



# HYDRAULIC FRACTURING & SAFE DRINKING WATER

*Hydraulic Fracturing Workshop*  
*March 30, 2011*





# Joseph J. Lee, Jr., P.G. President



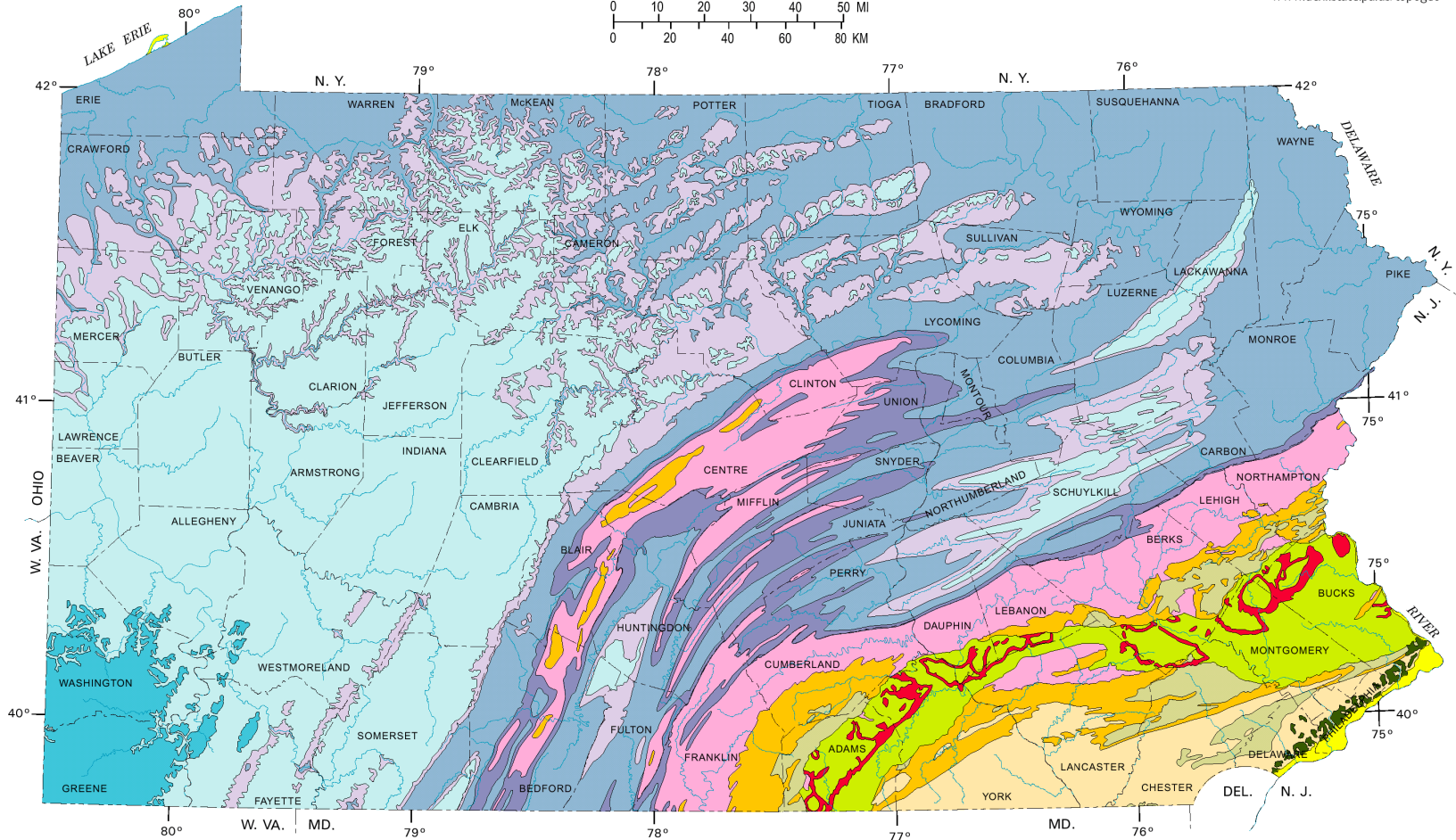
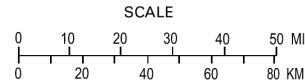
Pennsylvania Department of  
Environmental Protection  
Bureau of Watershed Management  
(717)783-5469  
[joslee@state.pa.us](mailto:joslee@state.pa.us)

# KEY MESSAGES

- 1. State Oil & Gas (O&G) regulations are adequate to protect water resources**
- 2. Well construction regulations are adequate for Hydraulic Fracturing (HF); However, development of adaptable BMPs would assist operators and states**
- 3. There are environmental challenges for water and drinking water programs posed by gas shale development**
- 4. We know surface water & ground water stressed by past mineral extraction in area of Marcellus Shale**
- 5. We have holes in our understanding of ground water going forward**

# GEOLOGIC MAP OF PENNSYLVANIA

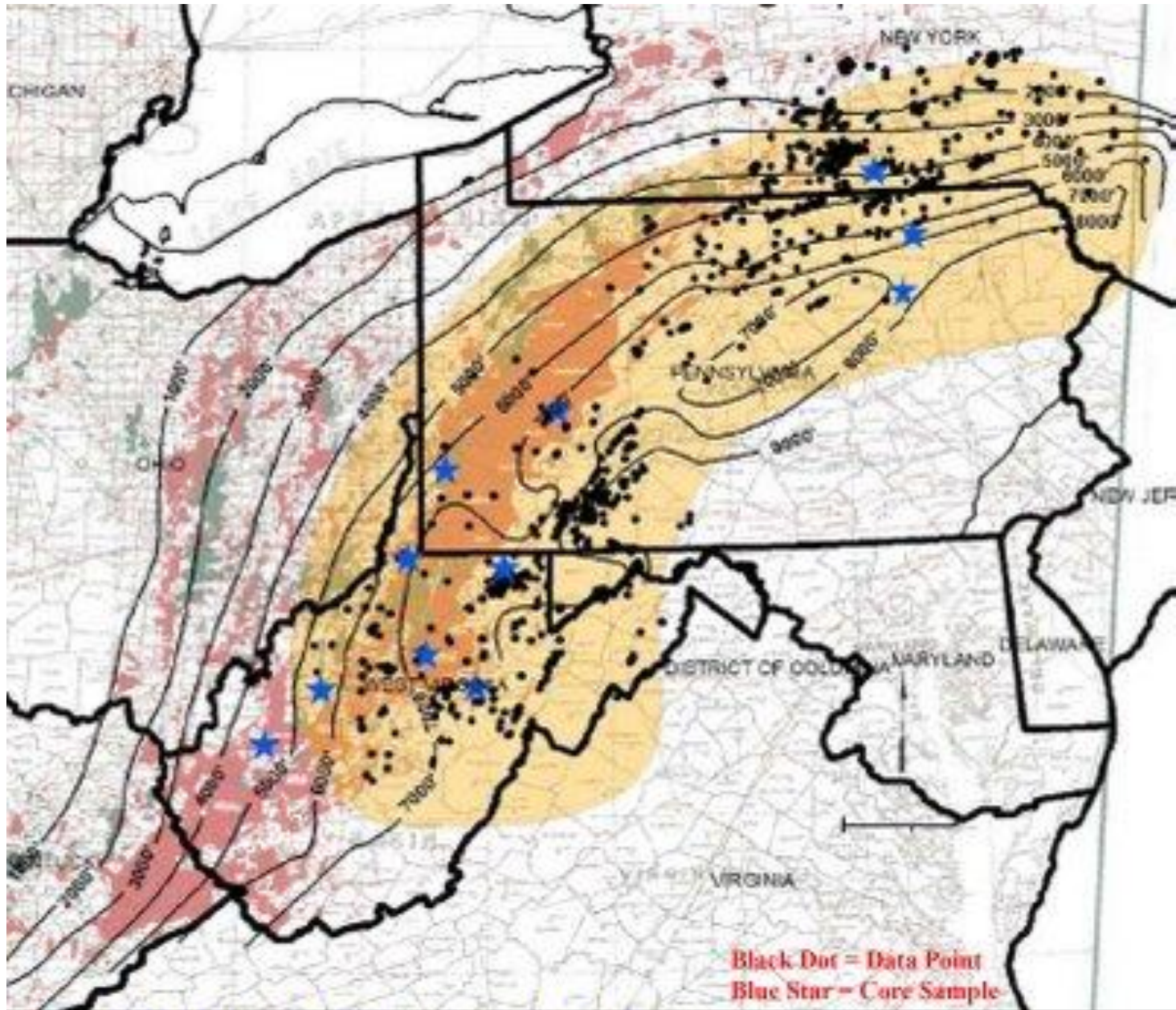
COMMONWEALTH OF PENNSYLVANIA  
DEPARTMENT OF  
CONSERVATION AND NATURAL RESOURCES  
BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY  
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## EXPLANATION

<b>QUATERNARY</b> (0-2 mil. yrs.) Sand, gravel, and silt. <i>Sand and gravel.</i>	<b>TERTIARY</b> (2-67 mil. yrs.) Sand, gravel, silt, and clay. <i>Sand and gravel.</i>	<b>JURASSIC AND TRIASSIC</b> (140-250 mil. yrs.) Red sandstone, shale, and conglomerate (green), intruded by diabase (red). <i>Building stone, iron.</i>	<b>PERMIAN</b> (250-290 mil. yrs.) Cyclic sequences of shale, sandstone, limestone, and coal. <i>Lime, clay.</i>	<b>PENNSYLVANIAN</b> (290-330 mil. yrs.) Cyclic sequences of sandstone, red and gray shale, conglomerate, clay, and limestone. <i>Coal, clay, lime, building stone.</i>	<b>MISSISSIPPIAN</b> (330-365 mil. yrs.) Red and gray sandstone, shale, and limestone. <i>Flagstone, limestone, clay.</i>	<b>DEVONIAN</b> (365-405 mil. yrs.) Red sandstone, gray shale, black shale, limestone, and chert. <i>Flagstone, silica sand, clay, lime.</i>	<b>SILURIAN</b> (405-430 mil. yrs.) Red and gray sandstone, conglomerate, shale, and limestone. <i>Lime, building stone.</i>	<b>ORDOVICIAN</b> (430-500 mil. yrs.) Shale, limestone, dolomite, and sandstone. <i>Slate, limestone, zinc, clay.</i>	<b>CAMBRIAN</b> (500-570 mil. yrs.) Limestone, dolomite, sandstone, shale, quartzite, and phyllite. <i>Lime, building stone.</i>	<b>LOWER PALEOZOIC</b> (430-570 mil. yrs.) Metamorphic rocks (metasedimentary and meta-igneous); schist, gneiss, quartzite, serpentine, slate, and marble. <i>Building stone, talc.</i>	<b>PRECAMBRIAN</b> (older than 570 mil. yrs.) Gneiss, granite, anorthosite, metabasalt, metarhyolite, and marble. <i>Building stone, graphite, sericite.</i>

# Depth to Marcellus Shale in feet



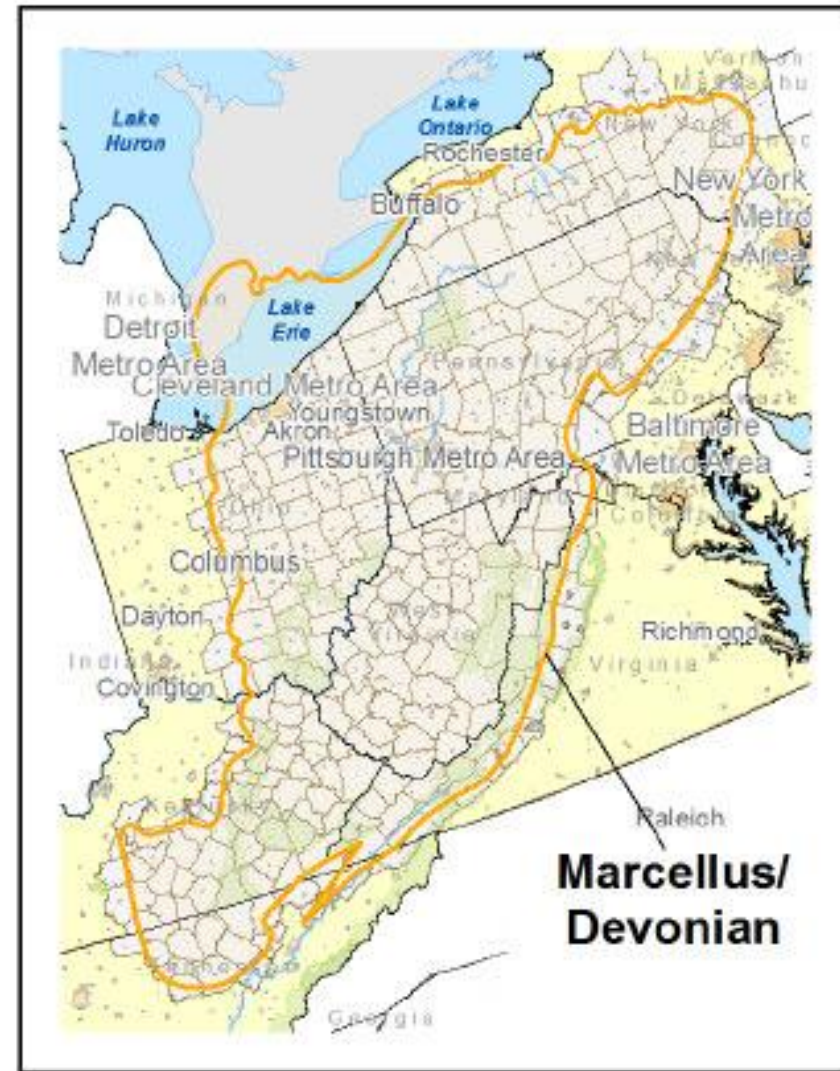
Source: CHK - October 16, 2008 Investor and Analyst Meeting

### EXHIBIT 18: STRATIGRAPHY OF THE MARCELLUS SHALE

Period		Group/Unit	
Penn		Pottsville	
Miss		Pocono	
Devonian	Upper	Conewango	
		Conneaut	
		Canadaway	
		West Falls	
		Sonyea	
		Genesee	
		Middle	Tully
	Hamilton Group		Moscow
			Ludlowville
			Skaneateles
		Marcellus	
		Onandaga	
	Lower	Tristates	
Helderberg			

Source: Arthur et al, 2008<sup>148</sup>

### EXHIBIT 19: MARCELLUS SHALE IN THE APPALACHIAN BASIN



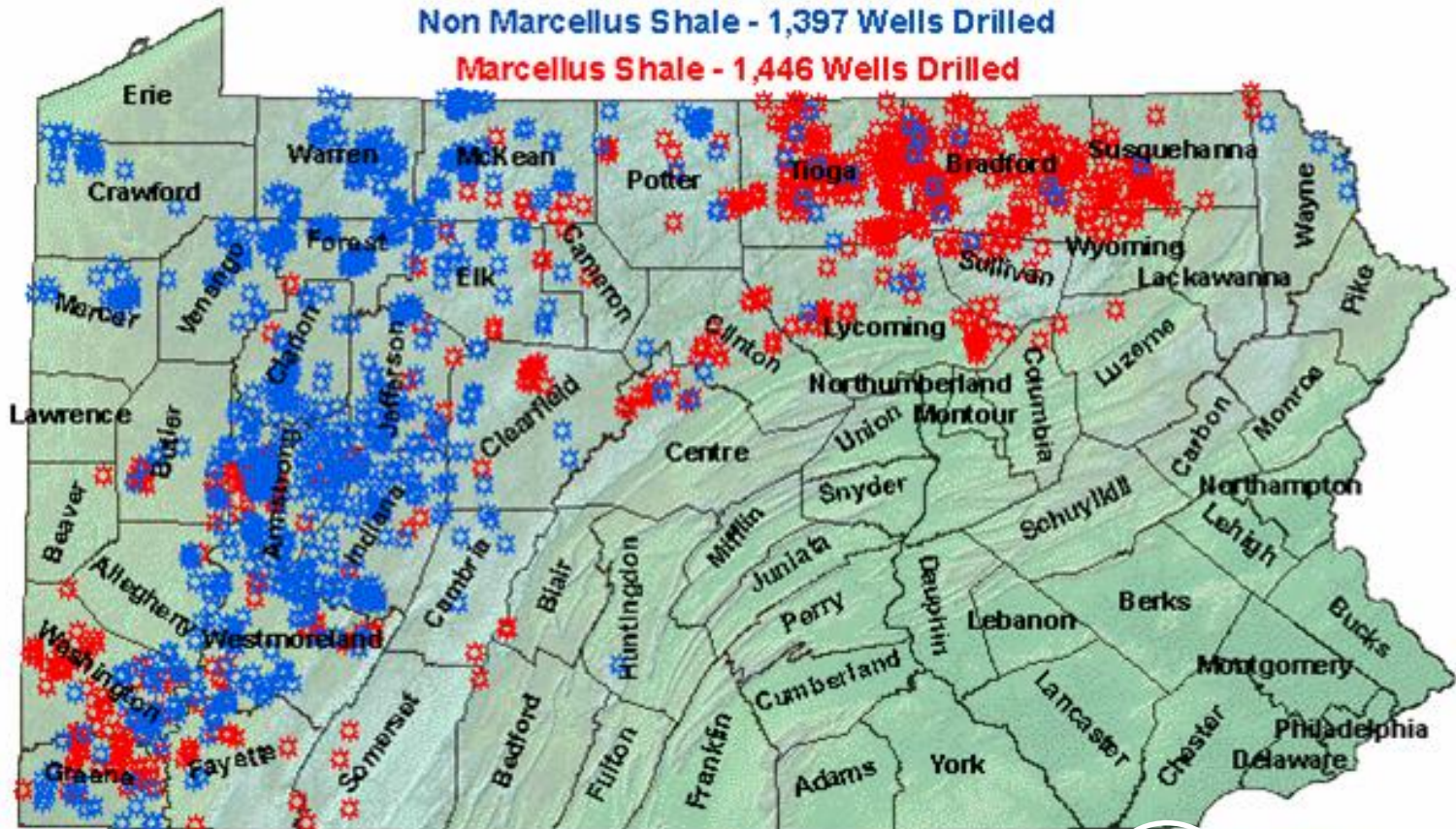
Source: ALL Consulting, 2009

# Department of Environmental Protection Bureau of Oil and Gas Management Wells Drilled

2010 January-December Wells Drilled - 2,843

Non Marcellus Shale - 1,397 Wells Drilled

Marcellus Shale - 1,446 Wells Drilled



As Reported by Operators

Updated 01/25/2011



# What We Know

## Impacts on Water Resources

- **Water withdraws for HF solutions: streams, CWS**
- **Produced water containment, transport, treatment, discharge or disposal.**
- **Earth disturbance / construction, access & pipelines**
- **Site waste – equipment maintenance repair & other operations.**





- Marcellus and Other Shale Issues

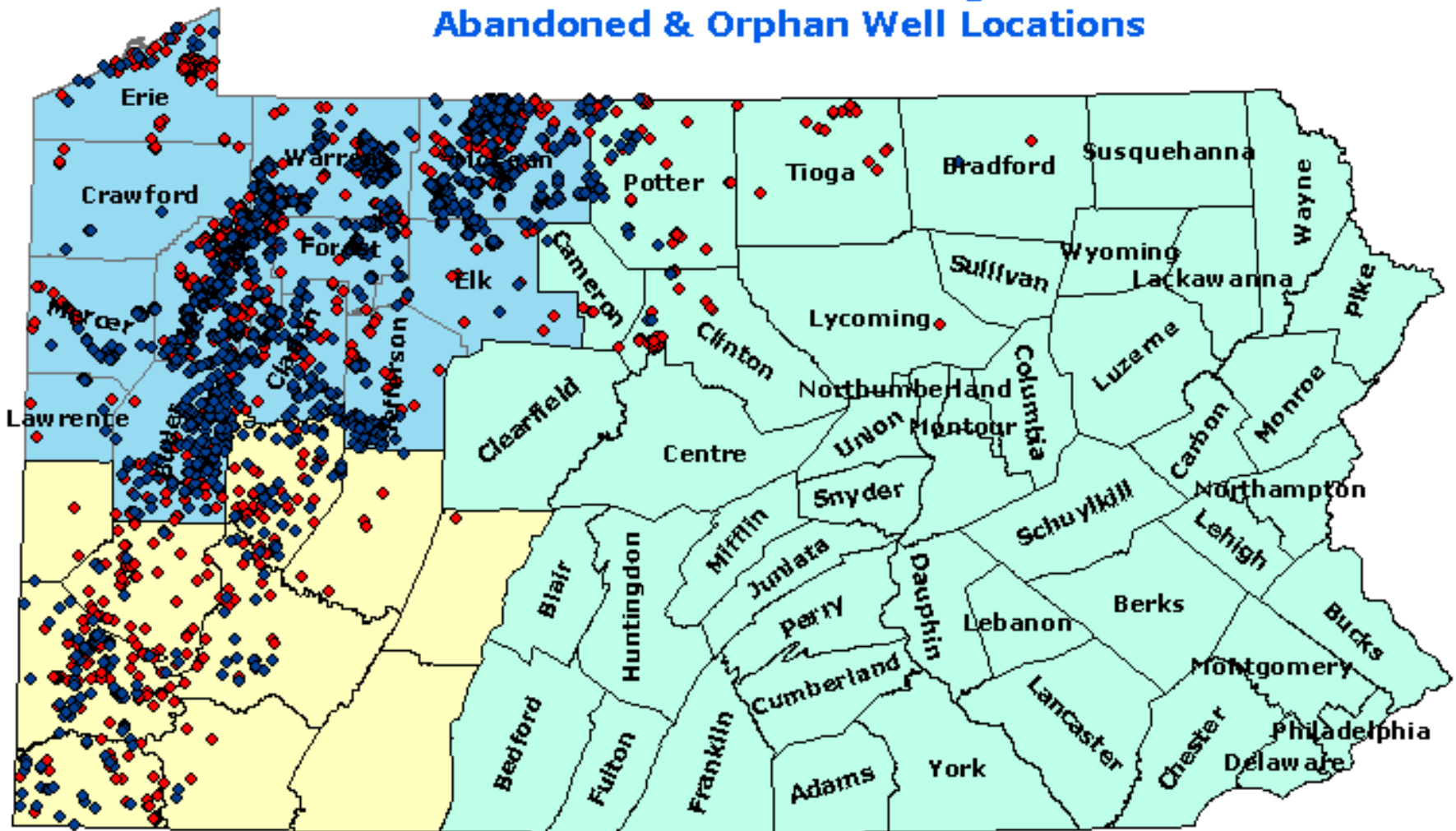


# What We Know

## Water Pollution Causes:

- **Loss of produced water or wastes at the surface**
- **Improper well casing design or construction**
- **Aquifer disturbance during drilling**
- **Improper treatment**
- **No evidence or concern in Pennsylvania that HF has caused direct migration of fluids to underground sources of drinking water**

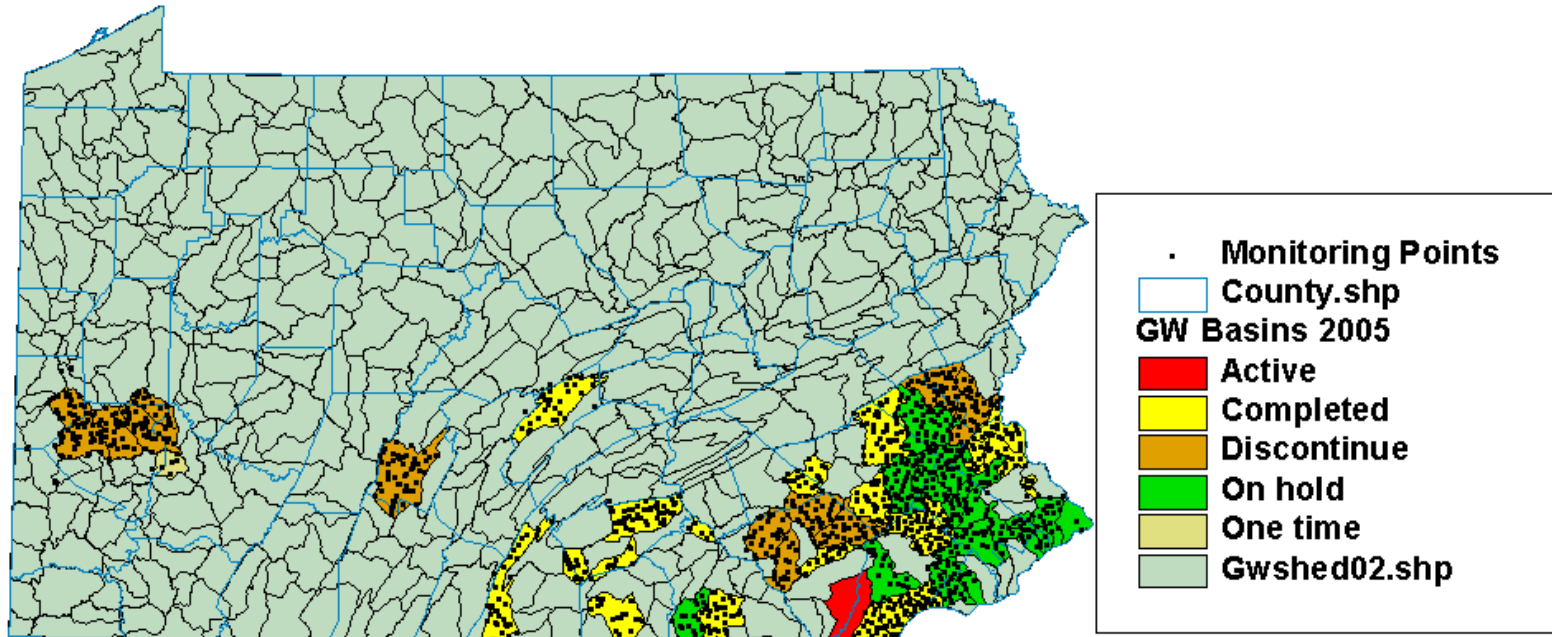
Commonwealth of Pennsylvania  
Department of Environmental Protection  
Bureau of Oil & Gas Management  
Abandoned & Orphan Well Locations



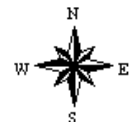
Abandoned Wells

Orphan Wells

# Ground Water Monitoring Status



30 0 30 60 Miles



# State Ground Water Quality

Map of Pennsylvania

## USGS Data Series Report 314 (2009):

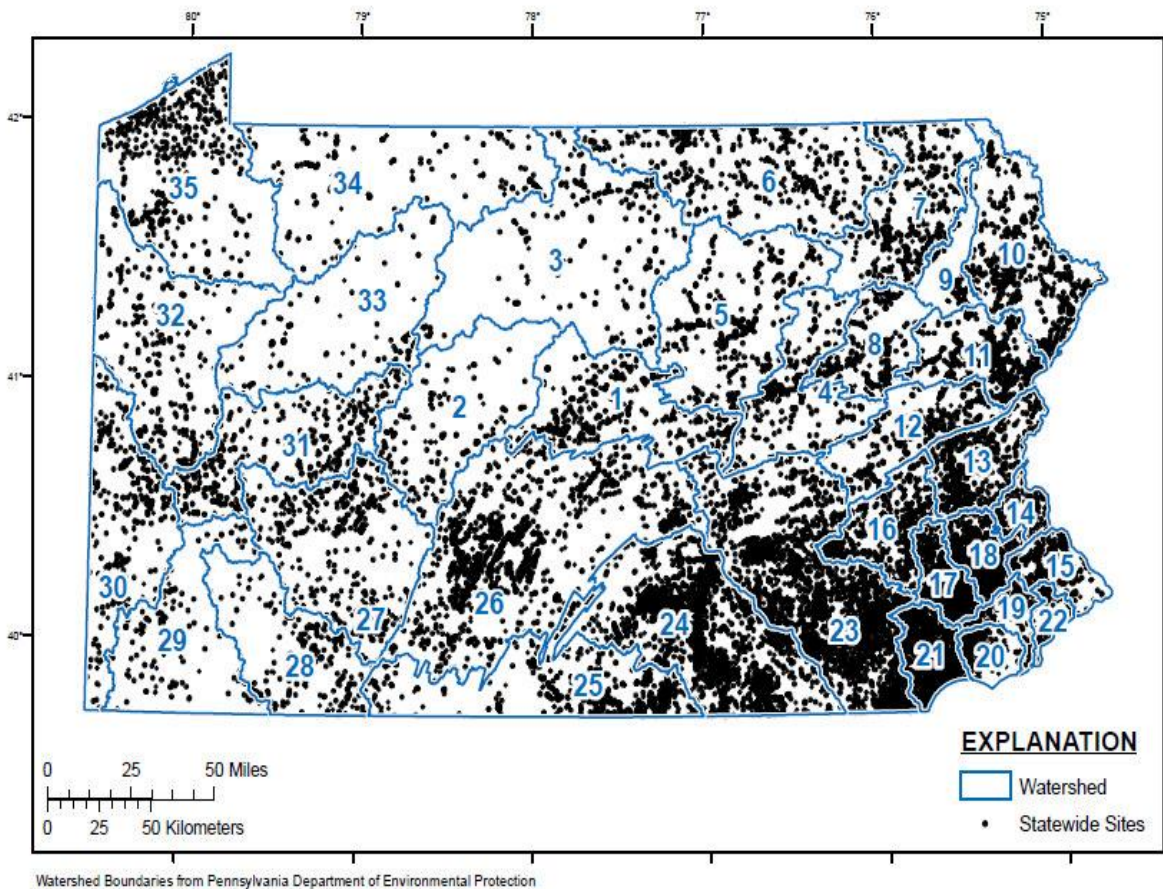
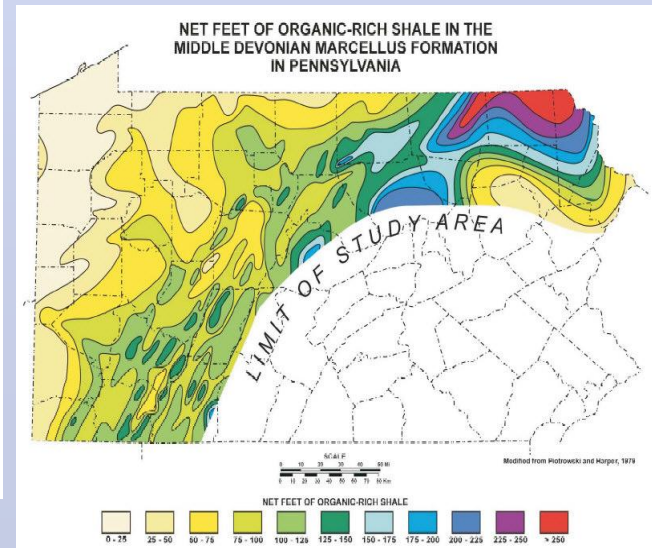


Figure 4. Well and spring locations with ground-water data compiled from 14 source agencies or programs representing the period 1979-2006 for Pennsylvania.







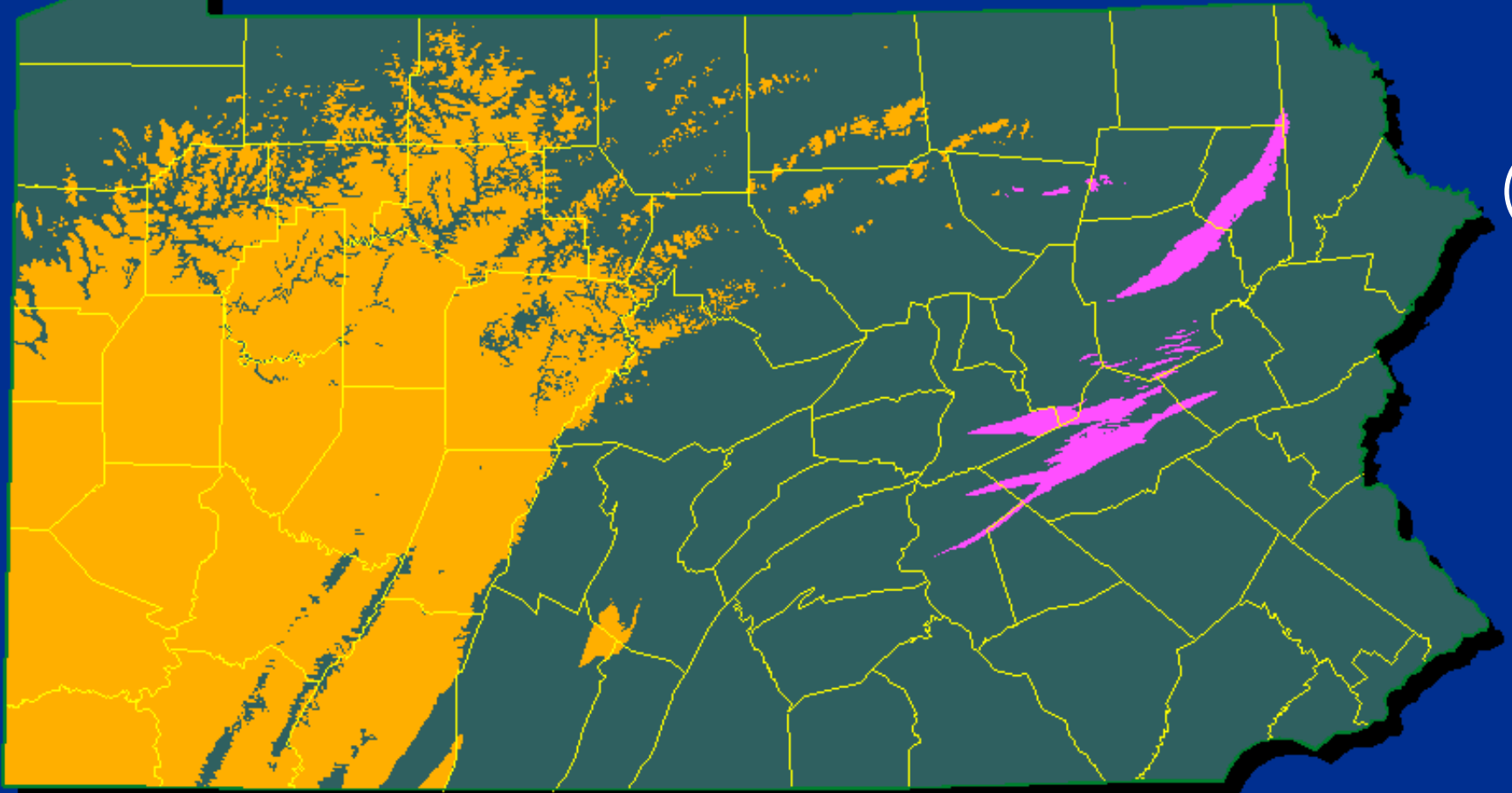
- Abandoned Mine Drainage



Bituminous Fields



Anthracite Fields





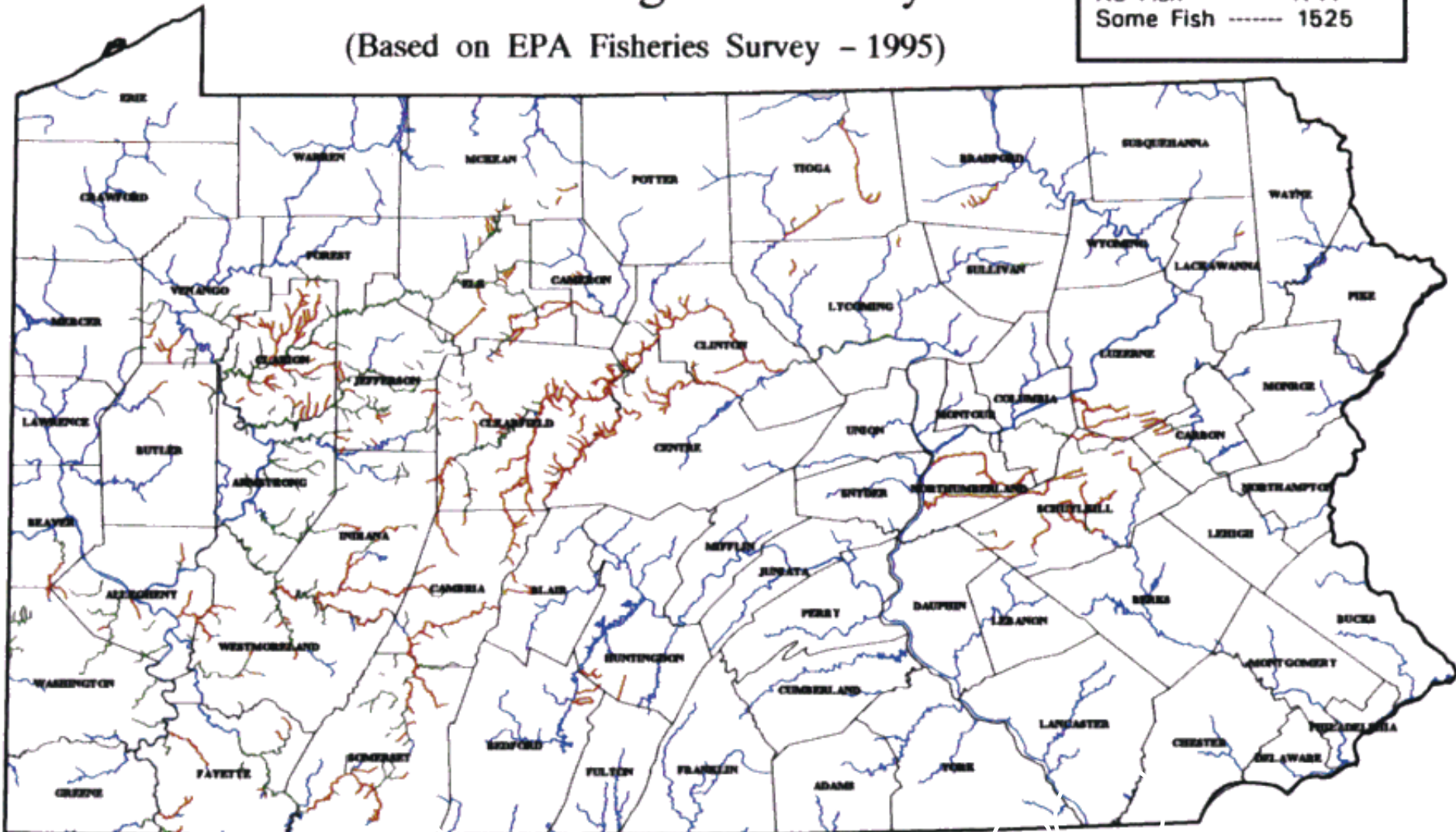
# Streams and Fisheries Impacted by Acid Mine Drainage in Pennsylvania

(Based on EPA Fisheries Survey - 1995)

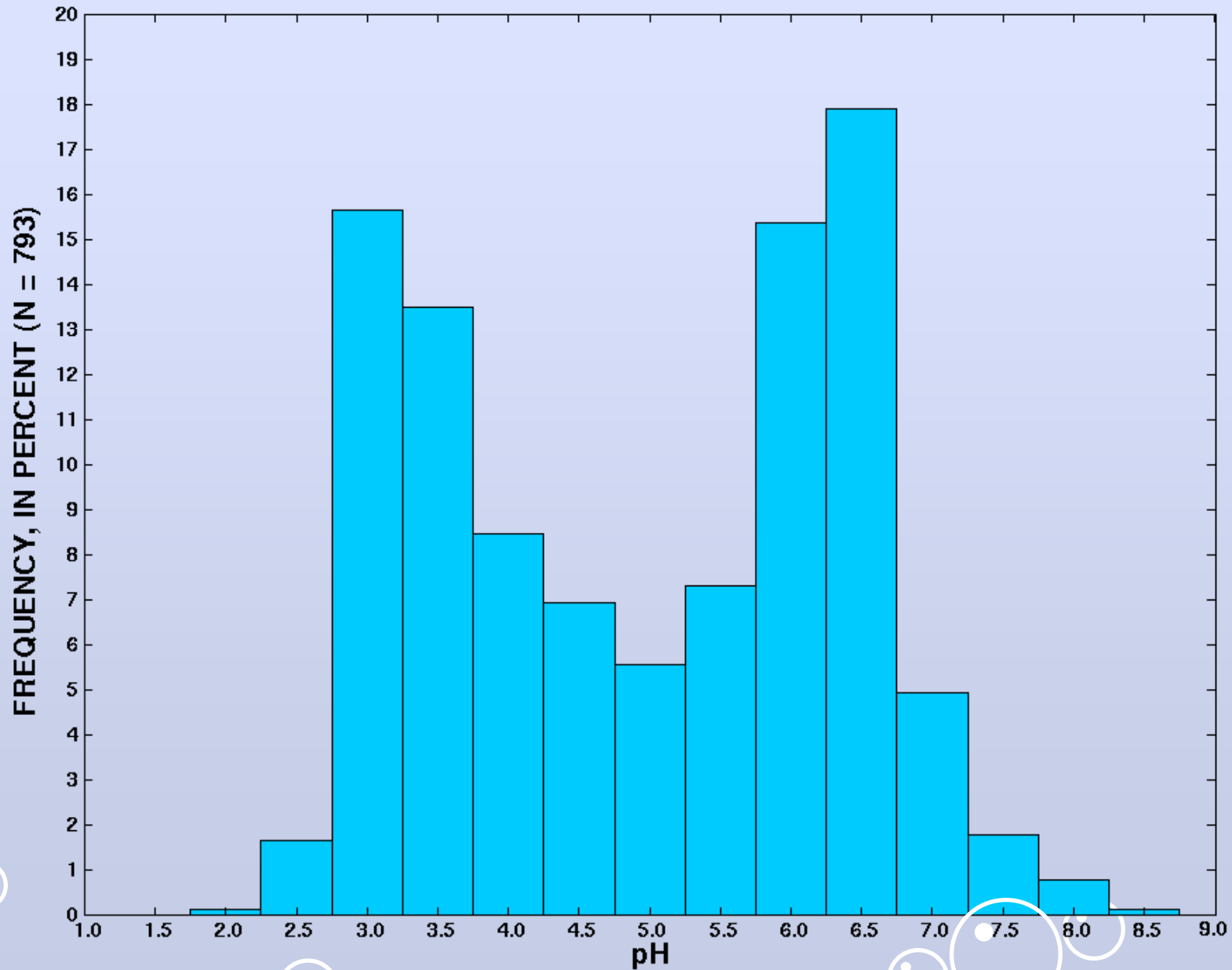
## Legend:

-  No Fish
-  Some Fish

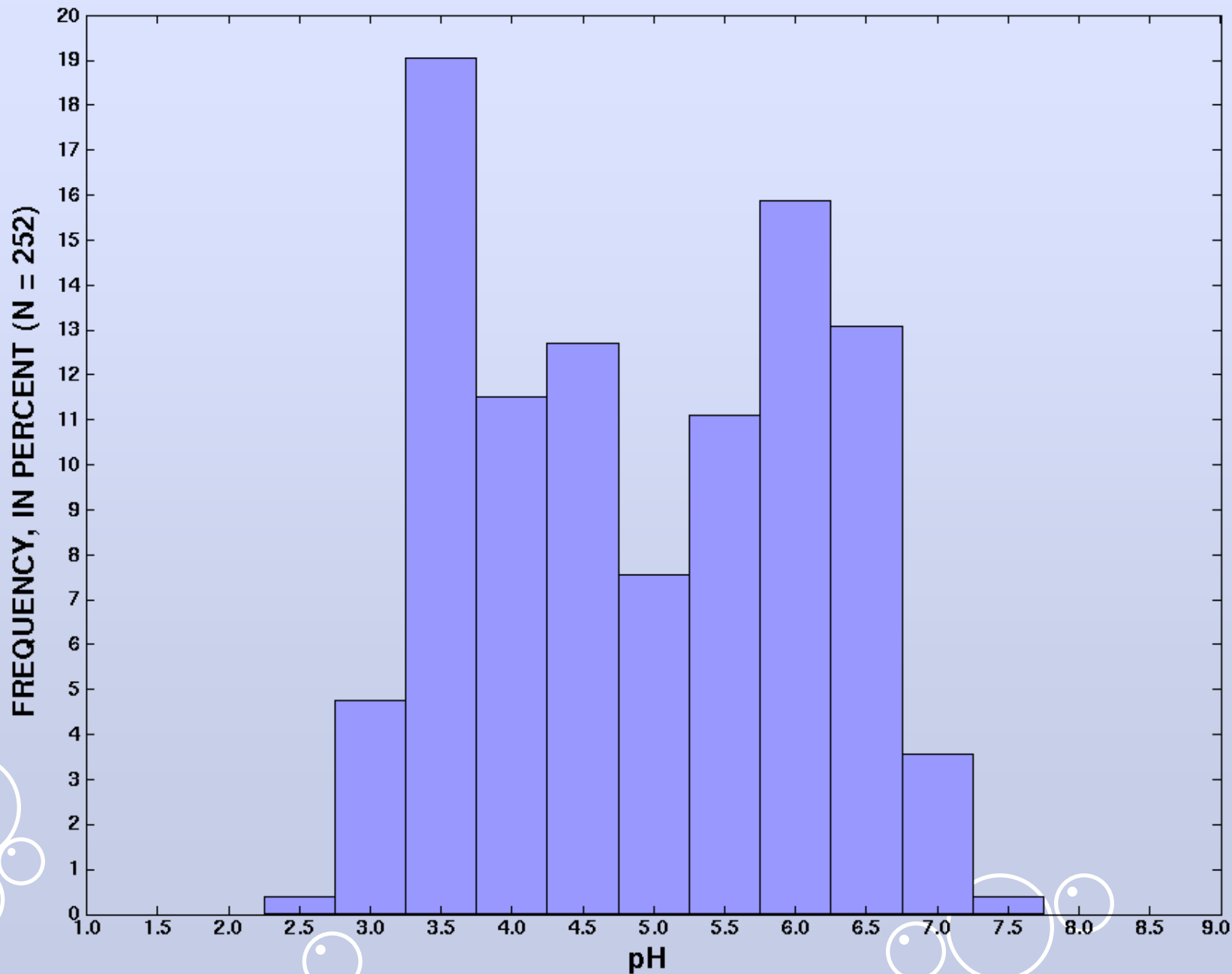
Impacted Stream Miles  
No Fish ----- 1714  
Some Fish ----- 1525



# BITUMINOUS COAL-MINE DISCHARGES IN PENNSYLVANIA



# ANTHRACITE COAL-MINE DISCHARGES IN PENNSYLVANIA



# Monogahela River - Elevated TDS 2008



- 10/2008 - Elevated total dissolved solids (TDS) > than SDWA standard (500 mg/l)
- Potential sources of TDS in watershed include abandoned & active surface and deep coal mines, waste water and industrial discharges (receiving HF flow-back)
- PA DEP reduced HF % flow at wastewater treatment plants
- River under historic low flow conditions
- TDS concentrations returned to normal in December 2008 after recovery of river flow



*Source: Chesapeake Energy Corporation, 2008*

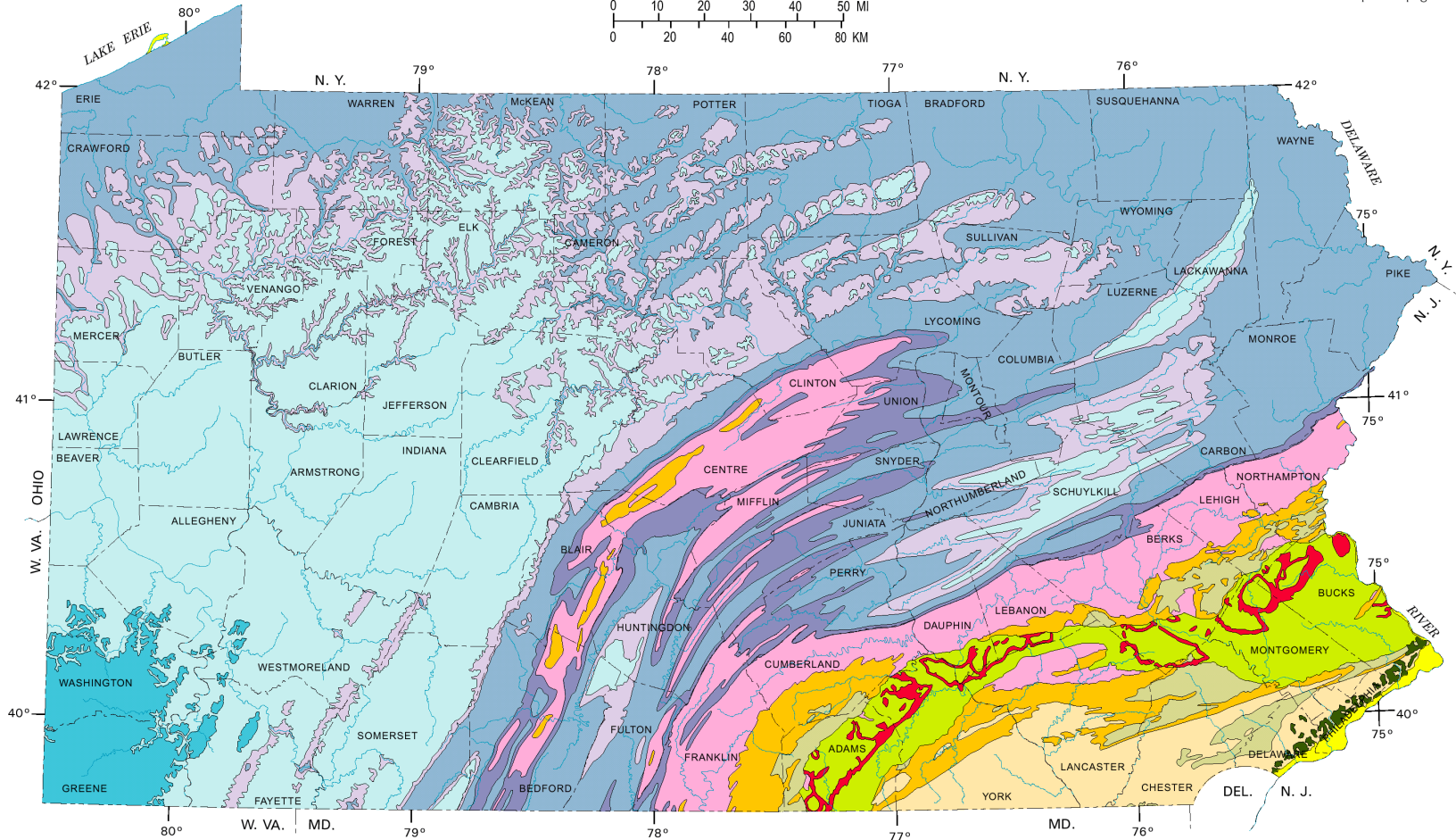
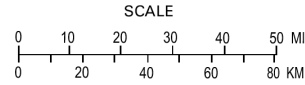
## *Hydraulic Fracturing of a Marcellus Shale Well, West Virginia*



- Marcellus and Other Shale Issues

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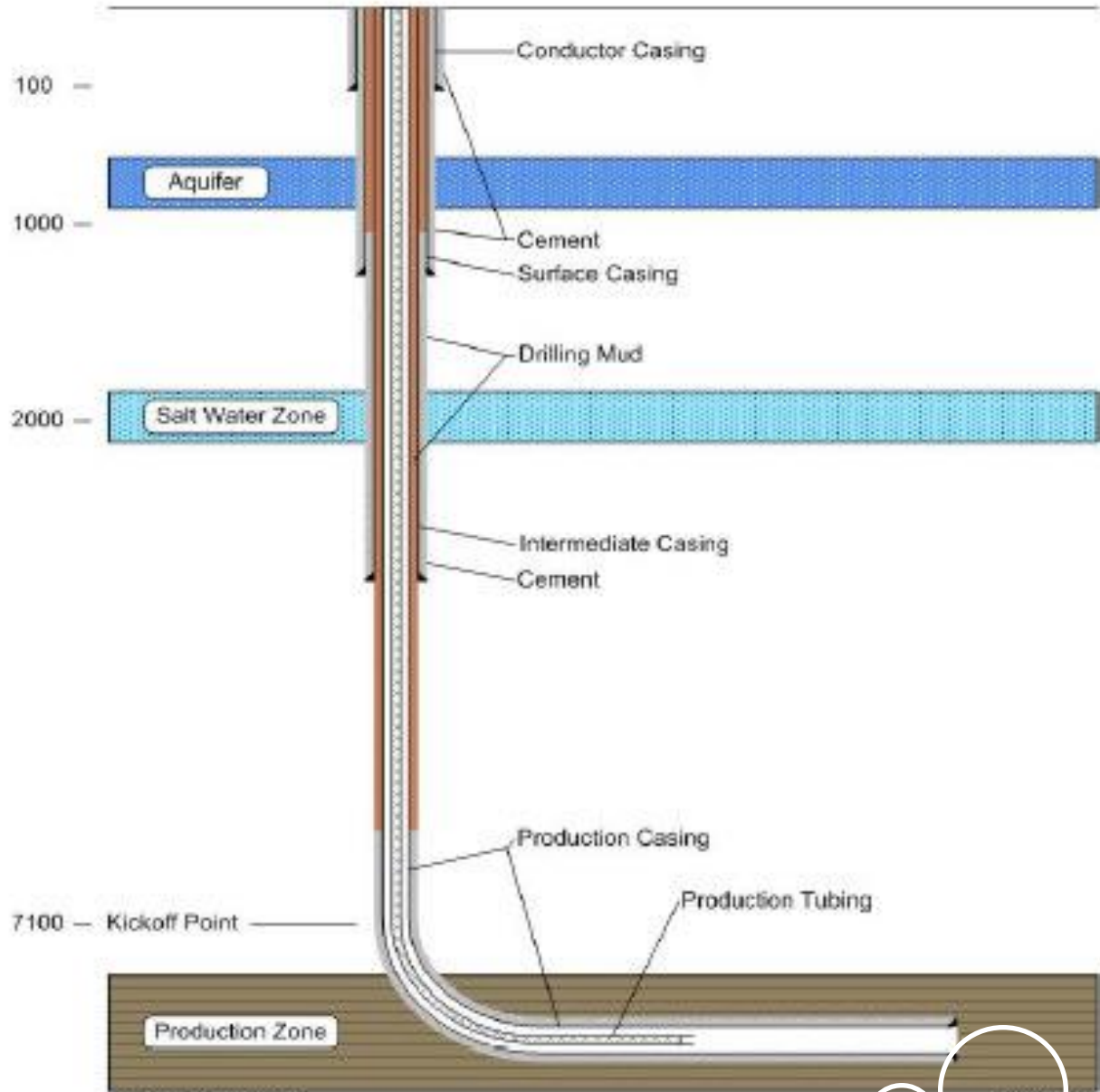
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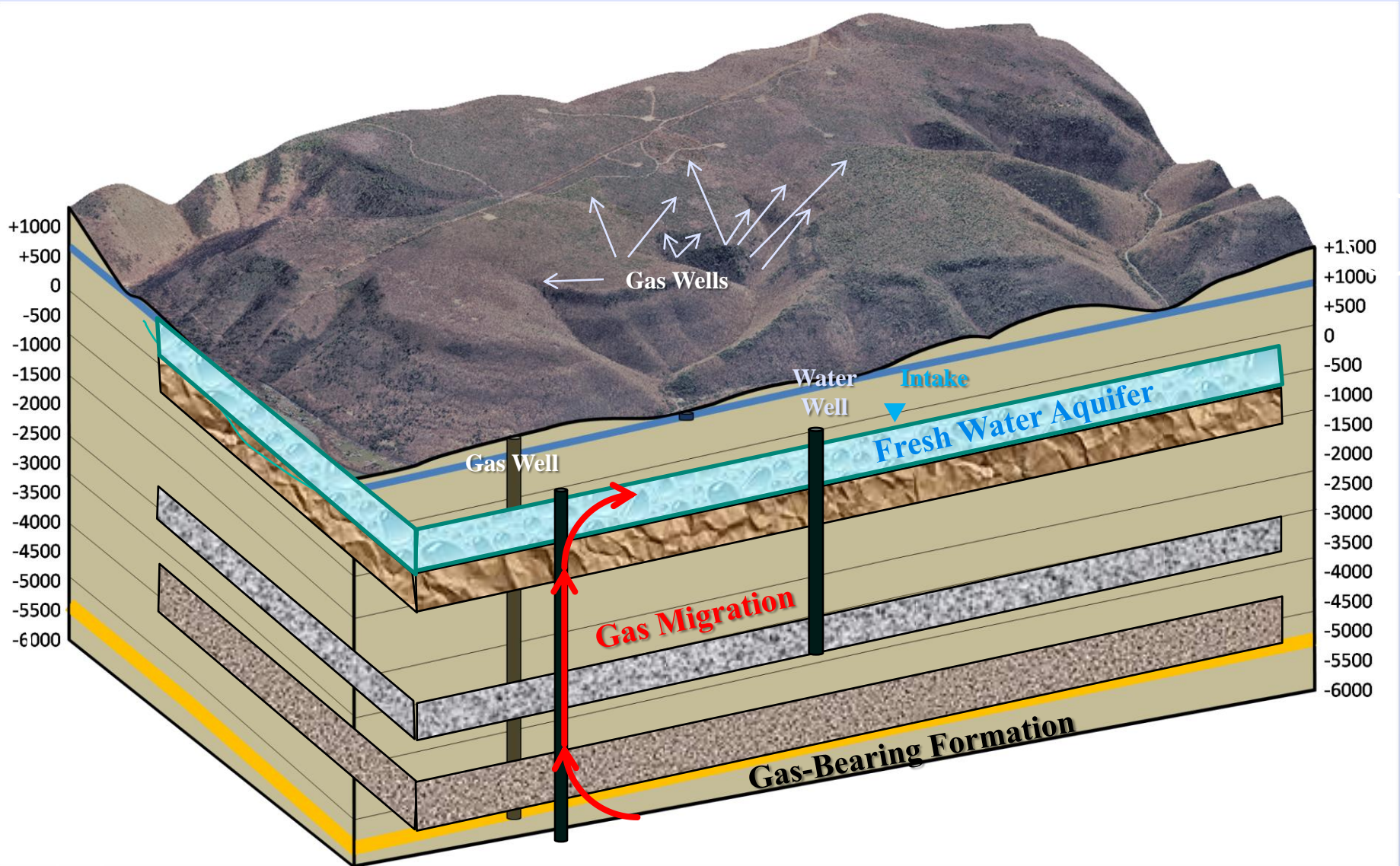
# EXHIBIT 30: CASING ZONES AND CEMENT PROGRAMS



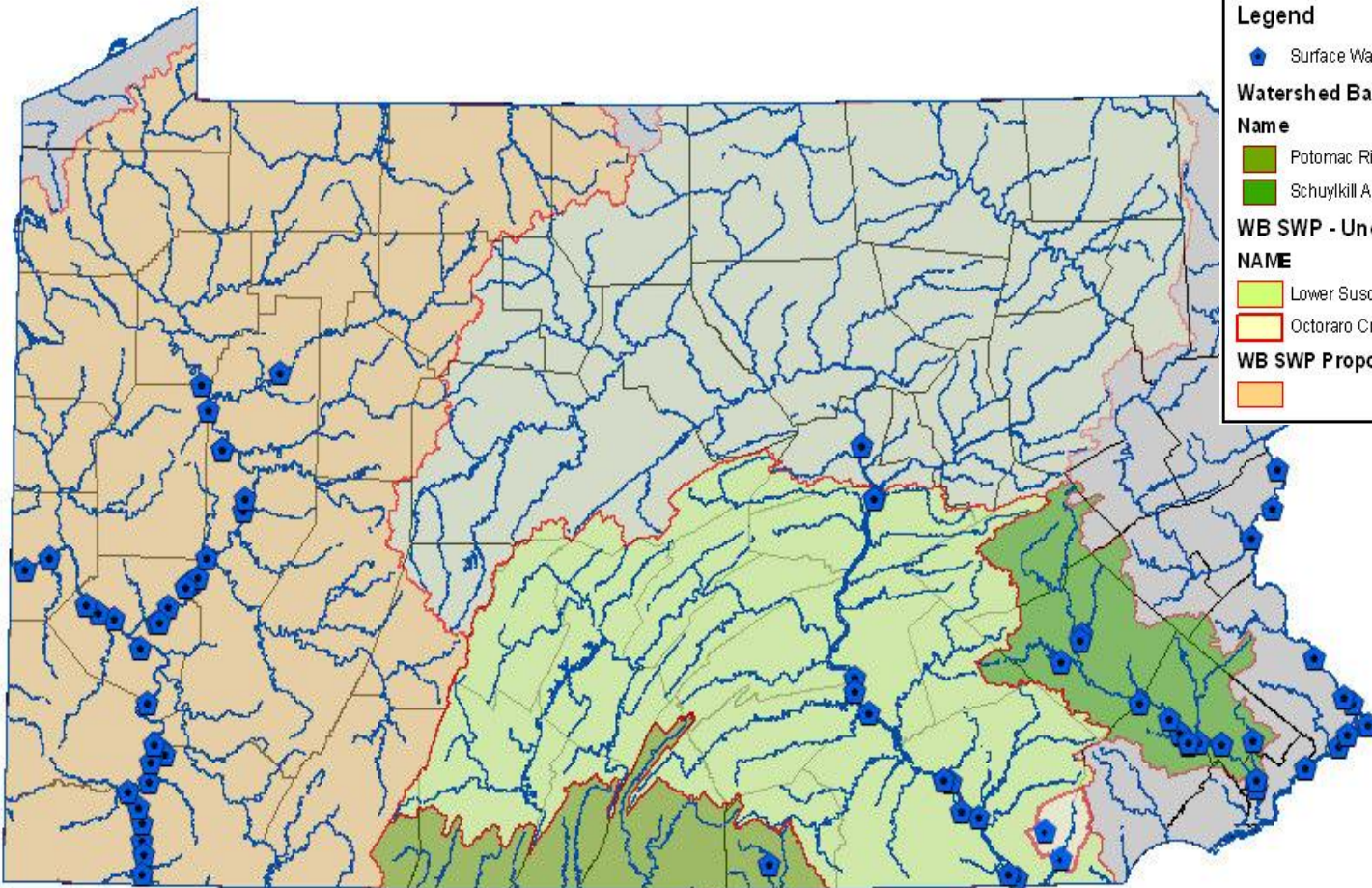
ALL Casingline 2008

Not to Scale






# PA Watershed Based Source Water Protection Program





## Legend

 Surface Water Intakes

### Watershed Based SWP


#### Name

 Potomac River Drinking Water Protection Partnersio

 Schuylkill Action Network

### WB SWP - Under Development

#### NAME

 Lower Susquehanna

 Octoraro Creek

### WB SWP Proposed 2011

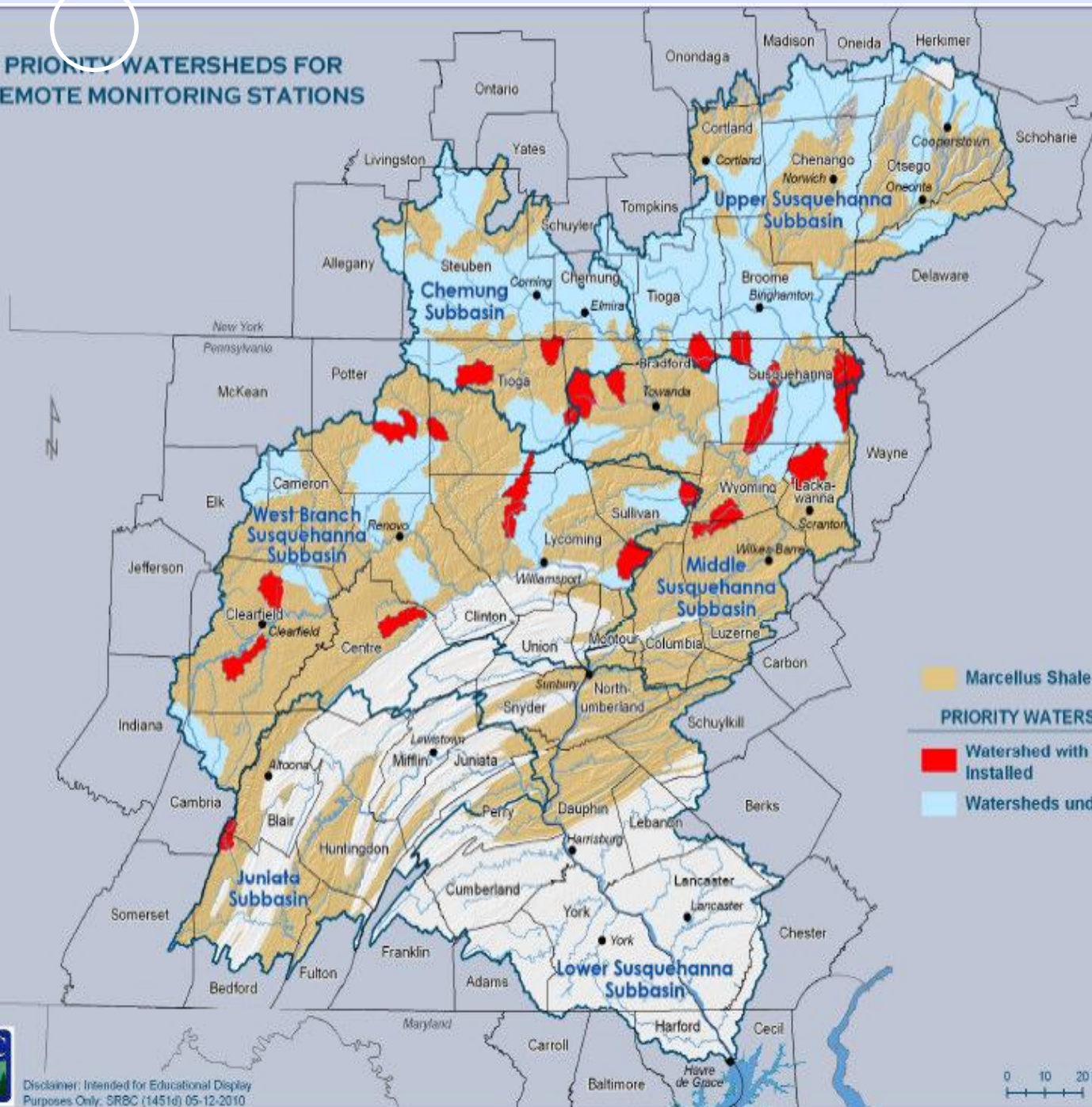




Bureau of Watershed Management

JJL - 09/23/2010

# PRIORITY WATERSHEDS FOR REMOTE MONITORING STATIONS



Disclaimer: Intended for Educational Display Purposes Only. SRBC (1451d) 05-12-2010



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