 106: Floodplain Management
- Chapter 110: Water Resources Planning
- Chapter 226: Licenses and Radiation Safety Requirements for Well Logging
- Chapter 245: Admin. of the Storage Tank and Spill Prevention Program
- Chapter 252: Environmental Laboratory Accreditation
- Chapter 271: Municipal Waste Management
- Chapter 285: Storage, Collection and Transportation of Municipal Waste
- Chapter 287: Residual Waste Management
- Chapter 289: Residual Waste Disposal Impoundments
- Chapter 293: Transfer Facilities for Residual Waste
- Chapter 297 Incinerator and Other Processing Facilities
- Chapter 298: Management of Waste Oil
- Chapter 299: Storage and Transportation of Residual Waste

Hydraulic Fracturing



- **Susquehanna River Basin Commission**
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  - Water Withdrawal Registration
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PA Code, Title 25, Environmental Protection

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- Chapter 95: Wastewater Treatment Requirements
- Chapter 105: Dam Safety and Waterway Management
- Chapter 106: Floodplain Management
- Chapter 110: Water Resources Planning
- Chapter 245: Admin. of the Storage Tank and Spill Prevention Program
- Chapter 252: Environmental Laboratory Accreditation
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- Chapter 285: Storage, Collection and Transportation of Municipal Waste
- Chapter 287: Residual Waste Management
- Chapter 289: Residual Waste Disposal Impoundments
- Chapter 293: Transfer Facilities for Residual Waste
- Chapter 297 Incinerator and Other Processing Facilities
- Chapter 298: Management of Waste Oil
- Chapter 299: Storage and Transportation of Residual Waste

Reclaimed/Completed Site

PA Code, Title 25, Environmental Protection

- Chapter 78: Oil and Gas Wells
- Chapter 79: Oil and gas Conservation
- Chapter 92a: National Pollutant Discharge Elimination System (NPDES) Permitting, Monitoring and Compliance.
- Chapter 93: Water Quality Standards
- Chapter 102: Erosion and Sediment Control
- Chapter 105: Dam Safety and Waterway Management
- Chapter 106: Floodplain Management
- Chapter 110: Water Resources Planning
- Chapter 271: Municipal Waste Management
- Chapter 285: Storage, Collection and Transportation of Municipal Waste

Midstream

PA Code, Title 25, Environmental Protection

- Chapter 102: Erosion and Sediment Control
- Chapter 105: Dam Safety and Waterway Management
- Chapter 106: Floodplain Management
- Chapter 110: Water Resources Planning
- Chapter 121: Air Resources – General Provisions
- Chapter 122: National Standards of Performance for New Stationary Sources
- Chapter 123: Standards for Containments
- Chapter 127: Construction, Modification, Reactivation and Operation of Sources
- Chapter 129: Air Resources – Standards and Sources
- Chapter 245: Admin. of the Storage Tank and Spill Prevention Program
- Chapter 285: Storage, Collection and Transportation of Municipal Waste

Environmental Protection

The Patriot-News

DEP says Marcellus Shale drilling waste no longer being discharged into streams

Published: Friday, June 03, 2011, 5:04 PM Updated: Friday, June 03, 2011, 7:16 PM

By DONALD GILLILAND, The Patriot-News

Follow

Pennsylvania has accomplished a "dramatic sea change" in its protection of water from pollution by drilling for natural gas in the **Marcellus Shale**, according to the state's top environmental regulator.

Focus on Wastewater / Bromides

- Bromide have been problematic in western PA rivers long before Marcellus Shale development commenced in 2005.
- Once the Marcellus industry understood the bromide issue, it took collective and immediate action to discontinue surface discharge.
- **MSC member companies not discharging flowback water to be treated at wastewater facilities – increased recycling and reuse**.

Environmental Protection

Less Reliance on Water Resources

	Gallons per million BTU	
	Range	Mid-point
Deep shale natural gas	0.60 – 5.80	3
Nuclear	8 – 14	11
Conventional oil	8 – 20	14
Coal	13 – 32	23
Fuel ethanol from corn	2,510 – 29,100	15,800
Biodiesel from soy	14,000 – 75,000	44,500

Source: Ground Water Protection Council, U.S. Department of Energy

Water Use: In Perspective

The 5 million gallons of water needed to drill and complete a typical deep shale gas well is equivalent to the amount of water consumed by:

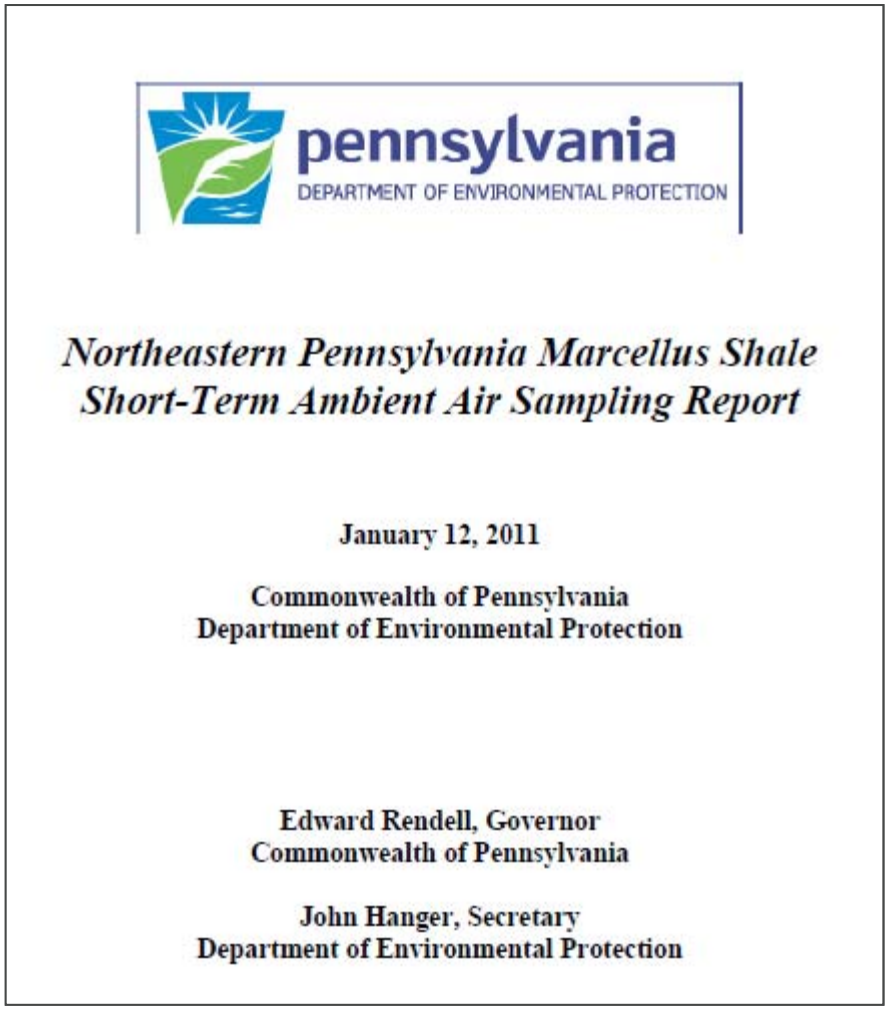
- New York City in approximately four minutes
- A 1,000 megawatt coal-fired power plant in 12 hours
- A golf course in 25 days
- OR flowed past Port Jervis in 2 minutes on March 9, 2012.

Source: CONSOL Energy, September 22, 2011/ USGS Current Water Data for the Nation 3/9/12

Environmental Protection

Air Quality Standards

- Short-term monitoring in Northeastern, Southwestern, and North Central PA:
  - **"[D]id not identify concentrations of any compound that would likely trigger air-related health issues associated with Marcellus Shale drilling activities."**
- Air quality standards tightly-regulated:
  - Gas Processing Plants: Plan approval/air permit
  - Compressors: Covered by GP-5
- Companies exploring "bifuel" rigs to reduce use of diesel


pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Northeastern Pennsylvania Marcellus Shale Short-Term Ambient Air Sampling Report

January 12, 2011

Commonwealth of Pennsylvania
Department of Environmental Protection

Edward Rendell, Governor
Commonwealth of Pennsylvania

John Hanger, Secretary
Department of Environmental Protection

Environmental Protection

Environmental, Public Health Benefits of Natural Gas

- When used to generate electricity, natural gas emits just over half of the CO_2 per megawatt-hour (MWh) of a traditional power plant.
- Natural gas combined-cycle turbines emit 60 percent less CO_2 per MWh than a typical coal plant.
- Natural gas vehicles emit 25% less CO_2 than vehicles that run on traditional fuels.
- According to the Congressional Research Service, if U.S. doubled the utilization of combined cycle natural gas capacity to 85%, we could displace approximately 636 million metric tons of CO_2. This amounts to an 8.8% reduction of all CO_2 emissions in the U.S.

Environmental Protection

Clean-Burning Natural Gas: What Others Are Saying

Energy Information Administration: "*There was also a decline in the carbon dioxide intensity of U.S. energy supply (CO2 per unit of energy) in 2009, caused primarily by a drop in the price of natural gas relative," as "more natural gas consumed for the generation of electricity*." (EIA release, 3/31/11)

Kathleen McGinty, Former DEP Secretary: "Shale gas is a game changer in energy with significant promise economically, in terms of national security, and in improving environmental quality." (US Senate testimony, 10/4/11)

John Quigley, PennFuture Lobbyist and Former PA DCNR Secretary: *"As the cleanest burning fossil fuel, expanding the use of natural gas in place of more polluting fossil fuels can – if done right – help clean our air, reduce global warming emissions, reduce soot and mercury pollution, and improve public health." (Testimony, 9/26/11)*

Cynthia Dougherty, Director, Office of Ground Water and Drinking Water, EPA: **"**Natural gas has the potential to improve air quality, stabilize energy prices, and provide greater certainty about future energy reserves." (US Senate testimony, 11/20/11)