Map Set 1: Development Projections

This series of maps displays information related to the potential environmental impacts of *additional* gas development in *Pennsylvania* if all remaining technically recoverable resources in the Interior Marcellus shale were developed using high volume hydraulic fracturing and horizontal drilling with eight wells per well pad.

This map set includes projections of well and well pad development by county and watershed (US Geological Survey Hydrologic Unit Code – 10 watersheds), as well as selected infrastructure development needed to support gas well development (access roads and gathering pipelines).

Note: These maps contain *projections* of natural gas development and associated environmental impacts under a particular set of circumstances and assumptions. They are not *predictions* of development or impacts, and should not be used for commercial purposes, to guide investment decisions, or for short-range planning decisions. Furthermore, the projected well locations should not be used to inform planning or decision making for geographic units smaller than the primary units of analysis (counties or HUC-10 watersheds).

Development Projections Maps

This map set includes the following maps:

1.1 Probability surface for well pad development in the Interior Marcellus

1.2 Projected well pad development locations

1.3 Projected well development by county

1.4 Projected well development by watershed

1.5 Projected well development density

1.6 Projected natural gas infrastructure by county

For additional documentation and methodology used to create these maps, please download the research report at: www.cna.org/PA-Marcellus

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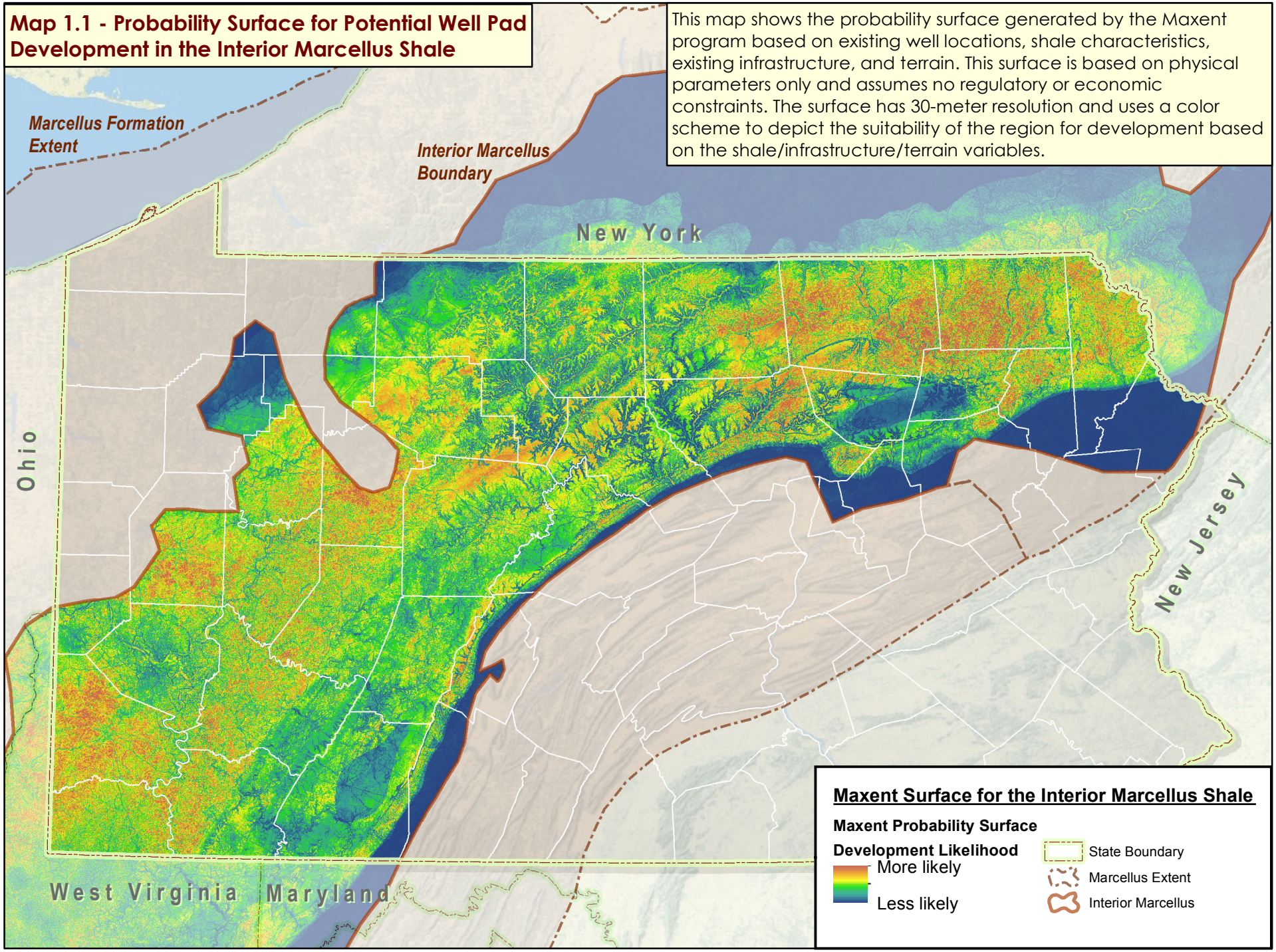
Map 1.1 - Probability Surface for Potential Well Pad Development in the Interior Marcellus Shale

This map shows the probability surface generated by the Maxent program based on existing well locations, shale characteristics, existing infrastructure, and terrain. This surface is based on physical parameters only and assumes no regulatory or economic constraints. The surface has 30-meter resolution and uses a color scheme to depict the suitability of the region for development based on the shale/infrastructure/terrain variables.



Note: Maximum entropy (Maxent) is a geospatial analysis method that correlates location of existing with characteristics of underlying geospatial layers. A higher 'Maxent' score means there is there is a higher probability that the underlying layers have conditions similar to those where existing have been developed.

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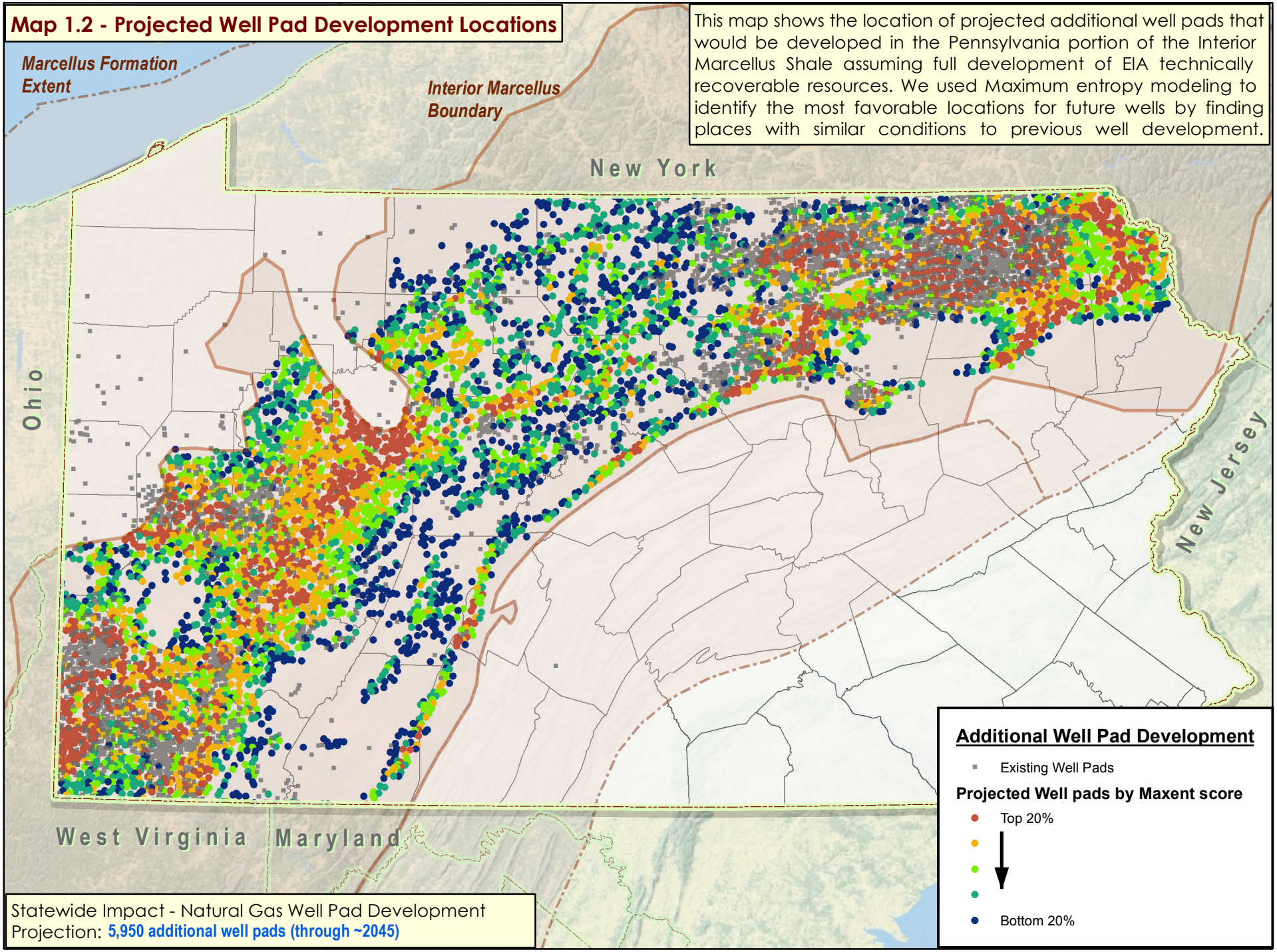
Map 1.2 - Projected Well Pad Development Locations

This map shows the location of projected additional well pads that would be developed in the Pennsylvania portion of the Interior Marcellus Shale assuming full development of EIA technically recoverable resources. We used Maximum entropy modeling to identify the most favorable locations for future wells by finding places with similar conditions to previous well development.



Statewide Impact - Natural Gas Well Pad Development Projection: **5,950 additional well pads (through ~2045)**

0 20 40 80 Miles

Note: Maximum entropy (Maxent) is a geospatial analysis method that correlates locations of existing wells with underlying geospatial layers. A higher 'Maxent score' means there is higher probability that the underlying layers have conditions similar to those where existing wells have been developed.

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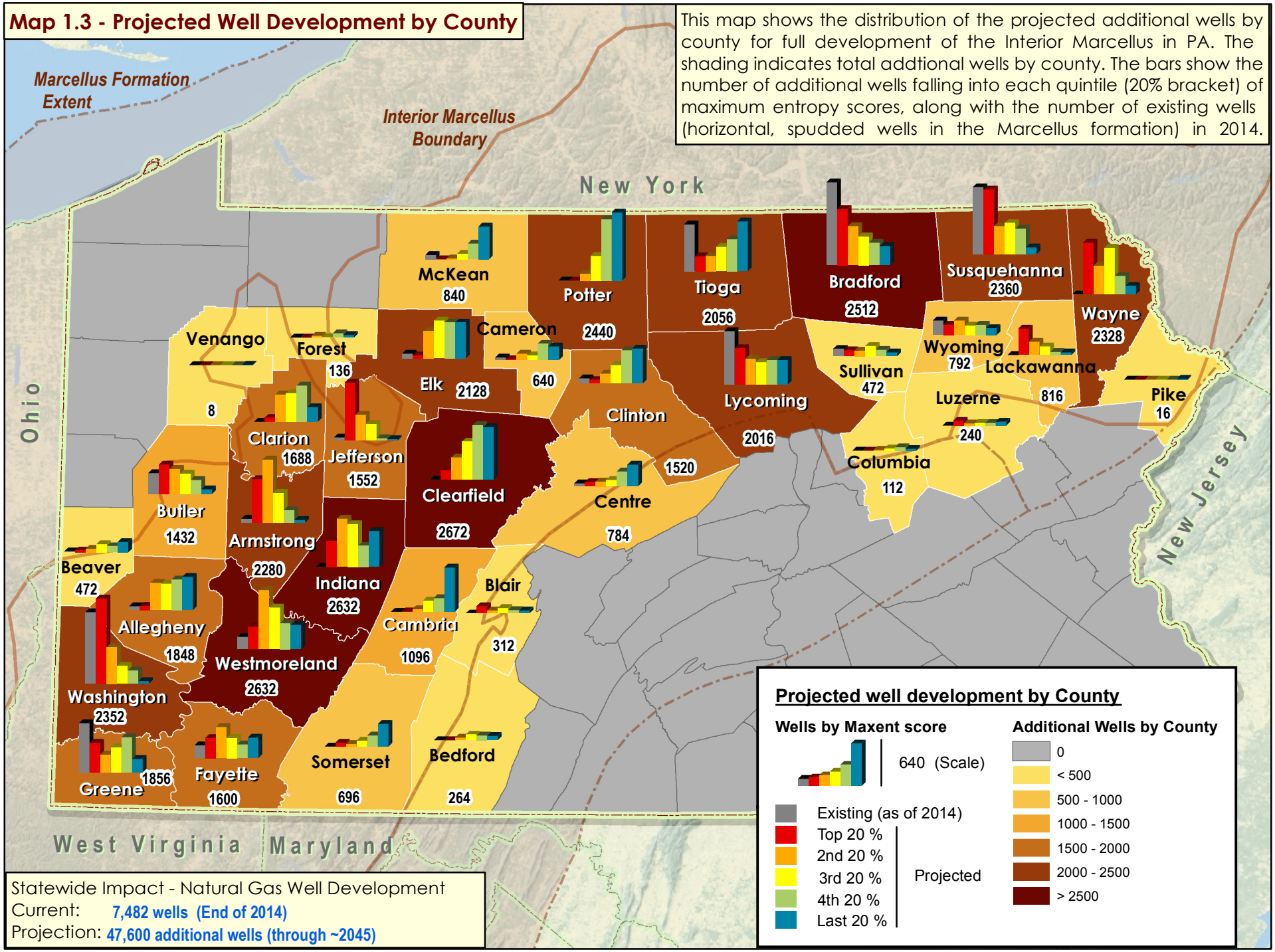
Map 1.3 - Projected Well Development by County

This map shows the distribution of the projected additional wells by county for full development of the Interior Marcellus in PA. The shading indicates total addtional wells by county. The bars show the number of additional wells falling into each quintile (20% bracket) of maximum entropy scores, along with the number of existing wells (horizontal, spudded wells in the Marcellus formation) in 2014.



Statewide Impact - Natural Gas Well Development
Current: 7,482 wells (End of 2014)
Projection: 47,600 additional wells (through ~2045)

Miles
0 20 40 80

Note: Maximum entropy (Maxent) is a geospatial analysis method that correlates locations of existing wells with underlying geospatial layers. A higher 'Maxent score' means there is higher probability that the underlying layers have conditions similar to those where existing wells have been developed.

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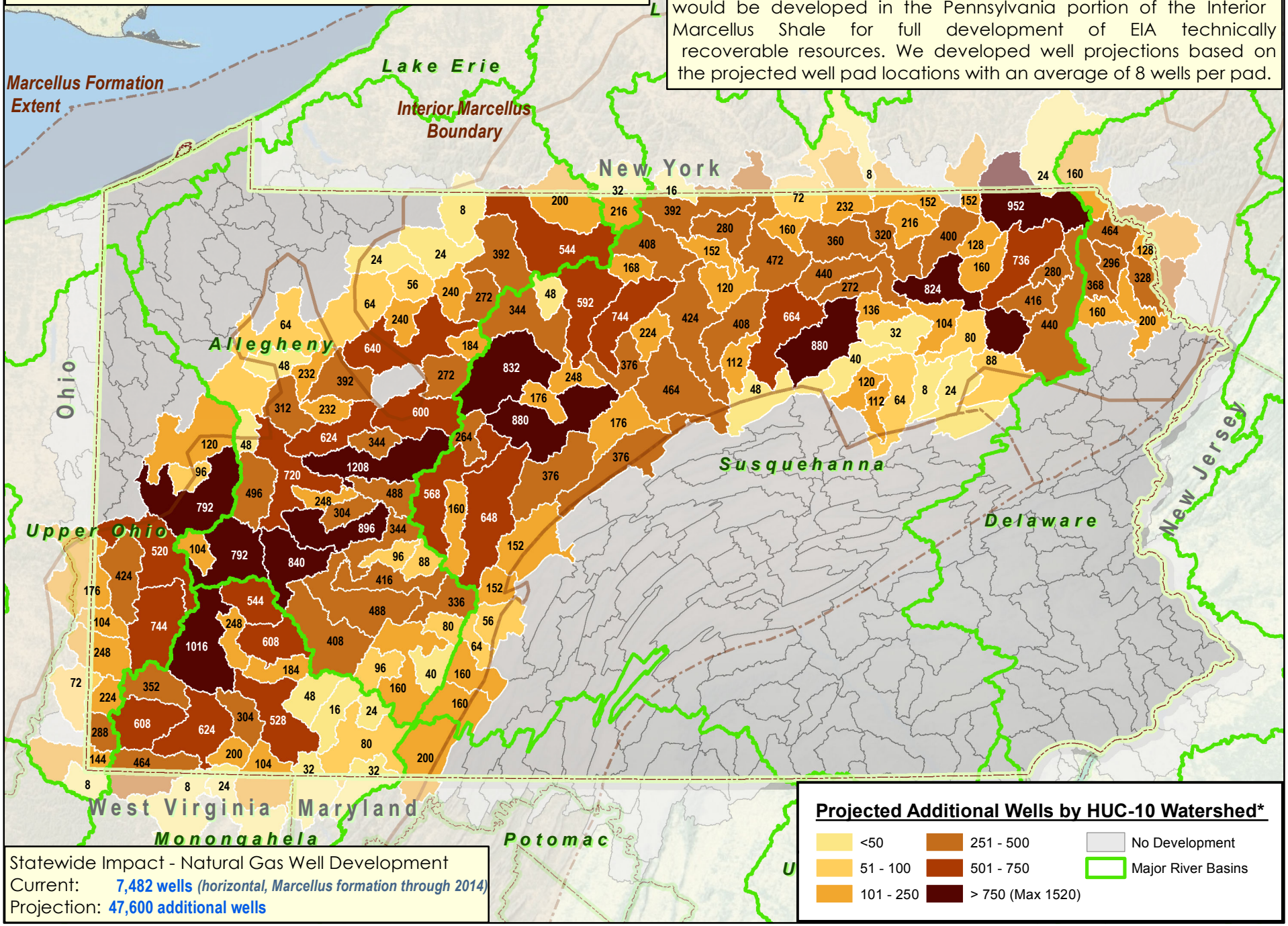
Map 1.4 - Projected Well Development by HUC-10 Watershed

This map shows the number of projected additional wells that would be developed in the Pennsylvania portion of the Interior Marcellus Shale for full development of EIA technically recoverable resources. We developed well projections based on the projected well pad locations with an average of 8 wells per pad.



Statewide Impact - Natural Gas Well Development
Current: 7,482 wells *(horizontal, Marcellus formation through 2014)*
Projection: 47,600 additional wells

Projected Additional Wells by HUC-10 Watershed*

<50	251 - 500	No Development
51 - 100	501 - 750	Major River Basins
101 - 250	> 750 (Max 1520)	

Miles
0 20 40 80

** Hydrologic Unit Code (HUC) 10 watersheds are delineated by the US Geological Survey. There are 332 HUC-10s in PA with an average area of 162 square miles.*

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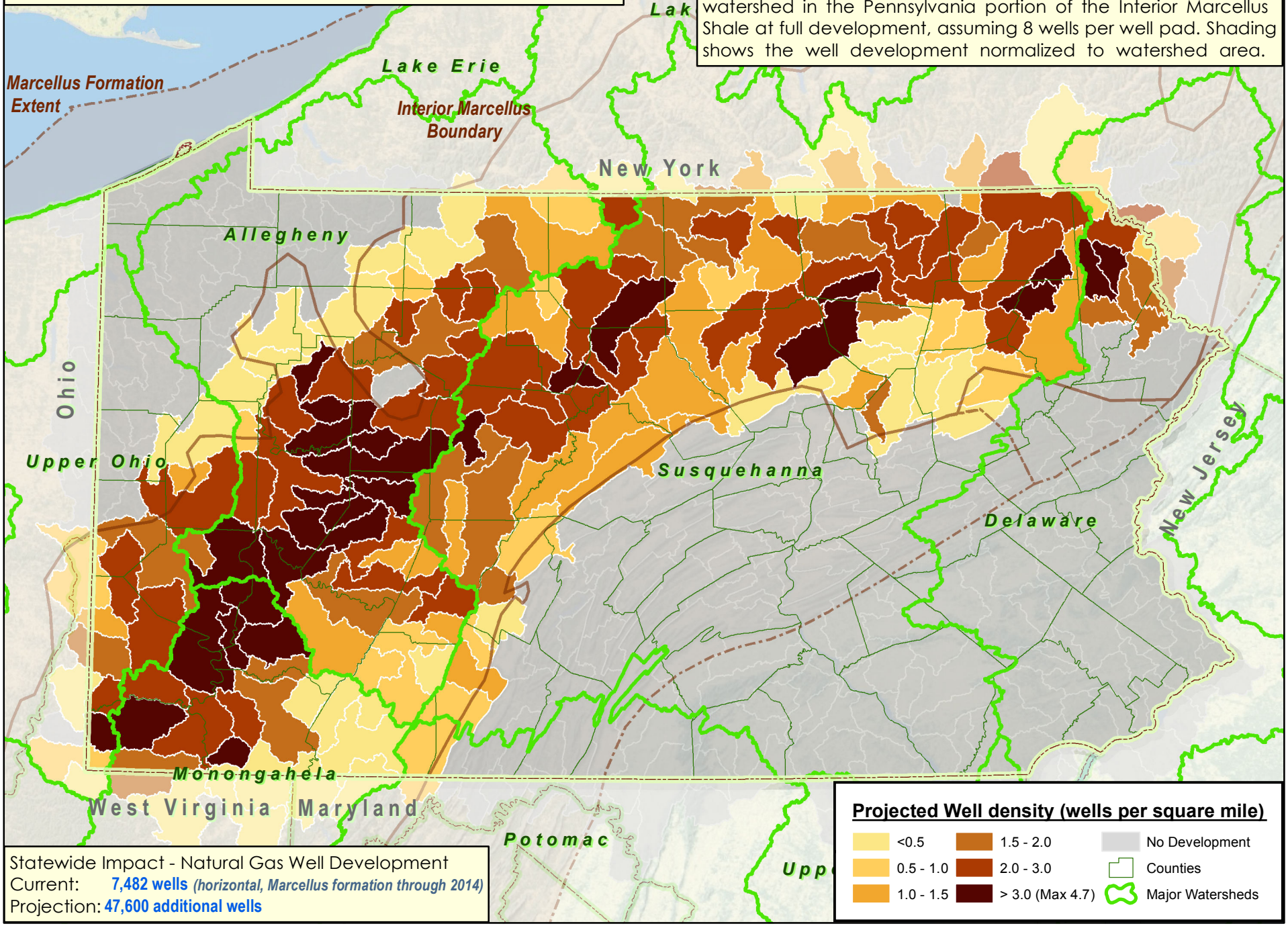
Map 1.5 - Well Development Density by HUC-10 Watershed

This map shows the projected density of new well development by watershed in the Pennsylvania portion of the Interior Marcellus Shale at full development, assuming 8 wells per well pad. Shading shows the well development normalized to watershed area.



Statewide Impact - Natural Gas Well Development
Current: 7,482 wells *(horizontal, Marcellus formation through 2014)*
Projection: 47,600 additional wells

Projected Well density (wells per square mile)

<0.5	1.5 - 2.0	No Development
0.5 - 1.0	2.0 - 3.0	Counties
1.0 - 1.5	> 3.0 (Max 4.7)	Major Watersheds

Miles
0 20 40 80

** Hydrologic Unit Code (HUC) 10 watersheds are delineated by the US Geological Survey. There are 332 HUC-10s in PA with an average area of 162 square miles.*

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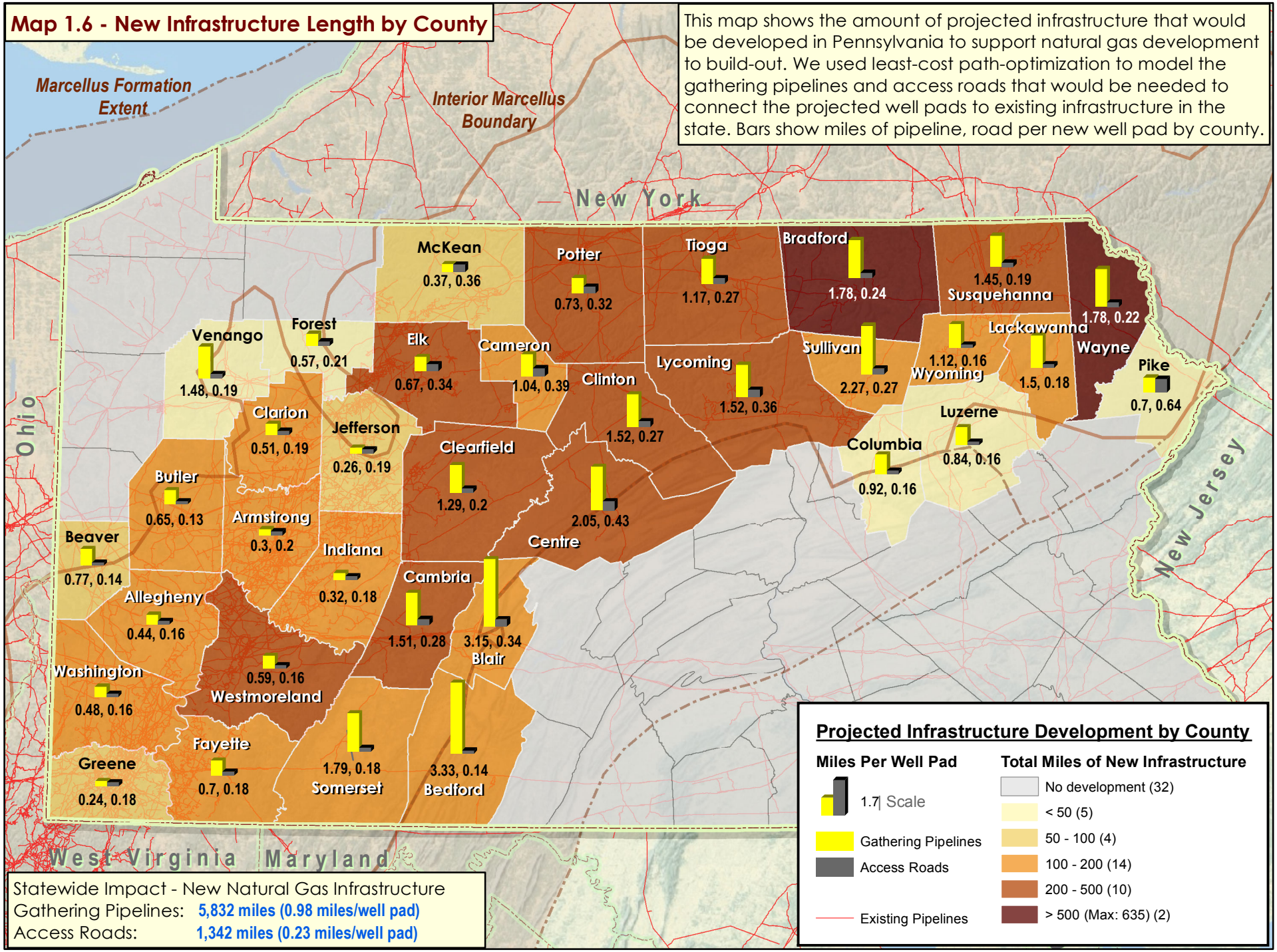
Map 1.6 - New Infrastructure Length by County

This map shows the amount of projected infrastructure that would be developed in Pennsylvania to support natural gas development to build-out. We used least-cost path-optimization to model the gathering pipelines and access roads that would be needed to connect the projected well pads to existing infrastructure in the state. Bars show miles of pipeline, road per new well pad by county.



Projected Infrastructure Development by County

Miles Per Well Pad

1.7| Scale

Gathering Pipelines

Access Roads

Existing Pipelines

Total Miles of New Infrastructure

- No development (32)
- < 50 (5)
- 50 - 100 (4)
- 100 - 200 (14)
- 200 - 500 (10)
- > 500 (Max: 635) (2)

Statewide Impact - New Natural Gas Infrastructure
Gathering Pipelines: 5,832 miles (0.98 miles/well pad)
Access Roads: 1,342 miles (0.23 miles/well pad)

0 20 40 80 Miles

Note: The pipeline projections are for gathering pipelines only and do not include additional interstate/intrastate tranmission pipelines that may be developed.