



pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION



Bureau of Waste Management

Origin of TENORM-containing Drill Cuttings and Treatment Sludges Generated at Well Sites and Wastewater Treatment Facilities in the 2012 Calendar Year

What is TENORM?

- TENORM: Technologically Enhanced Naturally Occurring Radioactive Material
- Regulatory Definition of NORM
 - A nuclide that is radioactive in its natural physical state.
 - Not manmade.
 - Does not include source or special nuclear material.

What is TENORM?

- TENORM occurs when the levels of radioactivity or potential for human exposure are increased by human activities.
- Since naturally occurring radioactive material is brought to the surface during drilling, the wastes are classified as TENORM.

Measuring Exposure and Dose

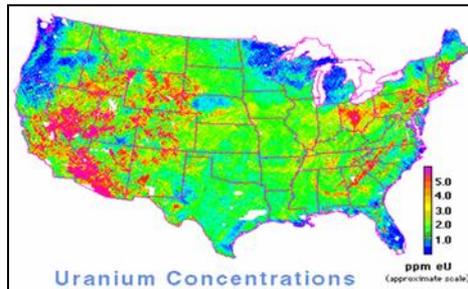
Radiation exposure is expressed as a dose rate.

The dose rates of gamma radiation for each of the 995 TENORM waste loads represented in this presentation are measured in $\mu R/hr$.

Based on the 2009 National Council on Radiation Protection and Measurements (NCRP) Report No. 160, the average public dose in the USA is ~620 mrem

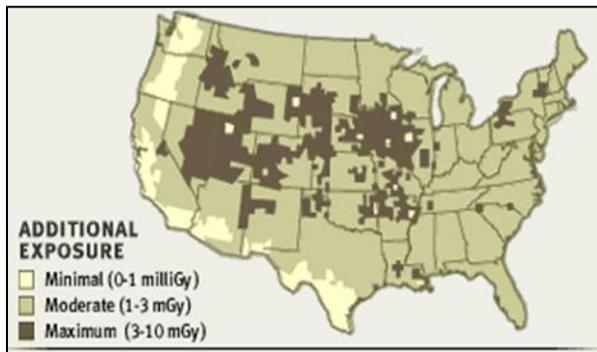
Average Dose from Natural Sources

- Radon in homes and buildings at a concentration of 2pCi/L : **~230 mrem/yr**
- Earth (Uranium/Thorium Series) : **~20 mrem/yr**
- Cosmic Radiation : **~30 mrem/yr**
- Food/Internal (K-40) : **~30 mrem/yr**



Average Dose from Man-Made Sources

- Chest x-ray : **~10 mrem /film**
- CT scan : **1,000 - 5,000 mrem/scan**
- Consumer Products : **~1 mrem/yr**
- Nuclear weapons testing fallout : **< 4 mrem/yr**
- Airplane flight (coast-to-coast) : **2.5 mrem (NY to LA)**



Focus of Study

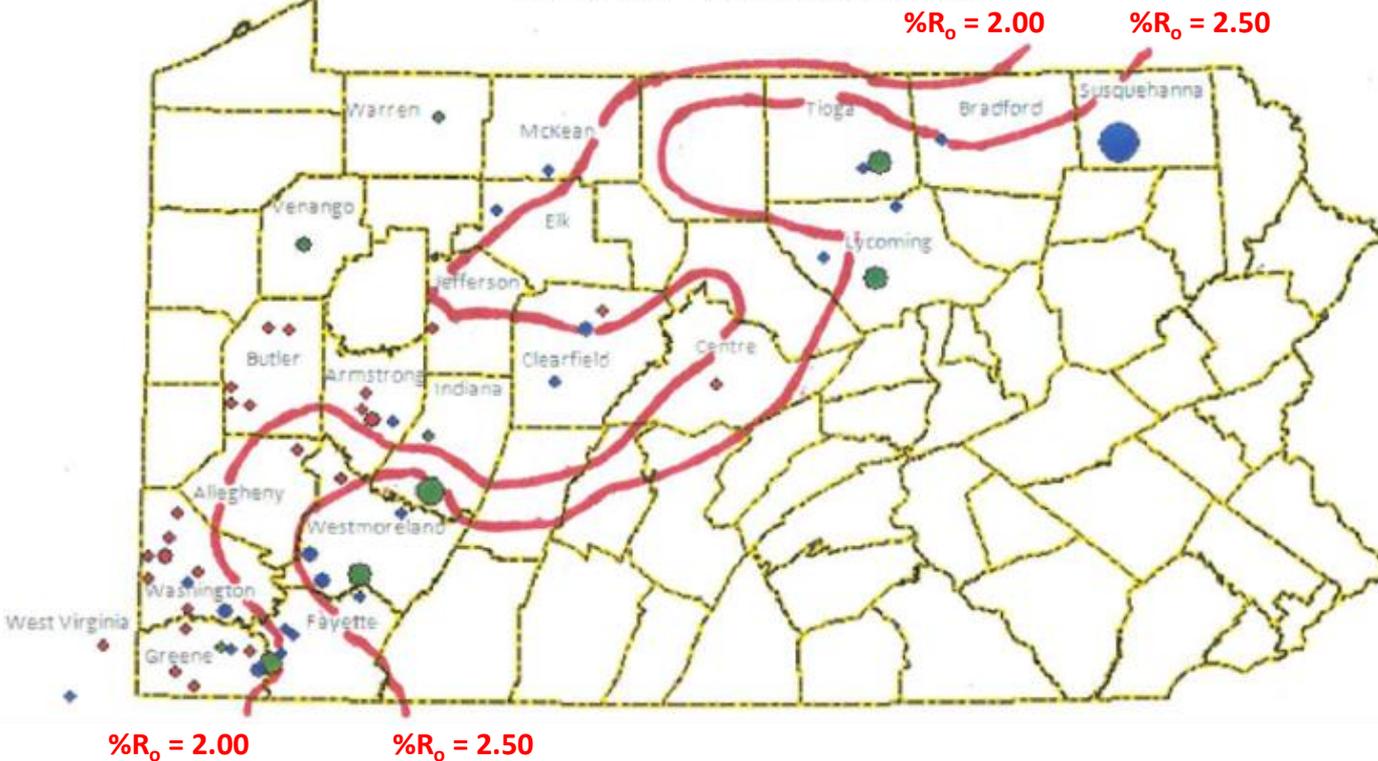
- This study focuses on TENORM found in:
 - Drill Cuttings – Residual Waste Code 810
 - Treatment Sludges – Residual Waste Code 804
 - 265/995 TENORM loads were designated with a 203 RWC, but because the sludges were generated by Oil and Gas Treatment Plants, we have reason to believe they are miscoded and have included them as 804s

Note

The 995 oil and gas related waste loads in this presentation represent those loads that triggered radiation monitoring alarms at Pennsylvania landfills during the 2012 calendar year. These waste loads are only a subset of the total number of oil and gas waste loads accepted for disposal in 2012.

Pennsylvania: Map of the Origin of 810s and 804s

Pennsylvania – Graduated Symbol Map



Symbol Key	
810s and 804s	
Number of Loads	
•	1 - 25
●	26 - 50
●	51 - 75
●	76 - 100
●	101 - 125
●	126 - 150
—	810 (Well)
—	804 (Well)
—	804 (WWTP)

$\%R_o$ - Vitrinite Reflectance

- One of the most commonly measured geothermometers used to map thermal maturity patterns in sedimentary basins

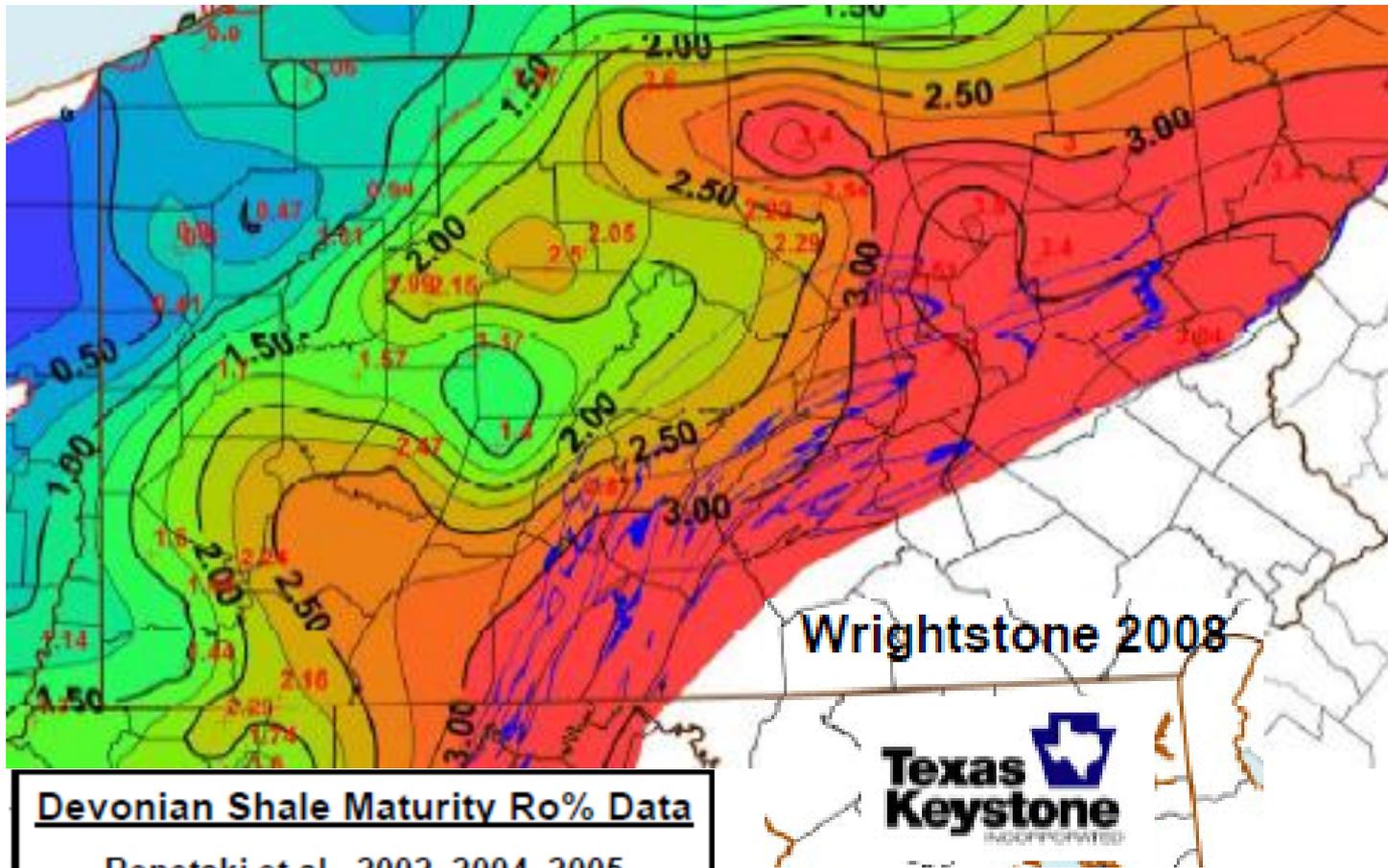
Measuring Vitrinite Reflectance

- Rock samples are separated and washed
- Mounted in resin
- Ground and polished
- 30 measurements per block at 50x magnification, immersed in oil
- Amount of light reflected

$\%R_o$ – Vitrinite Reflectance

- As the coal rank increases (time, heat, pressure) the chemical composition of the vitrinite within the coal correspondingly changes
- Coal Rank Increase (Lignite -> Anthracite) = Vitrinite Reflectance Increase
- R_o can be used as an indicator of maturity in hydrocarbon source rocks; corresponds to hydrocarbon generation

$\%R_o$ – Percent Vitrinite Reflectance

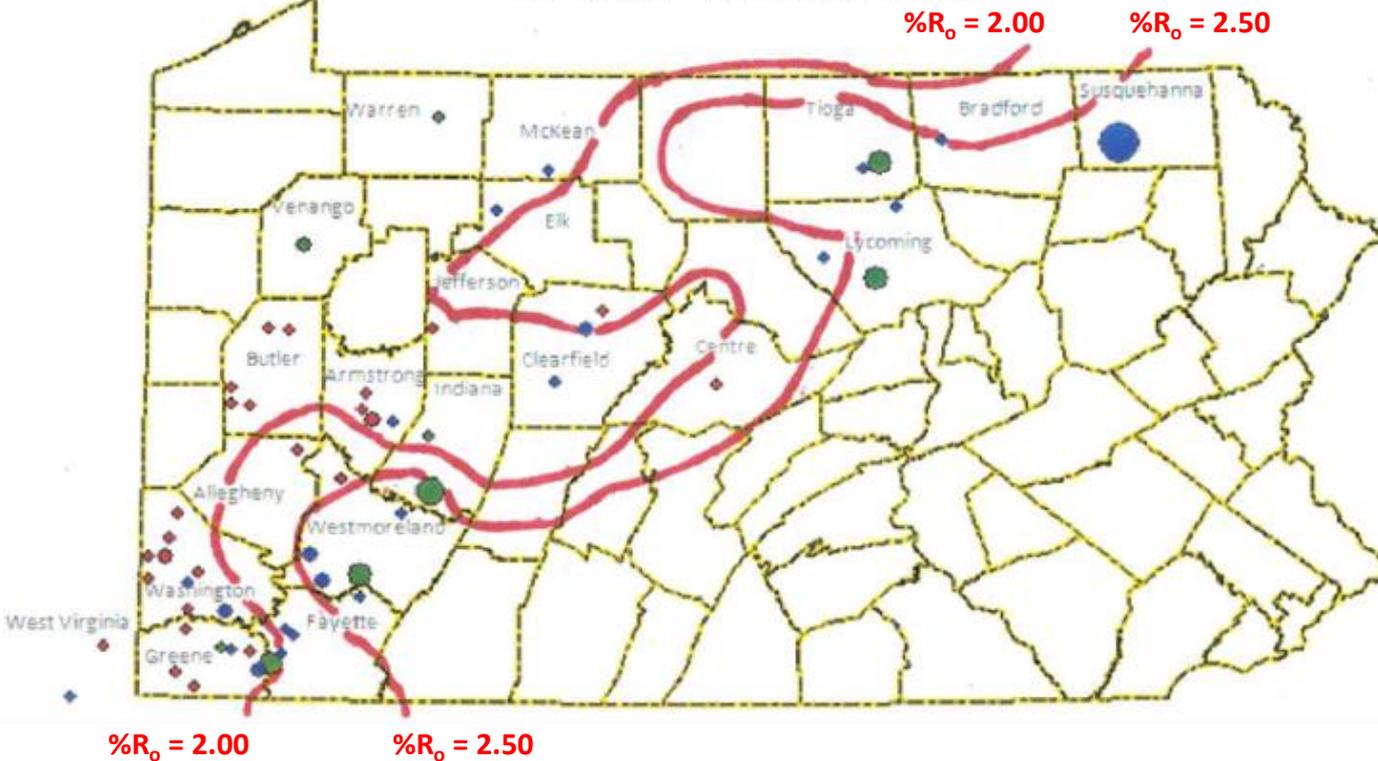


%R_o – Vitrinite Reflectance

- **Study conducted by Department of Energy - (DOE/NETL-2011/1478)**
 - **No hydrocarbon generation (immature) under 0.55%**
 - **Oil Window – 0.55% to 1.1%**
 - **Gas Window – 1.1% to 3.0%/3.5%**
 - **Wet Gas Window extends primarily from 1.1% to 1.6%**
 - **Dry Gas Window terminates around 3.0%/3.5%**

Origin of 810s and 804s

Pennsylvania – Graduated Symbol Map



Symbol Key

810s and 804s

Number of Loads

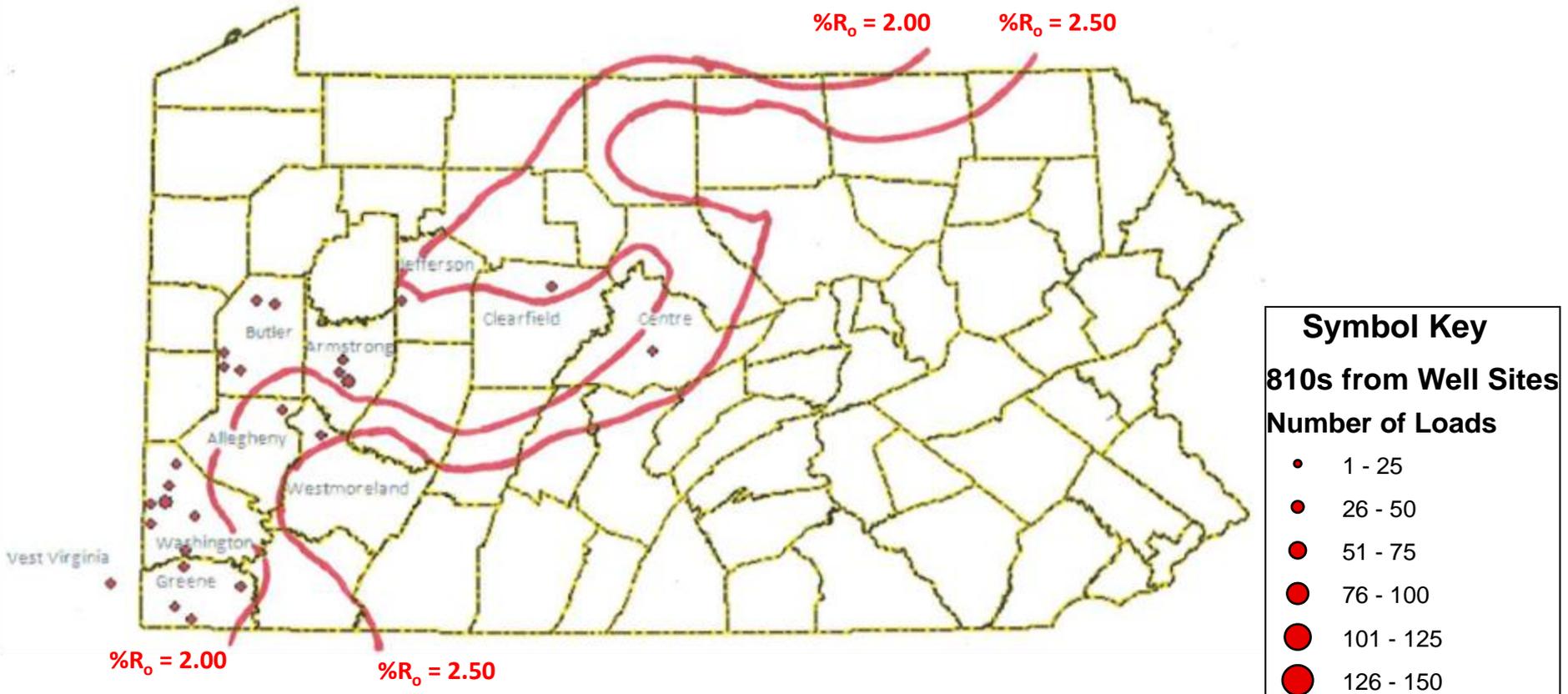
- 1 - 25
- 26 - 50
- 51 - 75
- 76 - 100
- 101 - 125
- 126 - 150

- 810 (Well)
- 804 (Well)
- 804 (WWTP)

Origin of 810s and 804s by County

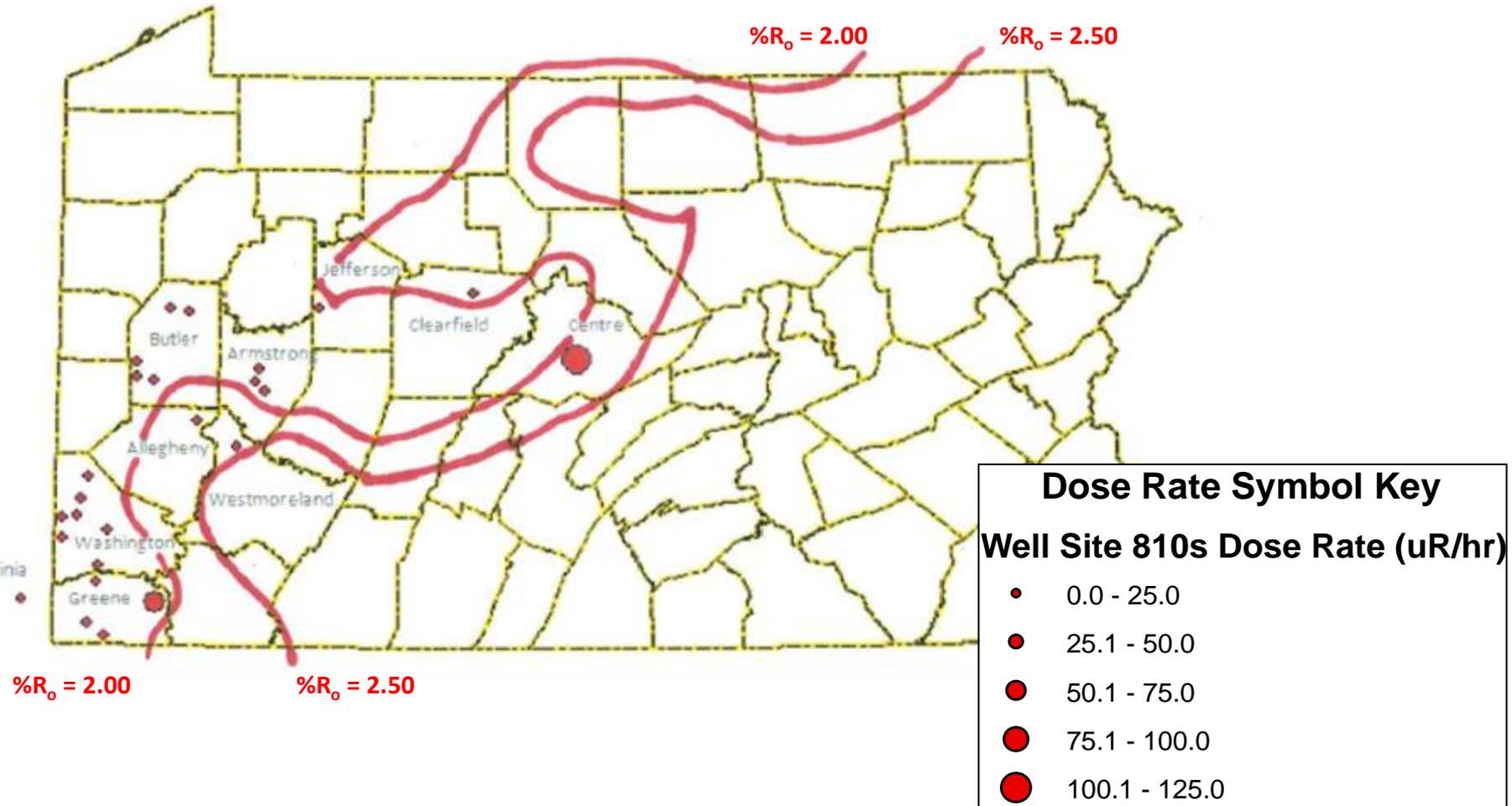
810s from Well Sites		804s from Well Sites		804s from WWTPs	
County	Loads	County	Loads	County	Loads
Allegheny	19	Armstrong	18	Fayette	63
Armstrong	59	Bradford	7	Greene	1
Butler	17	Clearfield	60	Indiana	87
Centre	1	Elk	2	Lycoming	69
Clearfield	1	Fayette	58	Tioga	54
Greene	27	Greene	38	Venango	33
Jefferson	3	Lycoming	3	Warren	4
Washington	80	McKean	2	Westmoreland	54
Westmoreland	2	Susquehanna	129		
		Tioga	2		
		Washington	33		
Out of State Origination		Westmoreland	55		
Marshall, WV	15				
		Out of State Origination			
		Wetzel, WV	1		
Total:	224	Total:	408	Total:	363

810s from Well Sites



- 201/224 loads originate west of the $\%R_0$ 2.00 line

Well Site 810 Dose Rate ($\mu\text{R/hr}$) Ranges



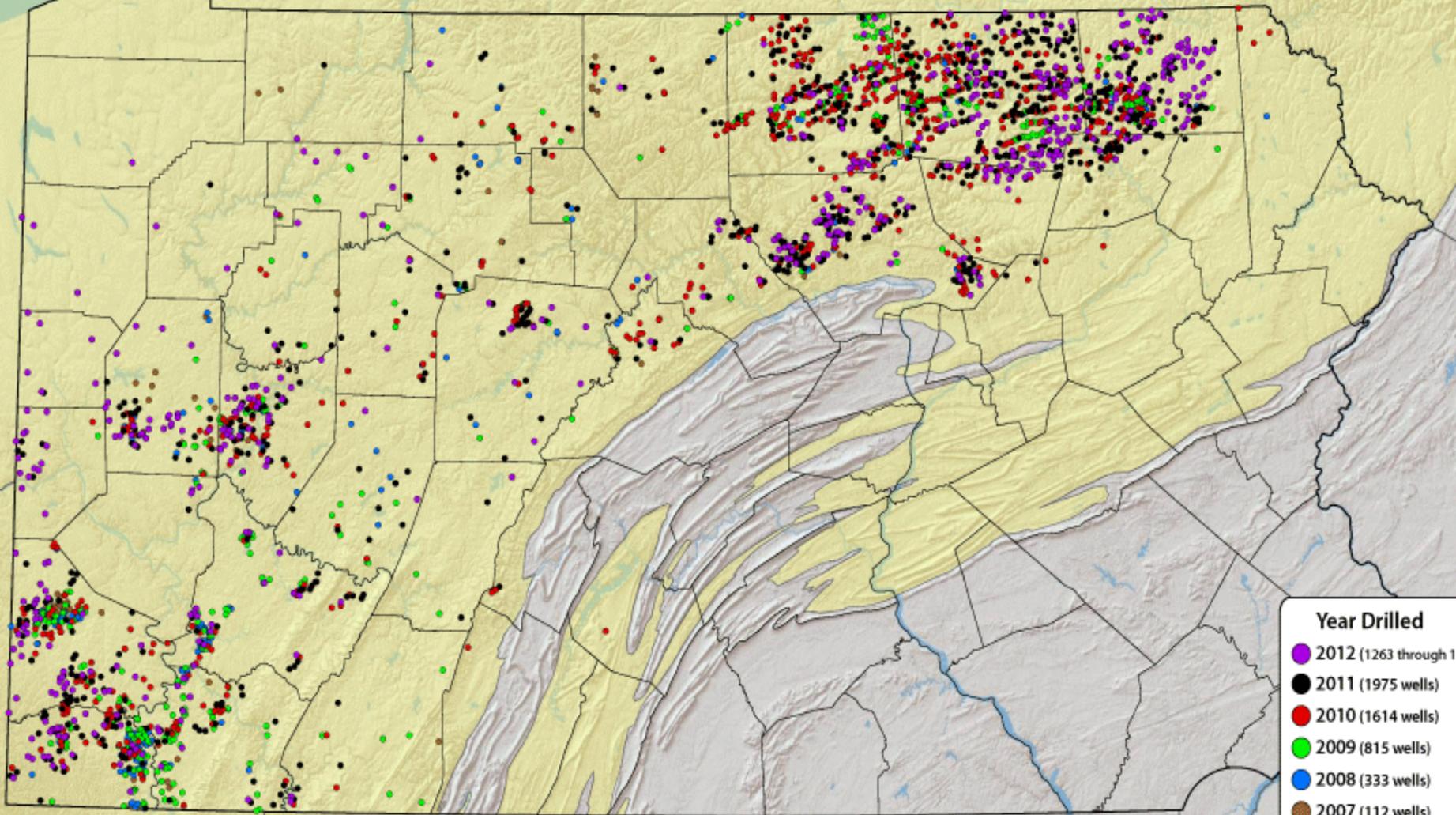
Well Site 810 Average Dose Rates ($\mu\text{R/hr}$)

County	Township	# of Loads	Average Load Dose Rate ($\mu\text{R/hr}$)	Range ($\mu\text{R/hr}$)
Allegheny	Frazer	19	17.1	4.1 – 28.7
Armstrong	Kittanning	46	23.9	7.7 – 50.1
Armstrong	Manor	8	16.9	11.6 – 24.6
Armstrong	Rayburn	5	15.4	4.1 – 26.4
Butler	Cherry	10	18.4	12 – 23.1
Butler	Forward	1	21.5	20.1 – 22.9
Butler	Jackson	3	23.5	17.9 – 27.6
Butler	Lancaster	2	17.4	15.8 – 18.5
Butler	Washington	1	14.1	4.6 – 23.6
Centre	Snow Shoe	1	100.5	100 – 101
Clearfield	Goshen	1	10.9	10.6 – 11.2
Greene	Cumberland	18	54.6	8 – 137.6
Greene	Jackson	3	15.8	3.4 – 41.4
Greene	Morris	4	18.1	12.5 – 23.5
Greene	Wayne	2	11.1	4 – 21.5

Well Site 810 Average Dose Rates ($\mu\text{R/hr}$)

County	Township	# of Loads	Average Load Dose Rate ($\mu\text{R/hr}$)	Range ($\mu\text{R/hr}$)
Jefferson	Beaver	3	9.5	6.1 – 12.9
Washington	Cross Creek	10	13.5	3.8 – 24
Washington	Donegal	5	13.4	4.6 – 20.2
Washington	Hopewell	29	13	2.1 – 40
Washington	Independence	12	12.6	3 – 23
Washington	Morris	2	13.4	9.7 – 16.2
Washington	Smith	17	15.6	3.8 – 28.9
Washington	South Franklin	5	10.4	2.3 – 22.4
Westmoreland	Washington	2	24.2	21.6 – 27.3
West Virginia	Marshall	15	15.6	3.8 – 32.4

Unconventional Wells

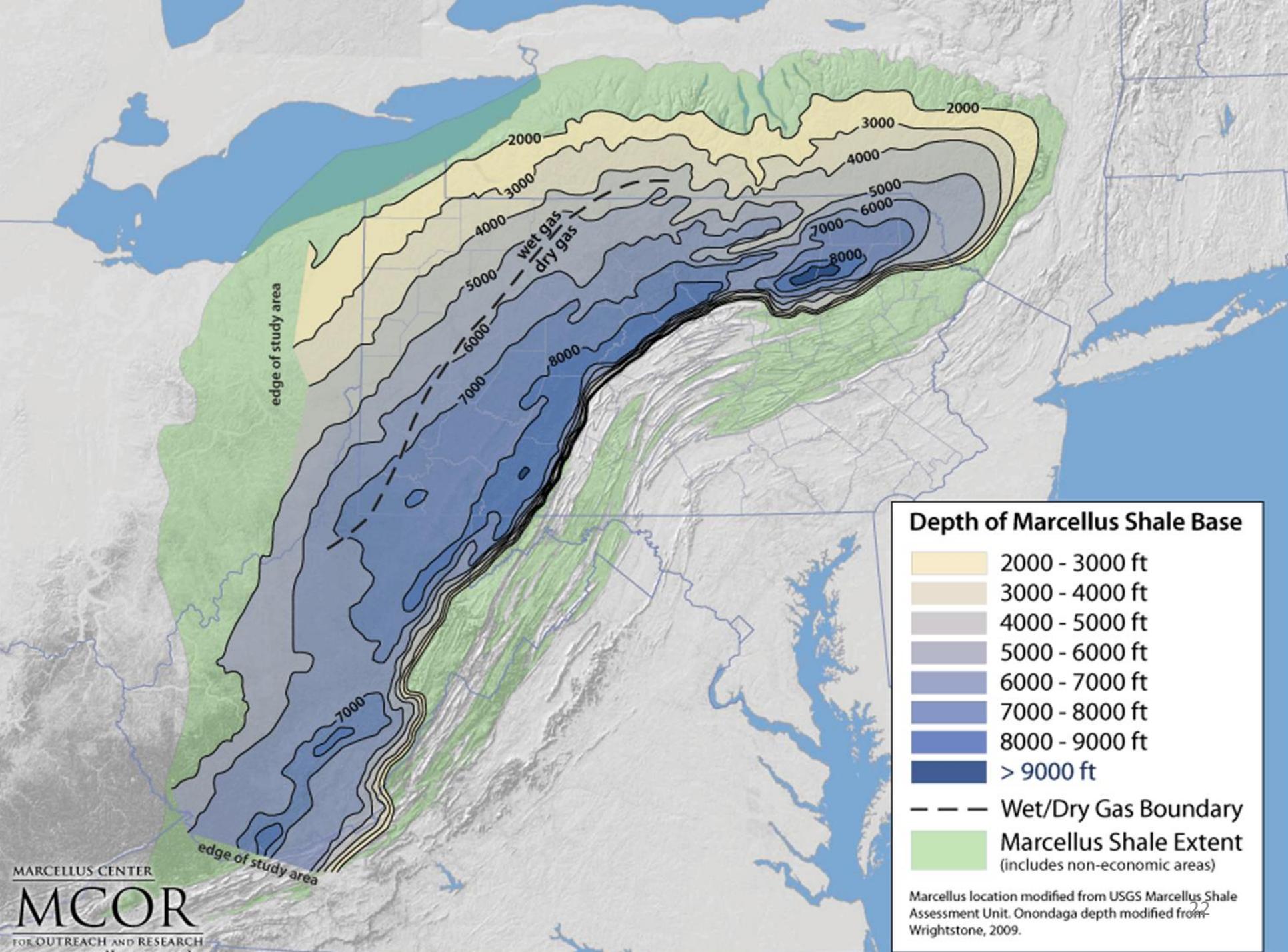


Year Drilled

- 2012 (1263 through 12)
- 2011 (1975 wells)
- 2010 (1614 wells)
- 2009 (815 wells)
- 2008 (333 wells)
- 2007 (112 wells)

Marcellus extent
(includes non-economic areas)

Based on Pennsylvania Department of Environmental Protection SPUD Data Report 21



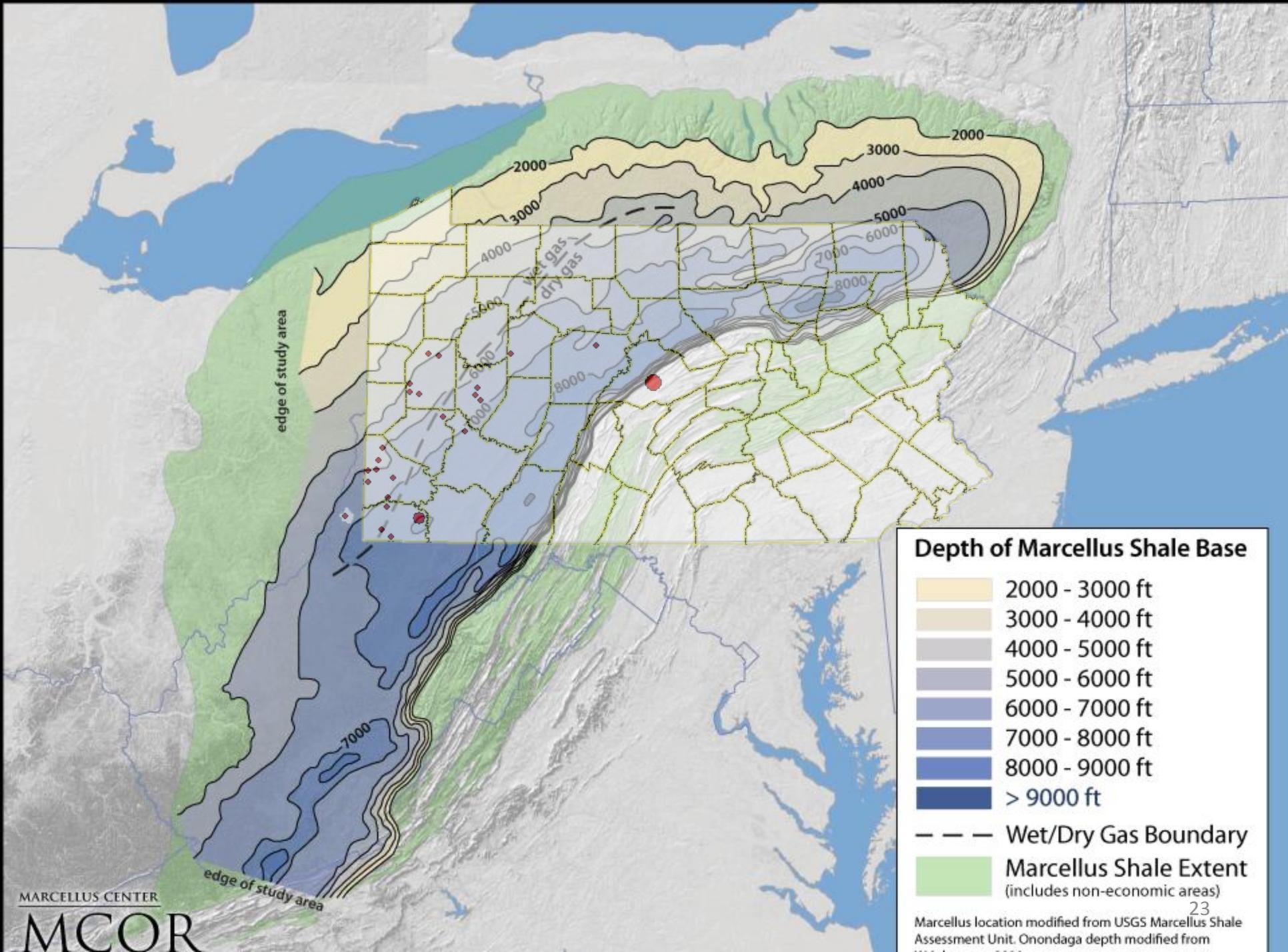
Depth of Marcellus Shale Base

- 2000 - 3000 ft
- 3000 - 4000 ft
- 4000 - 5000 ft
- 5000 - 6000 ft
- 6000 - 7000 ft
- 7000 - 8000 ft
- 8000 - 9000 ft
- > 9000 ft

--- Wet/Dry Gas Boundary

Marcellus Shale Extent
(includes non-economic areas)

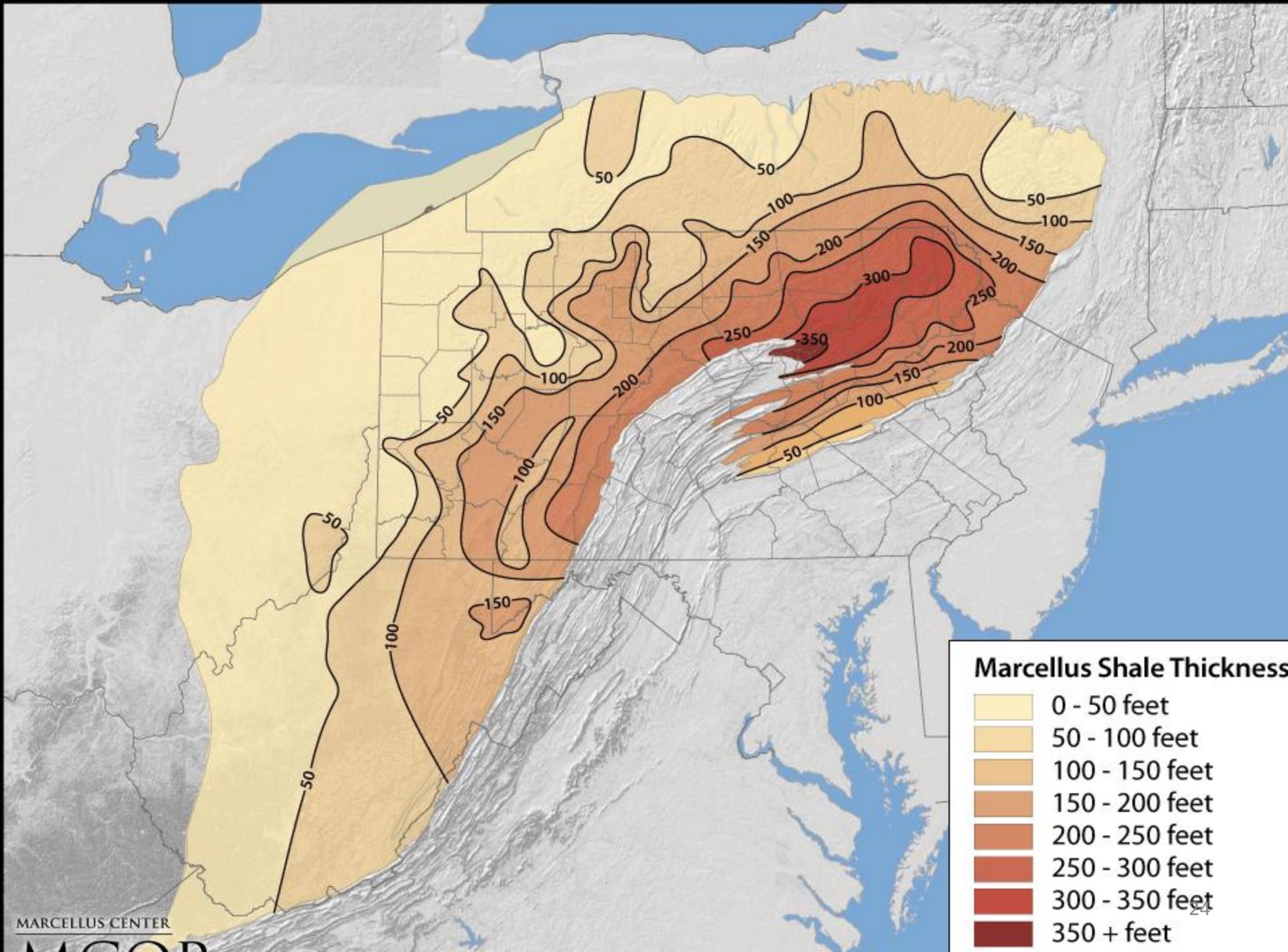
Marcellus location modified from USGS Marcellus Shale Assessment Unit. Onondaga depth modified from Wrightstone, 2009.



Depth of Marcellus Shale Base

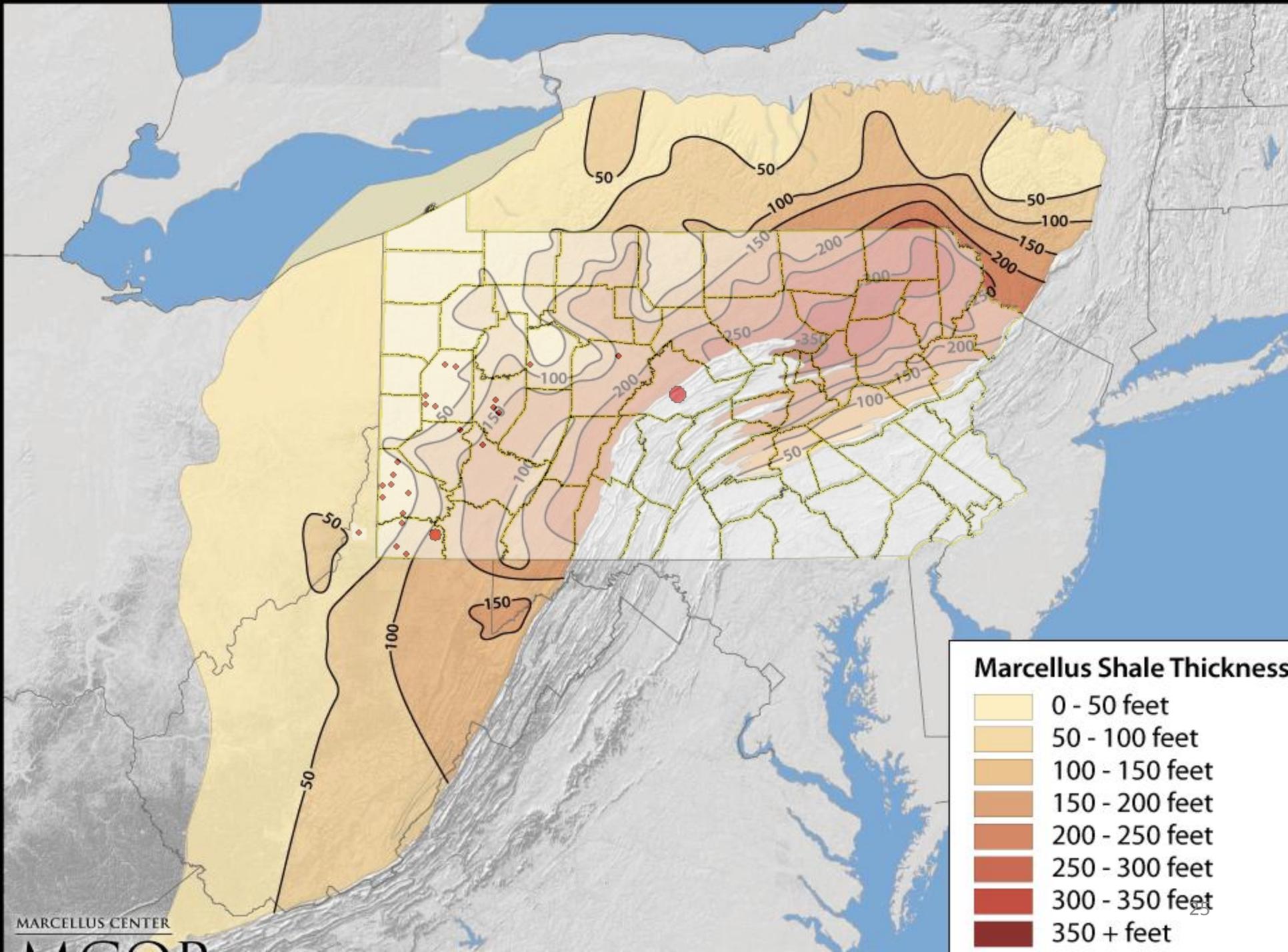
- 2000 - 3000 ft
- 3000 - 4000 ft
- 4000 - 5000 ft
- 5000 - 6000 ft
- 6000 - 7000 ft
- 7000 - 8000 ft
- 8000 - 9000 ft
- > 9000 ft
- Wet/Dry Gas Boundary
- Marcellus Shale Extent
(includes non-economic areas)

Marcellus location modified from USGS Marcellus Shale Assessment Unit. Onondaga depth modified from

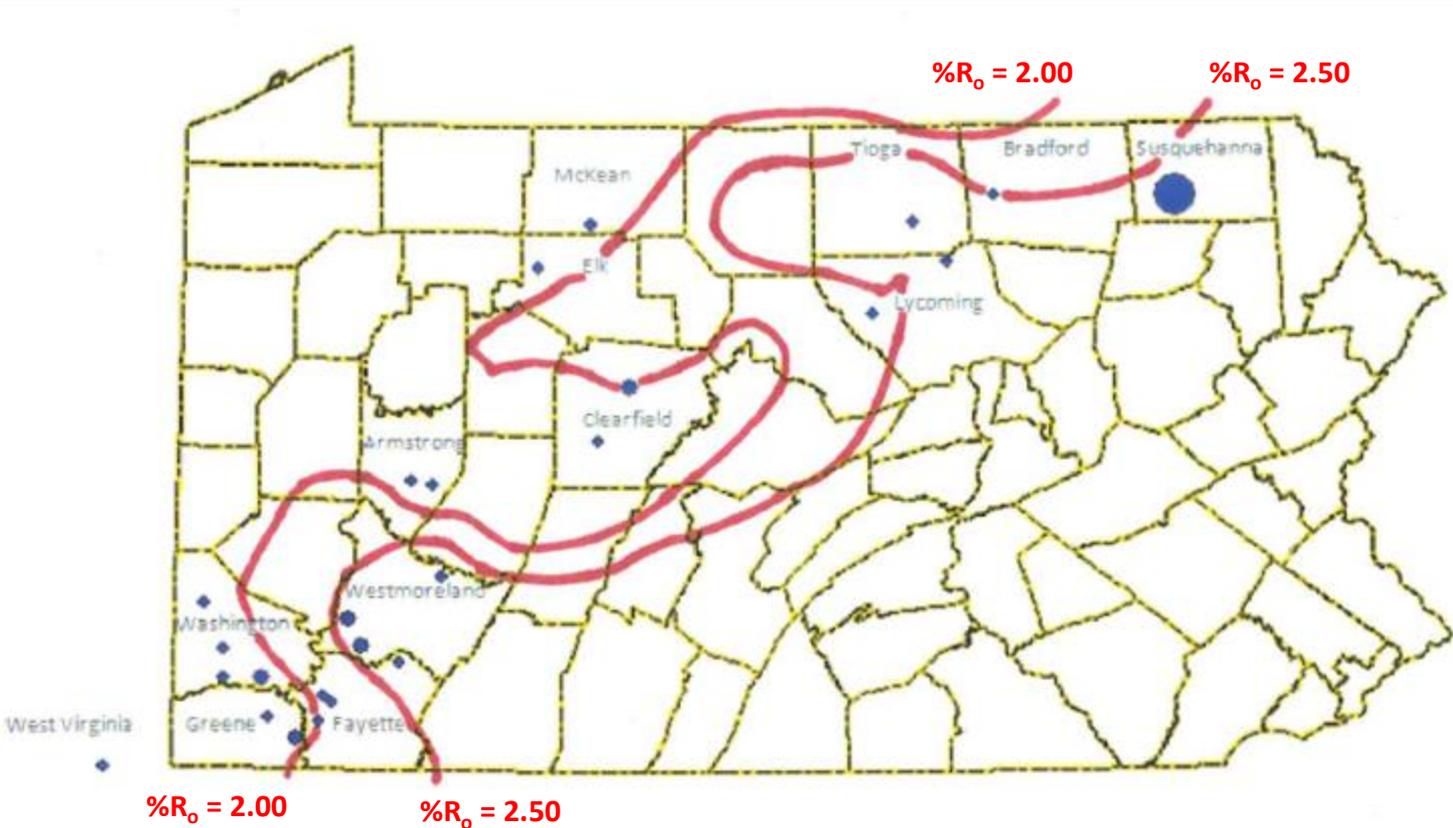


Marcellus Shale Thickness

- 0 - 50 feet
- 50 - 100 feet
- 100 - 150 feet
- 150 - 200 feet
- 200 - 250 feet
- 250 - 300 feet
- 300 - 350 feet
- 350 + feet

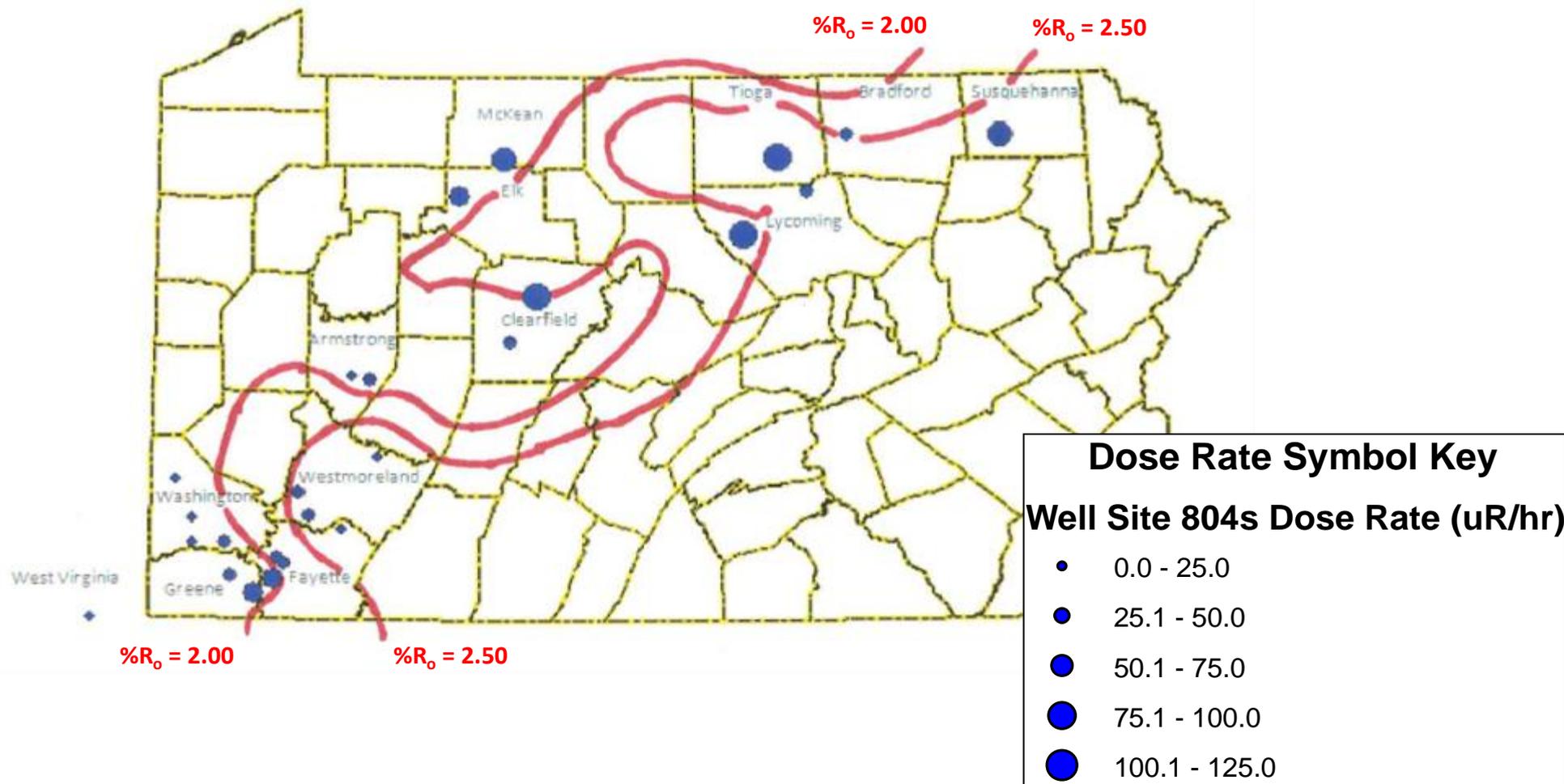


804s from Well Sites



Symbol Key	
804s from Well Sites	
Number of Loads	
•	1 - 25
●	26 - 50
●	51 - 75
●	76 - 100
●	101 - 125
●	126 - 150

Well Site 804 Dose Rate ($\mu\text{R/hr}$) Ranges



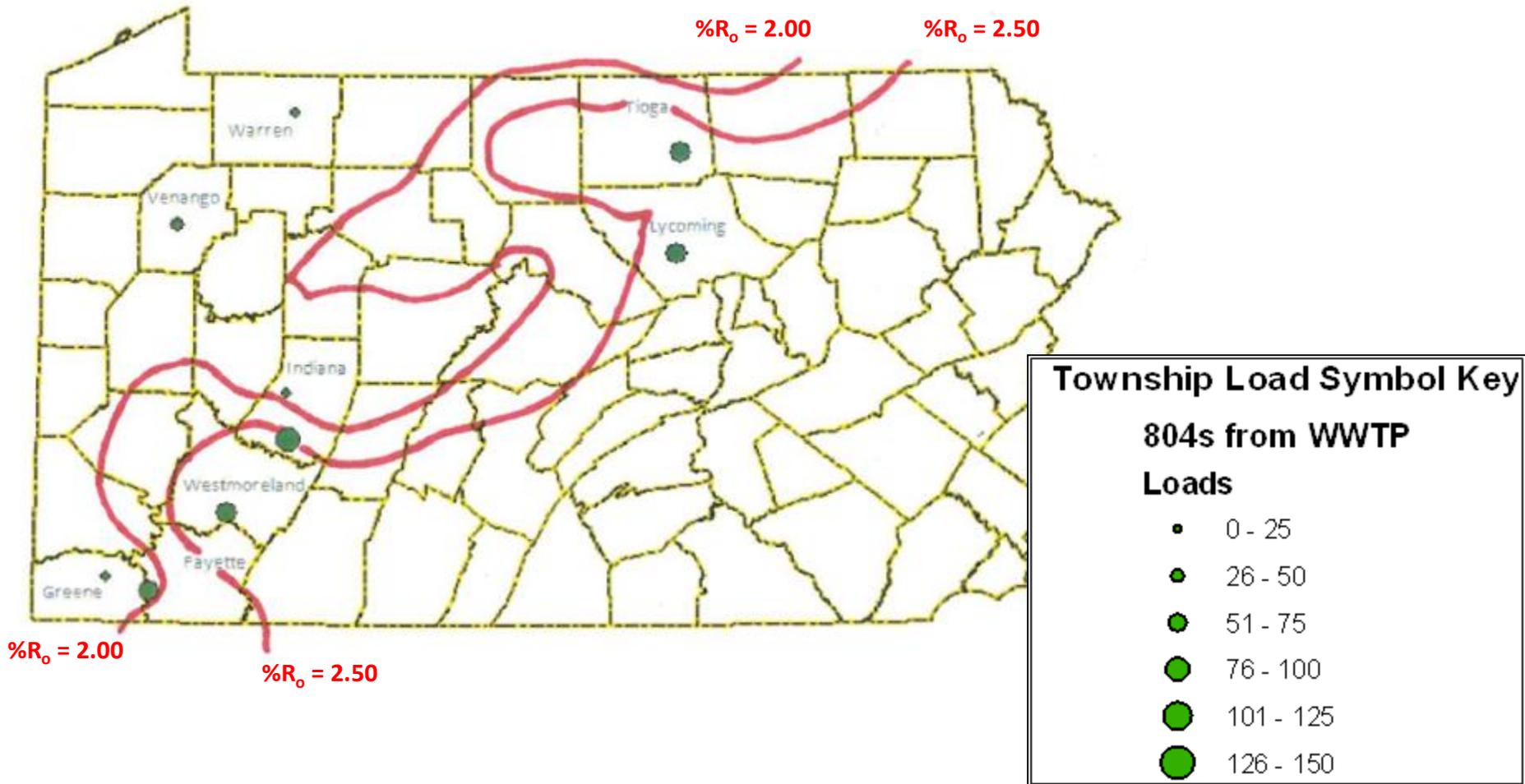
Well Site 804 Average Dose Rates ($\mu\text{R/hr}$)

County	Township	# of Loads	Average Load Dose Rate ($\mu\text{R/hr}$)	Range ($\mu\text{R/hr}$)
Clearfield	Lawrence	42	114.2	27.6 – 404
Clearfield	Ferguson	18	41.1	11.8 - 141
Elk	Highland	2	57.9	48.5 – 70.5
Greene	Monongahela	33	59.5	3.4 - 194.1
Greene	Jefferson	5	44.6	33 – 65.7
Bradford	Troy	7	25.8	15 – 37
McKean	Sergeant	2	88	62 – 112
Armstrong	Kittanning	8	24.7	14 – 31
Armstrong	Plumcreek	10	38.3	10.8 - 74
Lycoming	Cummings	1	101.7	23.4 – 180
Lycoming	McIntyre	2	41.6	17.2 - 72
Tioga	Bloss	2	110.8	42 -198

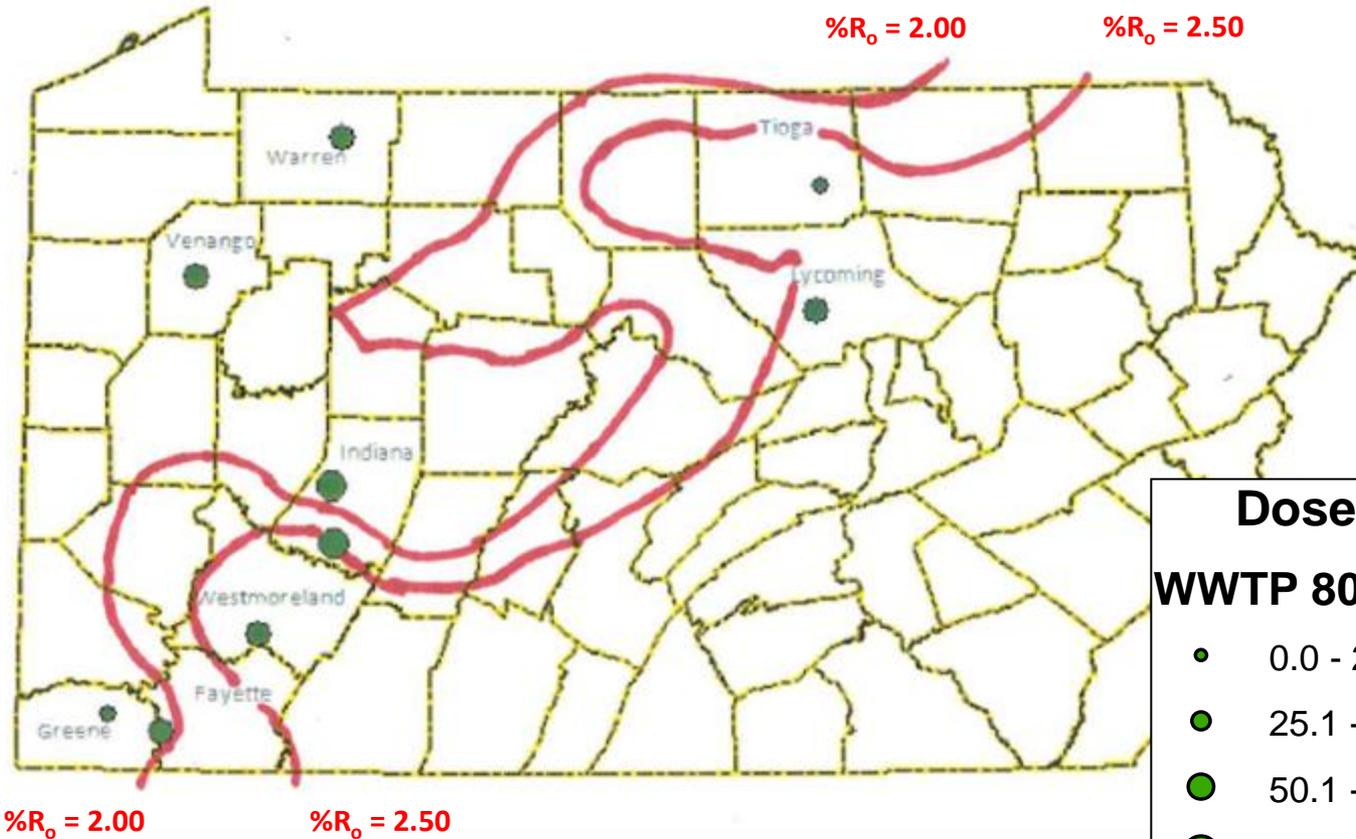
Well Site 804 Average Dose Rates ($\mu\text{R/hr}$)

County	Township	# of Loads	Average Load Dose Rate ($\mu\text{R/hr}$)	Range ($\mu\text{R/hr}$)
Fayette	Bullskin	13	19.4	7.42 – 53.6
Fayette	German	12	53.1	12.6 – 201
Fayette	Menallen	10	29	8.3 – 65.4
Fayette	Redstone	23	42.4	10.6 – 287.1
Westmoreland	Sewickley	28	26.8	4.8 – 58.6
Westmoreland	Derry	1	13.6	13.6 – 13.6
Westmoreland	South Huntingdon	26	33.8	4.2 - 141
Washington	Cross Creek	1	8.5	8.3 – 8.7
Washington	Morris	1	2.3	2.2 – 2.4
Washington	South Franklin	1	14.9	14.2 – 15.6
Washington	West Bethlehem	30	46.7	3.2 - 126
Susquehanna	Dimock	129	90.5	17 – 242
West Virginia	Wetzel	1	18.4	16.6 – 20.2

804s from WWTPs



WWTP 804 Average Dose Rates ($\mu\text{R/hr}$)



Dose Rate Symbol Key	
WWTP 804s Dose Rate ($\mu\text{R/hr}$)	
•	0.0 - 25.0
●	25.1 - 50.0
●	50.1 - 75.0
●	75.1 - 100.0
●	100.1 - 125.0

WWTP 804 Average Dose Rates ($\mu\text{R/hr}$)

County	Township	# of Loads	Average Load Dose Rate ($\mu\text{R/hr}$)	Range ($\mu\text{R/hr}$)
Greene	Franklin	1	39.5	33 – 46
Fayette	German	63	56.1	16.6 – 179
Lycoming	Old Lycoming	69	52.24	4.6 – 143
Tioga	Blossburg	54	26.9	8.2 – 55
Westmoreland	Mount Pleasant	52	54.4	8 – 126.8
Indiana	Burrell	80	90	28 – 202
Indiana	Washington	7	98.4	46 – 150.7
Warren	Warren	4	67.6	35 – 137
Venango	Franklin	33	53.8	25 – 103

Conclusions

Drill Cuttings (810s)

- 90% of waste loads originate west of the %R₀ 2.00 line
 - 100% West of the %R₀ 2.50 line
- Shale thickness = 52% (0-50 Feet)
99% (150 Feet or less)
- Shale Depth = 92% (4,000-8,000 Feet)

Conclusions

- No discernible patterns for 804s
 - Difficult to draw conclusions without knowing the point of origin



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Questions?