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## **Trout Unlimited's Conservation Success Index: Status and Threats to Trout and Coldwater Habitats in Pennsylvania**

**September 2011**

### ***Overview***

Trout Unlimited's Conservation Success Index (CSI) is a compilation and assessment of information related to a species' distribution, populations, habitat features, and future threats. The CSI assembles spatial data available from national, state, and non-profit resource management agencies into a database and summarizes the data by watershed. These watershed-scale summaries are interpreted within an analytical framework and assigned a categorical score of 5 (high) to 1 (low), allowing for the investigation and comparison of conditions and threats within and across watersheds.

CSI analyses are typically conducted across the distribution of a species. This analysis builds upon the CSI for eastern brook trout, completed in 2007, which used data assembled by the Eastern Brook Trout Joint Venture. This analysis uses local, Pennsylvania-specific data to provide a higher-resolution perspective on the condition of and threats to trout and coldwater habitats in Pennsylvania. This analysis provides summaries of the following:

- Wilderness, Class A, Natural Reproduction, and stocked trout streams and unassessed streams identified by the Pennsylvania Fish and Boat Commission (PFBC)
- Designated use streams identified by Pennsylvania Department of Environmental Protection (DEP) and aquatic communities identified by Pennsylvania Natural Heritage Program
- Coldwater habitat fragmentation, based on the barriers to connectivity in the form of dams and acid mine drainage
- Water quality and watershed condition, considering streams impaired by acid mine drainage and other sources using data from DEP, agricultural and urban area acreage, and road densities using the finest-scale road data available in PA
- Current resource development, summarizing the presence of oil and gas wells, Marcellus shale wells, wind turbines, acid mine drainage areas, and active mines using data from PA DEP and US Geological Survey
- Future resource development, mapping projected development of oil and gas resources in the Marcellus Shale formation and wind turbine development using forecasts from The Nature Conservancy and Western Pennsylvania Conservancy
- Vulnerability to climate change, an assessment of current and forecast summer temperatures and base flow index, a measure groundwater influence
- Combined summaries by theme, arrayed into conservation strategies
- Combined summaries by theme, arrayed into Marcellus Shale monitoring strategies

## ***Analysis***

The CSI for Pennsylvania trout and coldwater habitats incorporates data specific to Pennsylvania and is organized into three groups of analyses related to trout populations, habitats, and future security. Map 1 shows the analysis area along with subwatershed (6<sup>th</sup> field hydrologic unit or HUC 12) and subbasin (4<sup>th</sup> field hydrologic unit or HUC8) boundaries. All CSI results summarize data at the subwatershed scale; subbasin boundaries are provided for reference. Results are most comprehensive for watersheds that lie completely within Pennsylvania.

### ***Trout populations***

The trout populations group includes two indicators: Trout Designation and Distribution and Trout Habitat Extent. The Trout Designation and Distribution indicator looks at the percentage of the streams within each subwatershed in the state that are designated by PFBC as “Wilderness” (March 2008 data of streams that provide a wild brook trout fishing experience in remote and unspoiled environments), “Class A” (April 2009 data of streams supporting naturally reproducing (wild) trout of sufficient size and abundance to support a long-term and rewarding fishery without stocking), and “Natural Reproduction” (June 2010 data of streams supporting wild trout, but which may also be stocked with hatchery trout) (Map 2) or identified as stocked (April 2010 data). DEP existing use designations “Exceptional Value,” “High Quality,” and “Cold Water” (2010 Chapter 93 Existing Use data) are also considered in the indicator. Streams that lack a PFBC designation are considered “Unassessed.” Highest CSI scores are assigned to subwatersheds with highest proportions of “Wilderness” streams; moderate scores are assigned to those with high proportions of “Class A” or “Natural Reproduction” trout waters; moderately low scores are assigned to those with existing use designations, while subwatersheds solely containing stocked trout receive the lowest scores (Table 1). Highest CSI scores are scattered throughout headwaters streams in central Pennsylvania (Map 4). PA Natural Heritage Program modeled coldwater (trout and sculpin dominated) and coolwater (dace, sculpin, and sucker dominated, but with trout present) aquatic communities in 2007 and experts characterized watersheds with brook trout present through the Eastern Brook Trout Joint Venture in 2006 (Maps 4, 5); these data may be useful overlays when interpreting trout population indicators.

**Table 1:** Indicator scoring for Trout Designation and Distribution

<b>Percent “Wilderness” Trout Streams</b>	<b>Percent “Class A” Trout Streams</b>	<b>Percent “Natural Reproduction” Trout Streams</b>	<b>Percent “Exceptional Value”, “High Quality”, or “Cold Water”</b>	<b>Percent stocked</b>	<b>CSI Score</b>
≥ 10%					5
1.0 – 9.9%	≥ 1.0%				4
		≥ 10%			3
		1.0 – 9.9%	> 1.0%		2
				> 1.0%	1

Score for best case by subwatershed. Trout-less or unassessed subwatersheds not scored

The Trout Habitat Extent analysis summarizes the maximum habitat patch size available to trout within a subwatershed. Potential trout habitat is defined as any stream designated as “Wilderness,” “Class A,” or “Natural Reproduction” by PFBC. Within the CSI, these streams are fragmented by dams (identified by US Army Corps of Engineer’s National Inventory of Dams) and acid mine drainage impaired streams (identified by DEP (April 2010 data)), and the largest connected stream habitat patch is reported for each subwatershed. Subwatersheds are scored following the rationale that populations with less available habitat are more vulnerable to extirpation as a result of small, localized disturbances (Table 2). Map 6 shows the pattern of CSI scores for Habitat Extent, with high scores predominating in the core of trout distribution in north/central Pennsylvania, and low scores occurring at the periphery. Because only trout stream designations are used to identify trout habitat, CSI scores are least informative in watersheds with high proportions of unassessed waters. Within watersheds with trout, this analysis likely overestimates the extent of habitat available for trout due to the lack of a comprehensive barrier assessment for smaller barriers like road culverts.

**Table 2:** Indicator scoring for Trout Habitat Extent

Maximum occupied habitat size	CSI Score
> 31.3 mi (50 km) connected habitat	5
18.6 – 31.3 mi (30-50 km) connected habitat	4
12.4 – 18.6 mi (20-30 km) connected habitat	3
6.2 – 12.4 mi (10-20 km) connected habitat	2
< 6.2 mi (10 km) connected habitat	1

Score by scenario. Trout-less, stocked-only, and unassessed subwatersheds not scored

### *Trout habitats*

The trout habitat group of analyses includes the Watershed Condition and Resource Development (Current and Legacy) indicators. The Watershed Conditions indicator includes several metrics, including miles of stream listed as “Impaired for Aquatic Life” by DEP (2010 data). Several factors that act on the terrestrial portions of a watershed, but can influence instream habitat condition, are also considered: percentage area developed as urban or agricultural use (data from US Geological Survey’s National Land Cover Dataset 2001) and average road density (2010 state and local road data from PA Dept. of Transportation). Additionally, the analysis summarizes the ratio of miles of road within 150 ft of streams to miles of stream by watershed, a metric that reflects the degree to which floodplain processes and river connectivity are impaired by altered or constrained river courses. Highest scores are assigned to subwatersheds with the least disturbance (Table 3). Lowest scores occur in the vicinity of Philadelphia and Pittsburgh in southern Pennsylvania, with scattered high scores in the north/central portions of the state, particularly along the Allegheny River (Map 7).

**Table 3:** Indicator scoring for Watershed Conditions

Miles listed as Impaired	Percent agriculture/urban	Road density (miles/miles <sup>2</sup> )	Road mi/ Stream mi	CSI Score
	0-20%	< 2.0	0 – 0.09	5
	20-39%	2.0 – 3	0.10 – 0.19	4
> 0.1	40-59%	3 – 3.5	0.20 - 0.29	3
	60-79%	3 – 4.7	0.30 – 0.49	2
	80-100%	≥ 4.7	0.5 – 1.0	1

Score for worst case by subwatershed

The Resource Development (Current and Legacy) indicator summarizes a variety of mining and gas development features by subwatershed. These features can influence water quality by altering water chemistry, introducing chemicals, and causing sedimentation through associated road building. The increasing presence of active oil and gas wells (DEP data from January 2011), active Marcellus shale wells (DEP data for 2006 – Sept 2, 2011, provided by [www.fractracker.org](http://www.fractracker.org)), active mines (US Geological Survey data through 2005), wind turbines (The Nature Conservancy data for existing turbines through December 2010), or acid mine drainage areas (DEP Abandoned Mine Land Inventory System problem area data for January 2010) results in decreasing CSI scores (Table 4). Acid mine drainage area is calculated using a correction factor related to reclaimed features, so that unreclaimed sites are counted for their entire acreage, 90% reclaimed sites are counted for 10% of their acreage, etc. Active Marcellus Shale well counts are weighed more heavily than traditional oil and gas well counts due to the larger water demands and effluent discharge associated with Marcellus Shale wells. These effluents are treated in a variety of ways – reinjected into wells, left in evaporative pools, or trucked to treatment facilities. Because of the possibility that water quality can be impaired away from well sites, a summary of Marcellus Shale wells operating within each subbasin is added to Map 8. Lowest CSI scores are found throughout the Allegheny plateau (Map 8).

**Table 4:** Indicator Scoring for Resource Development (Current and Legacy)

Oil and gas wells	Marcellus wells	Active mines	Wind turbines	Percent acid mine drainage	CSI Score
0	0	0	0	0%	5
1 - 19	1 - 9	1-3	1 - 19	1-14%	4
20 - 99	10 - 24	4-6	20 - 59	15-39%	3
100 - 199	25 - 49	7-9	60 - 99	40-69%	2
≥ 200	≥ 50	≥10	≥ 100	70-100%	1

Score for worst case by subwatershed

### *Future security*

The CSI indicators assessing future threats to Pennsylvania's brook trout focus on Resource Development (Future) and Climate. Resource development is often associated with road

construction that may affect water quality and stream connectivity. Additionally, Marcellus Shale development requires surface water inputs and creates effluent that can degrade water quality. The Resource Development (Future) indicator summarizes the number of Marcellus Shale wells and wind turbines forecast to be developed in each subwatershed using projections for 2030. The Marcellus Shale Projections Dataset and Wind Projections Dataset are owned jointly by The Nature Conservancy and Western Pennsylvania Conservancy. They represent the relative probability of Marcellus natural gas and wind development and possible patterns (not absolute predictions) of future development under three different scenarios in Pennsylvania. Additional information is available at [nature.org/paenergy](http://nature.org/paenergy). The CSI uses the medium-impact development scenario - for Marcellus Shale, this assumes 10,000 new wells by 2030 with 6 wells/pad and a pad spacing of 4,100 ft; for wind, this assumes 1,200 new turbines by 2030. For a given development scenario, the probability of a site's development as a Marcellus Shale well is based on geological variables such as shale depth, thickness, and thermal maturity and site characteristics such as slope, distance to roads, and distance to pipelines. The probability of a site's development for wind is based on wind power measurements and site characteristics such as slope, land cover, distance to roads, and distance to transmission lines. Table 5 presents the CSI scoring scheme for the Resource Development (Future) indicator. The pattern of future resource development is a broad mosaic of Marcellus Shale drilling stretching from the southwest to northeast corners of the state, with wind development limited to ridge tops in the Ridge and Valley region (Map 9).

**Table 5:** Indicator Scoring for Resource Development (Future)

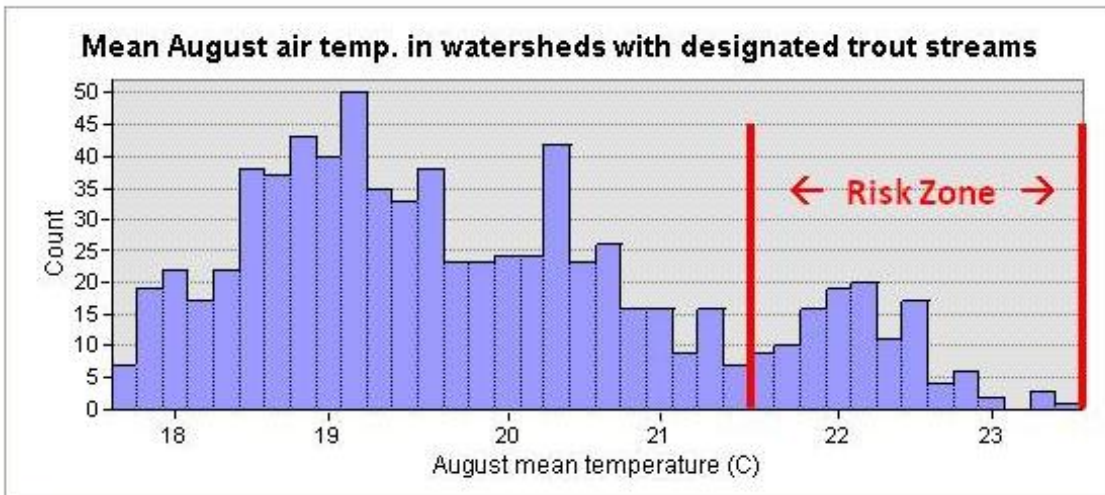
<b>Marcellus wells (med scenario)</b>	<b>Wind turbines (med scenario)</b>	<b>CSI Score</b>
0	0	5
1 - 9	1 - 19	4
10 - 24	20 - 59	3
25 - 49	60 - 99	2
≥ 50	≥ 100	1

Score for worst case by subwatershed

The Climate indicator summarizes current and forecast August mean temperature trends and considers the influence of groundwater in Pennsylvania watersheds. Because of the limited availability of water temperature data across large landscapes and the difficulty of modeling water temperatures, air temperature for the hottest portion of the year is often used as a proxy for critical instream temperatures. The CSI summarizes current average August temperature (Oregon State University's PRISM Climate Group data for the period 1971 – 2000) and forecast average August temperature (ClimateWizard forecasts for 2050) by subwatershed. Based on a histogram of current average August temperature in watersheds with "Wilderness," "Class A," or "Natural Reproduction" designated streams, the CSI uses 21.5°C as a threat threshold and 23.5°C as an absolute threshold for trout distribution (Figure 1). A subwatershed is scored based on whether it exceeds these thresholds under current and forecast climate (Table 6). Scores are mitigated by 1 point if average subwatershed Base Flow Index values are greater

than 50%, reflecting the buffering effects of groundwater on instream temperature. Base Flow Index is the ratio of base flow, or groundwater flows, to total flow, expressed as a percentage. Base Flow Index data is provided by the US Geological Survey. Climate indicator scores are highest in the highest elevation portions of the Allegheny Plateau (Map 10).

**Figure 1:**



**Table 6:** Indicator Scoring for Climate

Current August air temperature (C)	Predicted 2050 August air temperature (C)	CSI Score
< 21.5	< 21.5	5
< 21.5	21.5 - 23.5	4
< 21.5	> 23.5	3
21.5 - 23.5	> 23.5	2
> 23.5	> 23.5	1

Score by scenario, add one point if Base Flow Index is  $\geq 50\%$

### *Other Factors*

Map 11 provides a summary of the percent of each subwatershed that is owned by federal and state agencies, counties, or land trusts (data from US Geological Survey's Protected Areas Database version 1.1, May 2010). The level of protection provided to natural resources and wildlife will vary across ownership agency, but management decisions are likely to involve more public participation on these lands.

Map 12 summarizes the percent of each watershed that is a forest patch at least 500 acres in size (data from The Nature Conservancy, based on 2001 land cover data, and considering roads and transmission corridors). Because large patches of unfragmented, interior forest provide essential habitat for many imperiled neotropical migratory bird species and other wildlife,

watersheds with these features may be locations for collaboration with other conservation organizations.

### ***Interpretation***

The results provided summarize and interpret a variety of data at the subwatershed scale and represent the pattern of that data across Pennsylvania. *Finer resolution patterns of trout distribution, the footprint of human activities, and future threats, including Marcellus Shale development, will occur within each subwatershed – local information should be consulted when considering any activity within a subwatershed.*

Nonetheless, by arraying the indicators by combined group scores, the CSI suggests general conservation strategies for the highest scoring subwatersheds in Pennsylvania. Map 13 shows these strategies, with public ownership and forest habitat information provided for reference.

- **Protection** strategies are priorities in areas with the *highest* Trout Designation and Distribution scores (i.e. scores > 3, or those subwatersheds with any streams designated as “Wilderness” or “Class A” or at least 10% of stream miles designated as “Natural Reproduction”) and *highest* scores trout habitat indicators (Watershed Conditions + Resource Development (Current and Legacy) ≥ 7), and at least *moderate* scores for future security indicators (Resource Development (Future)) + Climate ≥ 5).
- **Population restoration** strategies are likely appropriate in watersheds with *moderate* Trout Designation and Distribution scores (i.e. scores 3 - 2, or those subwatersheds with streams designated as “Natural Reproduction” or any streams with a designated use of “Coldwater,” “Exceptional Value,” or “High Quality”), but *highest* trout habitat and at least *moderate* future security indicator scores.
- **Habitat restoration** strategies are likely appropriate in areas with *highest* trout population integrity scores, but *moderate* trout habitat (5 -6) and at least *moderate* future security indicator scores.
- **Population and habitat restoration** strategies are likely appropriate in watersheds with *moderate* trout population and habitat scores, and at least *moderate* future security scores.
- **Assessment (high)** strategies occur in unassessed watersheds with *highest* trout habitat and at least *moderate* future security scores.
- **Assessment (low)** strategies occur in unassessed watersheds with *moderate* trout habitat and at least *moderate* future security scores.

Given the limitations of the population data included in this analysis, all strategies would necessarily require on-the-ground or local assessments of watersheds to determine the species composition, reasons for stream designations, and other factors. Similarly, continued efforts to restore habitats, especially those affected by acid mine drainage, will boost watersheds not displayed into conservation strategy categories or shift mapped watersheds into different strategy categories.

By arraying the trout population scores against the forecasts for Marcellus Shale development, the CSI suggests strategies for monitoring the impacts of Marcellus Shale drilling on water quality and aquatic communities within watersheds in the Marcellus Shale formation area. Map 14 shows these strategies, with public ownership and forest habitat information provided for reference.

- **Baseline** watersheds have relatively undisturbed coldwater habitats, as reflected in highest trout population scores ( $\geq 3$ ), and are not forecast for Marcellus Shale development. These offer opportunities for baseline measures of water quality. Only watersheds within the Marcellus Shale formation region are assigned monitoring strategies.
  - **Monitoring (immediate)** watersheds receive high trout population scores. However, these watersheds contain current drilling (at least 5 wells) and are forecast for continued development (at least 5 total wells). They are priorities for monitoring and comparison against baseline values.
  - **Monitoring (long-term)** are similar to monitoring (immediate) watersheds, but currently have no active drilling, but are forecast for future development (at least 5 total wells).
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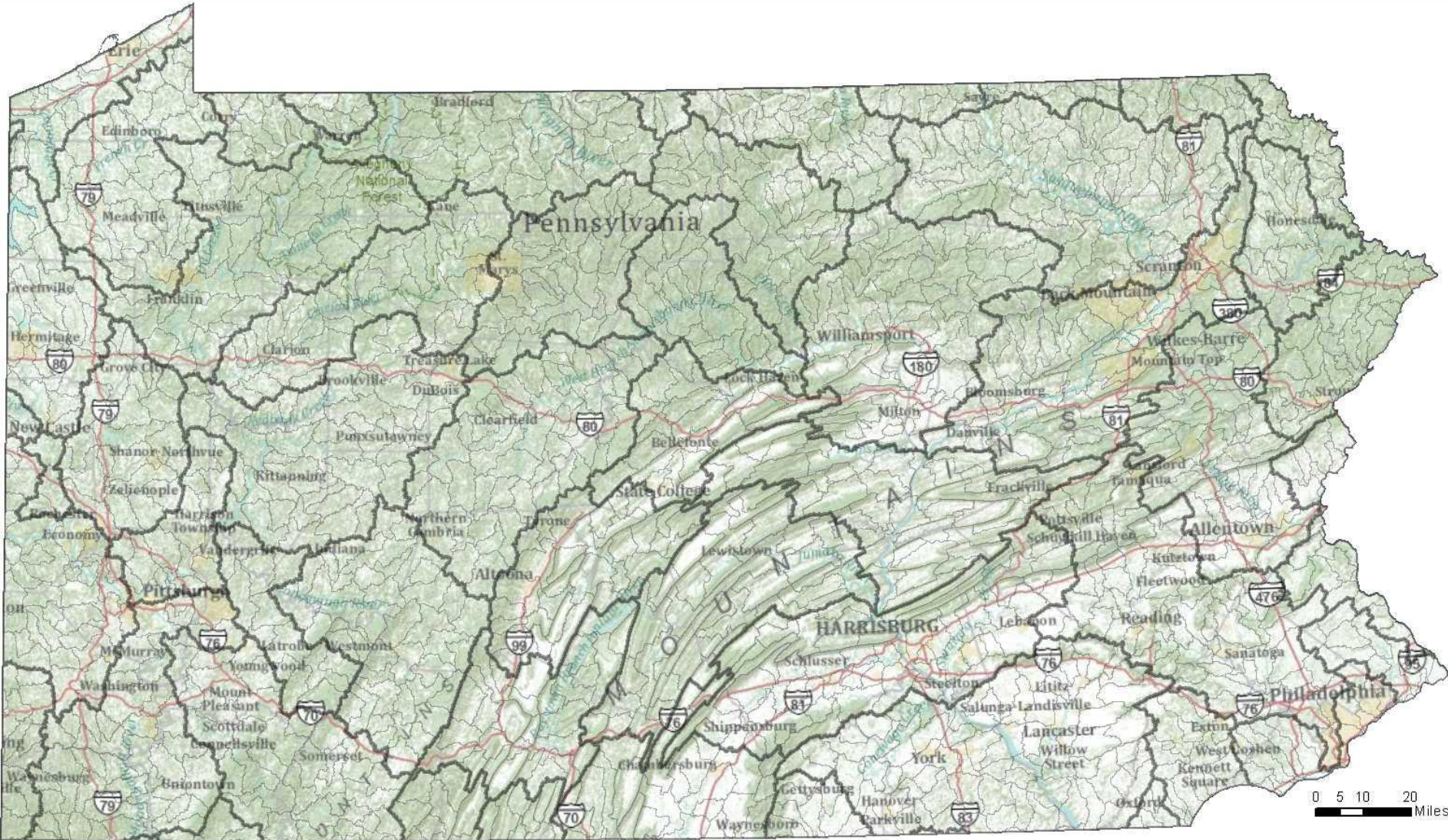
### ***Acknowledgements***

Becky Dunlap and Dave Sewak identified data and analyses for inclusion in the CSI. The majority of data used in the analysis were served by PASDA, the Pennsylvania Geospatial Data Clearinghouse ([www.pasda.psu.edu](http://www.pasda.psu.edu)). The Nature Conservancy provided forecasts of Marcellus shale and wind development. These data were developed for the joint TNC/Western Pennsylvania Conservancy report "Pennsylvania Energy Impacts Assessment" ([http://www.nature.org/media/pa/tnc\\_energy\\_analysis.pdf](http://www.nature.org/media/pa/tnc_energy_analysis.pdf)). TNC, University of Washington, and The University of Southern Mississippi provided climate forecast data through ClimateWizard ([www.climatewizard.org](http://www.climatewizard.org)). Current climate data are served by Oregon State University's PRISM Climate Group ([www.prism.oregonstate.edu](http://www.prism.oregonstate.edu)). Base Flow Index data are provided by US Geological Survey (<http://ks.water.usgs.gov/pubs/abstracts/of.03-263.htm>). TNC also provided forest patch data.

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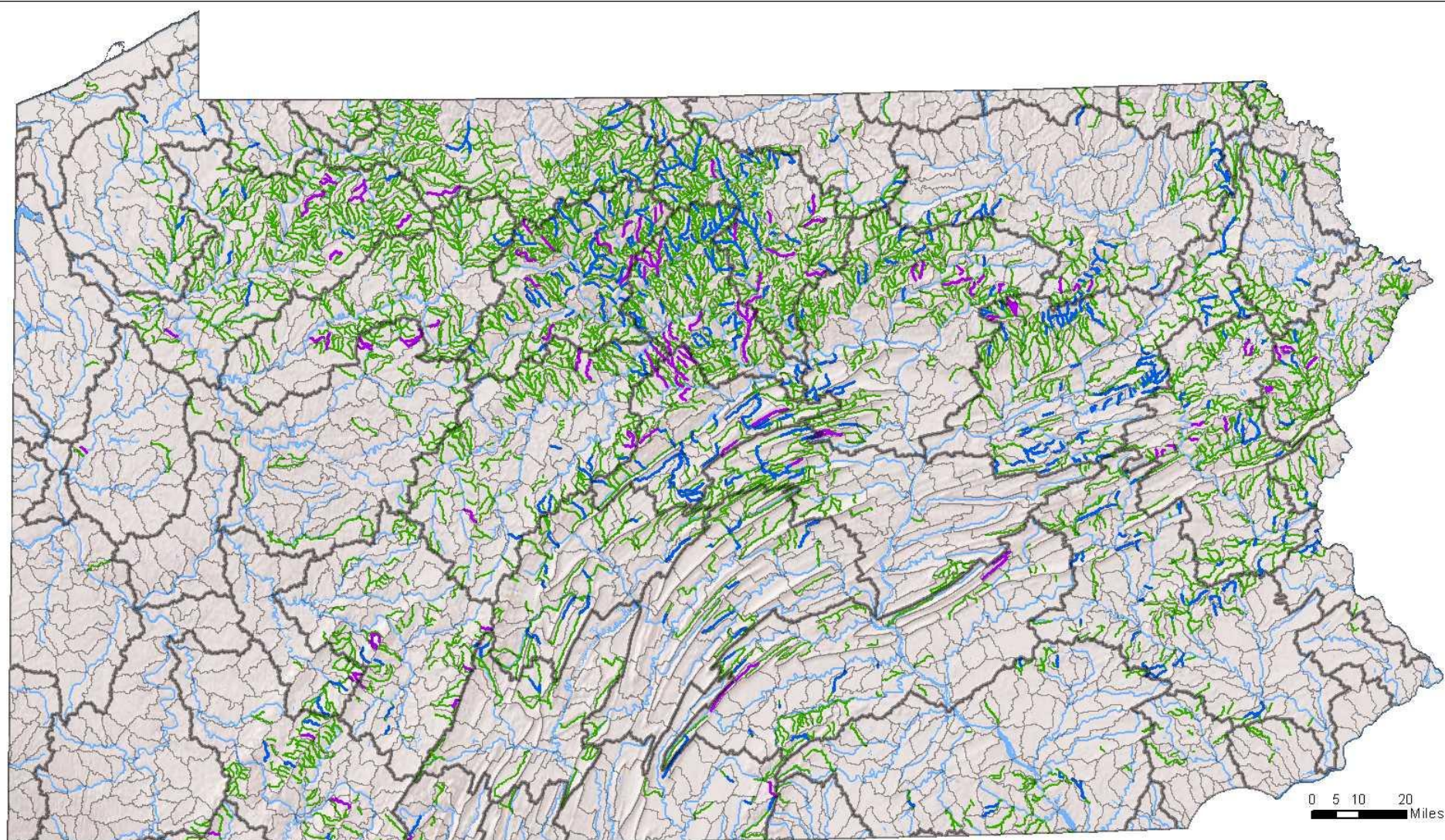
**Map 1:** Pennsylvania analysis area with subwatershed and subbasin outlines



Subwatershed boundaries Subbasin boundaries



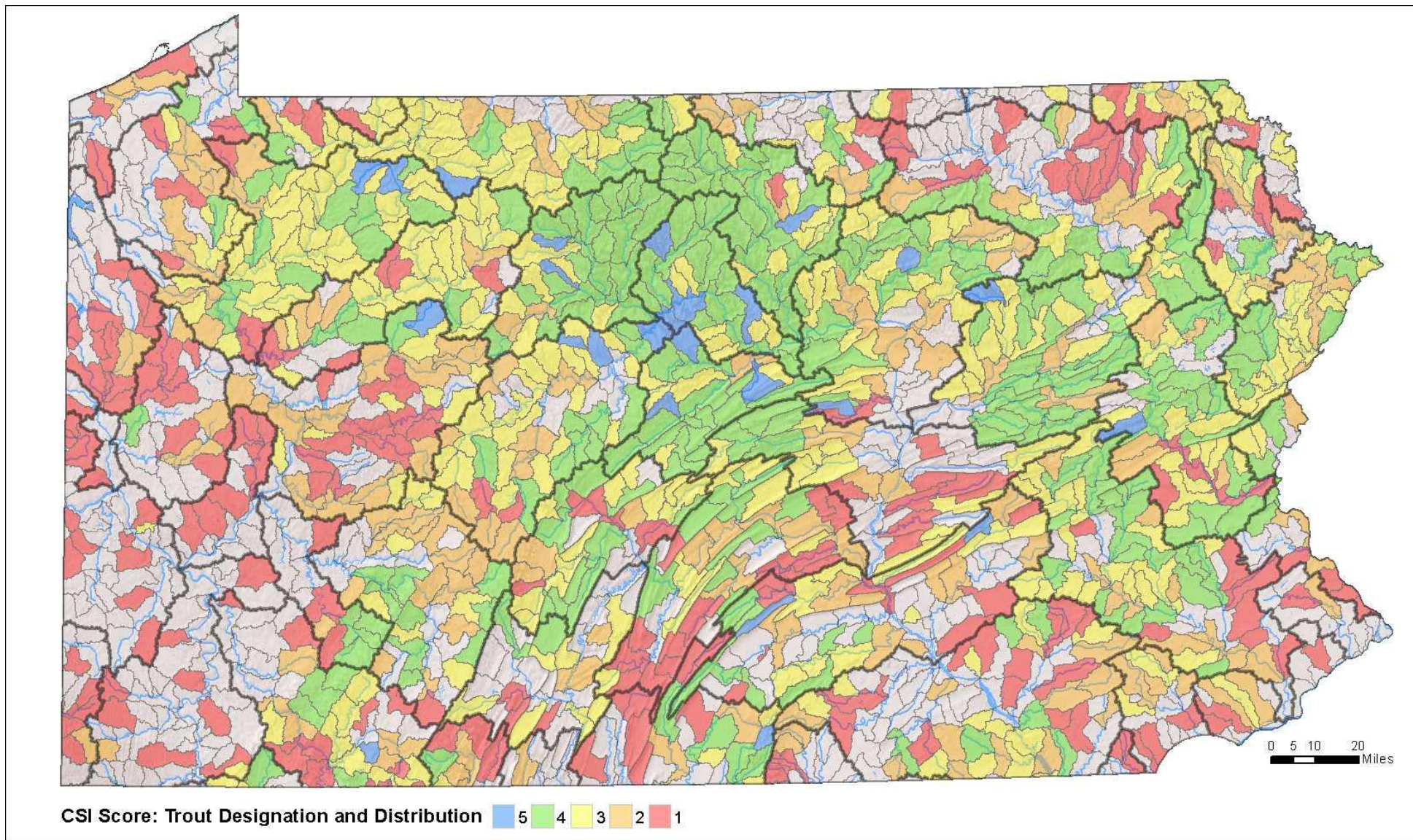
**Map 2:** Trout stream designations and distribution from PFBC



**Stream Designations** — Wilderness — Class A — Natural Reproduction

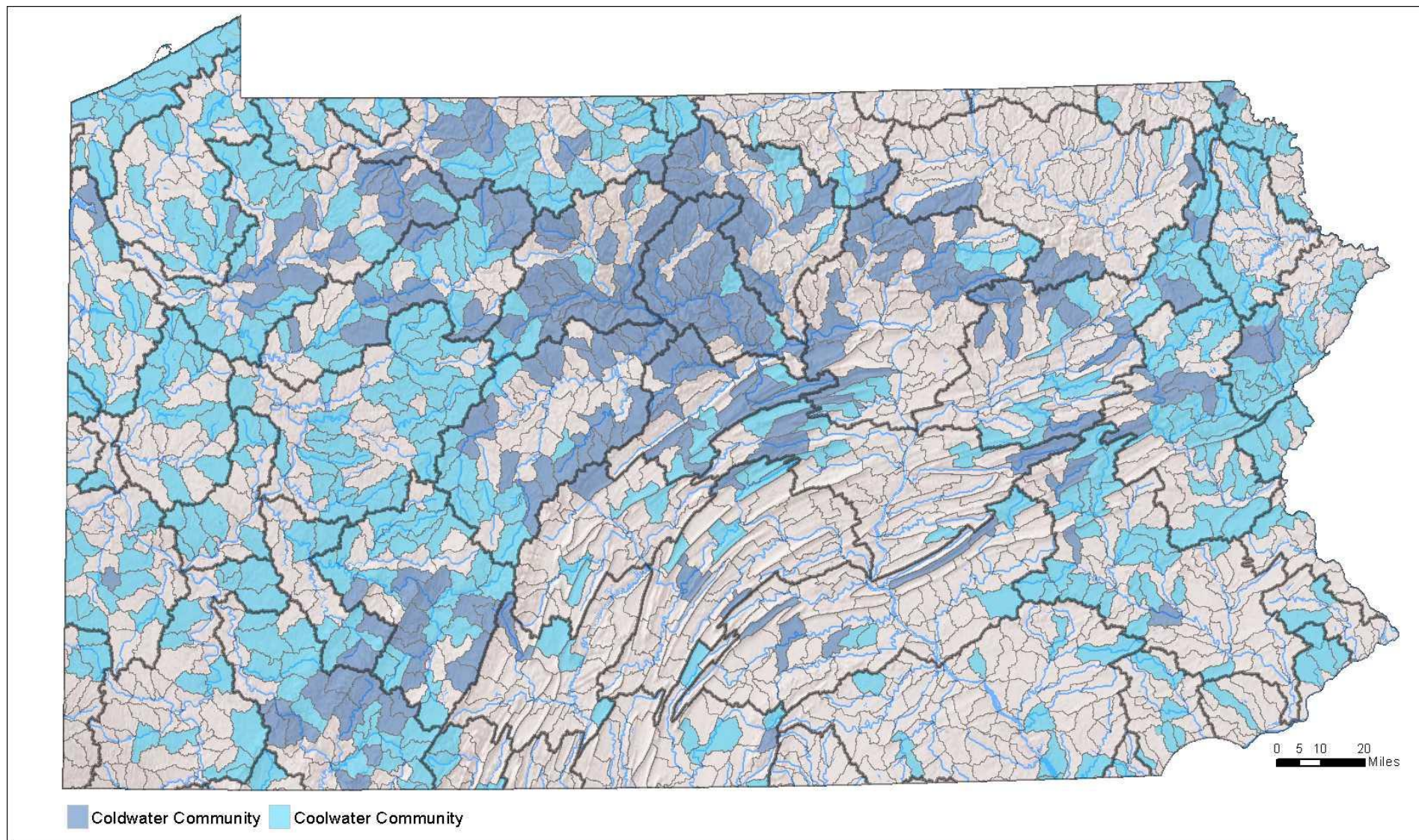


**Map 3:** CSI results for Trout Designation and Distribution analysis



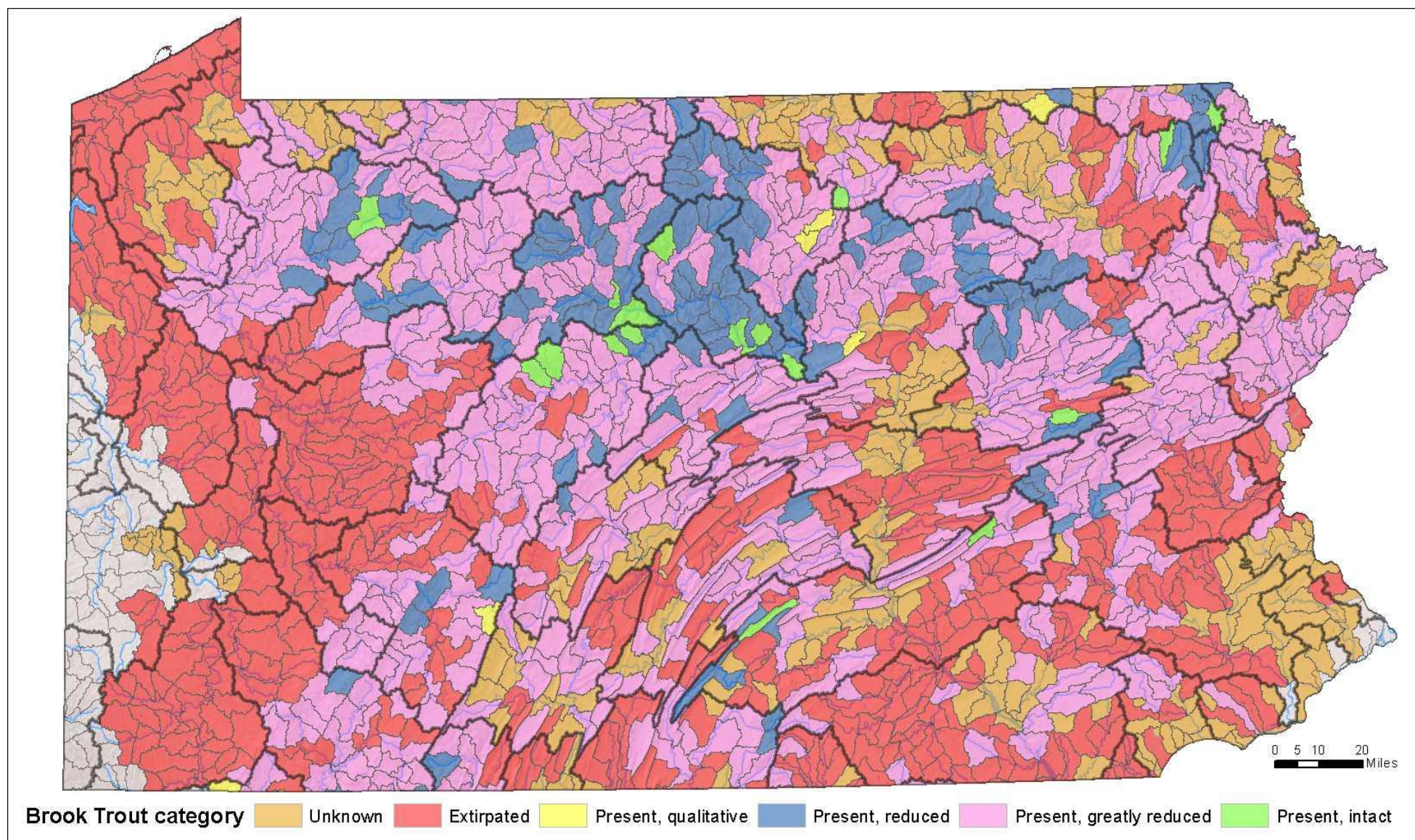


**Map 4:** PA Natural Heritage Program Aquatic Community Classification (Coldwater and Coolwater Communities)



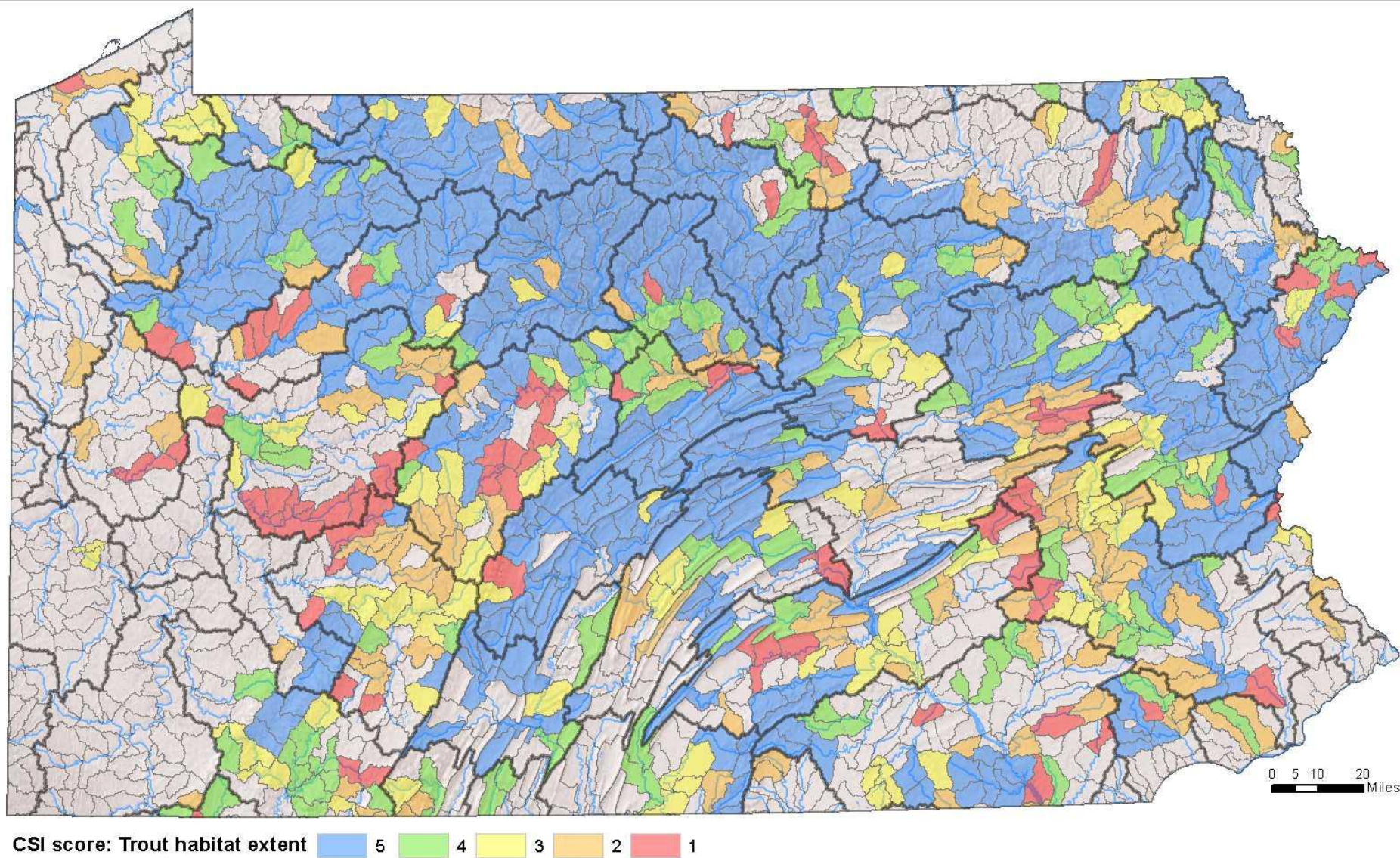


**Map 5:** Eastern Brook Trout Joint Venture watershed characterizations



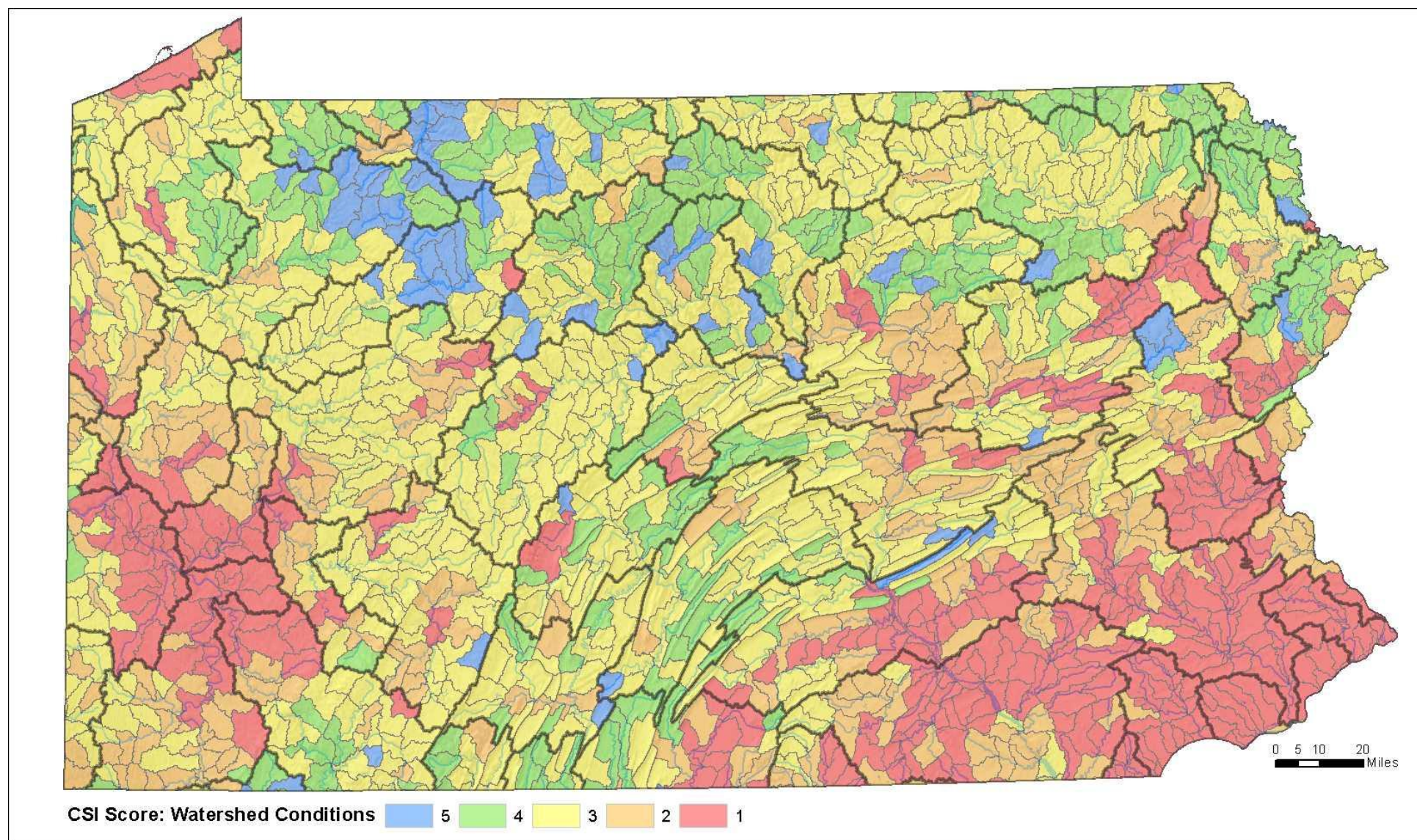


**Map 6:** CSI results for Trout Habitat Extent analysis



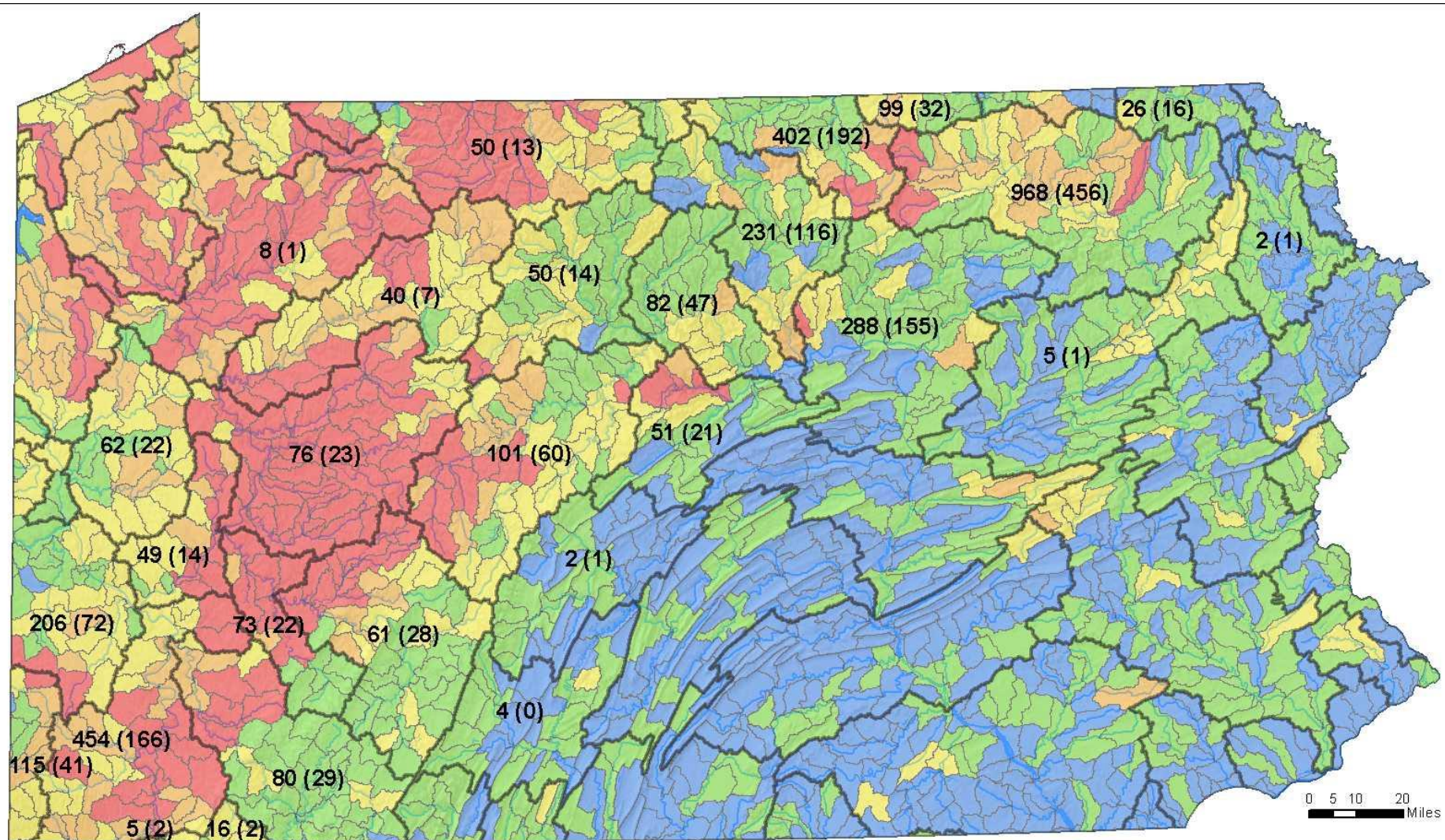


**Map 7:** CSI results for Watershed Conditions analysis





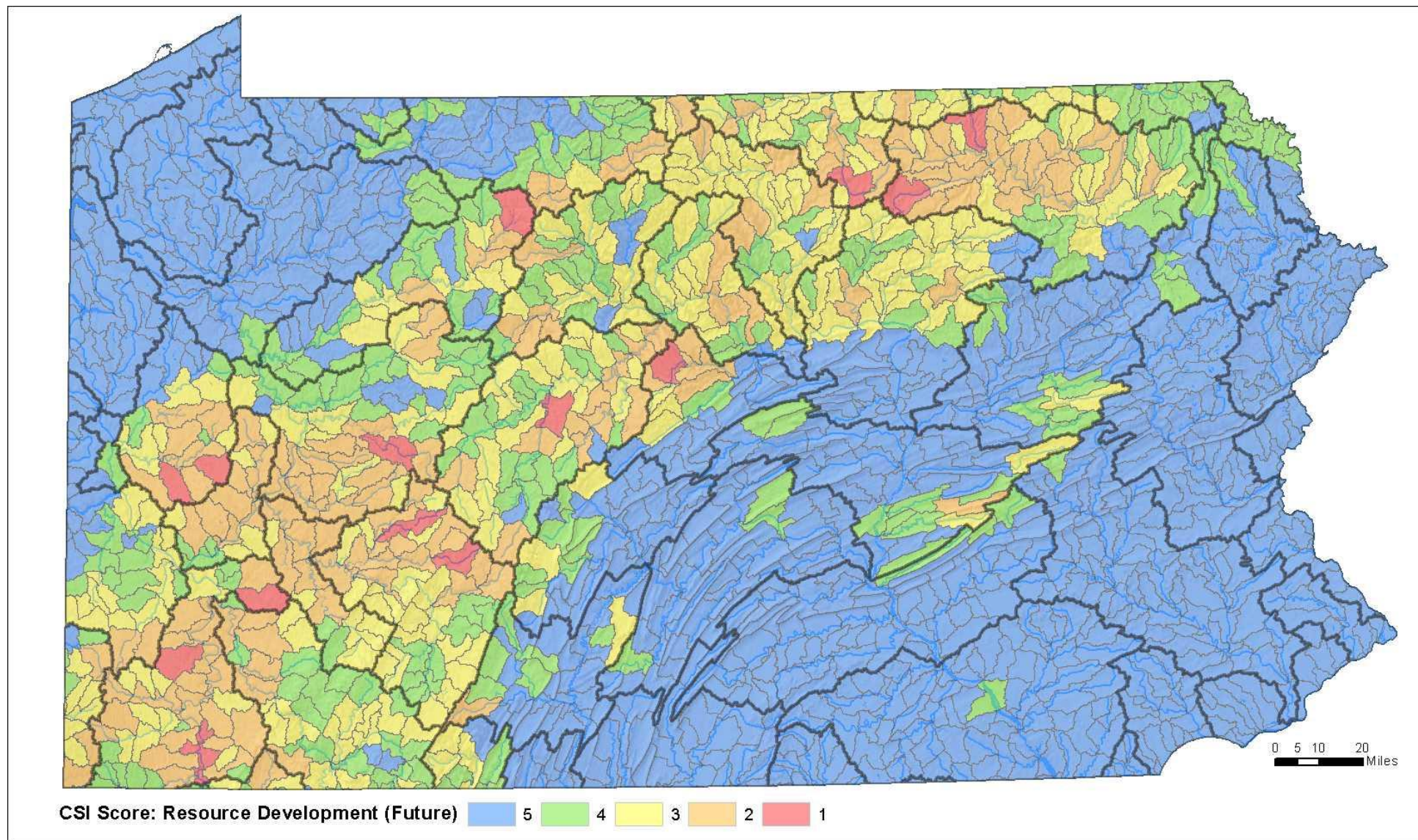
**Map 8:** CSI results for Resource Development (Current and Legacy). Subbasins (outlined in thick black) are labeled with the total number of drilled Marcellus Shale wells from 2006 - Sept 2, 2011 and the number of wells drilled in 2011 (in parenthesis)



CSI Score: Resource Development (Current and Legacy) 5 4 3 2 1

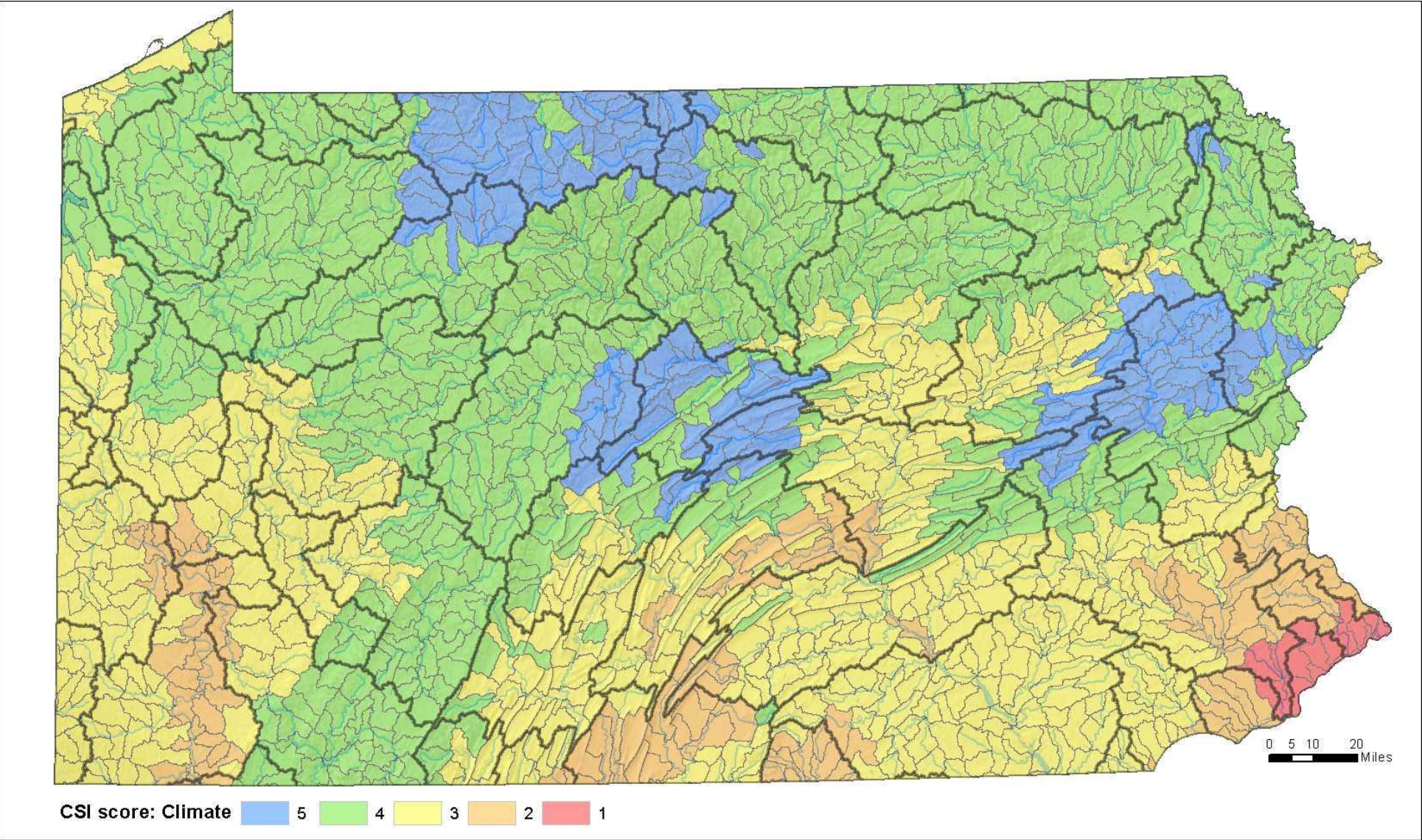


**Map 9:** CSI analysis for Resource Development (Future)



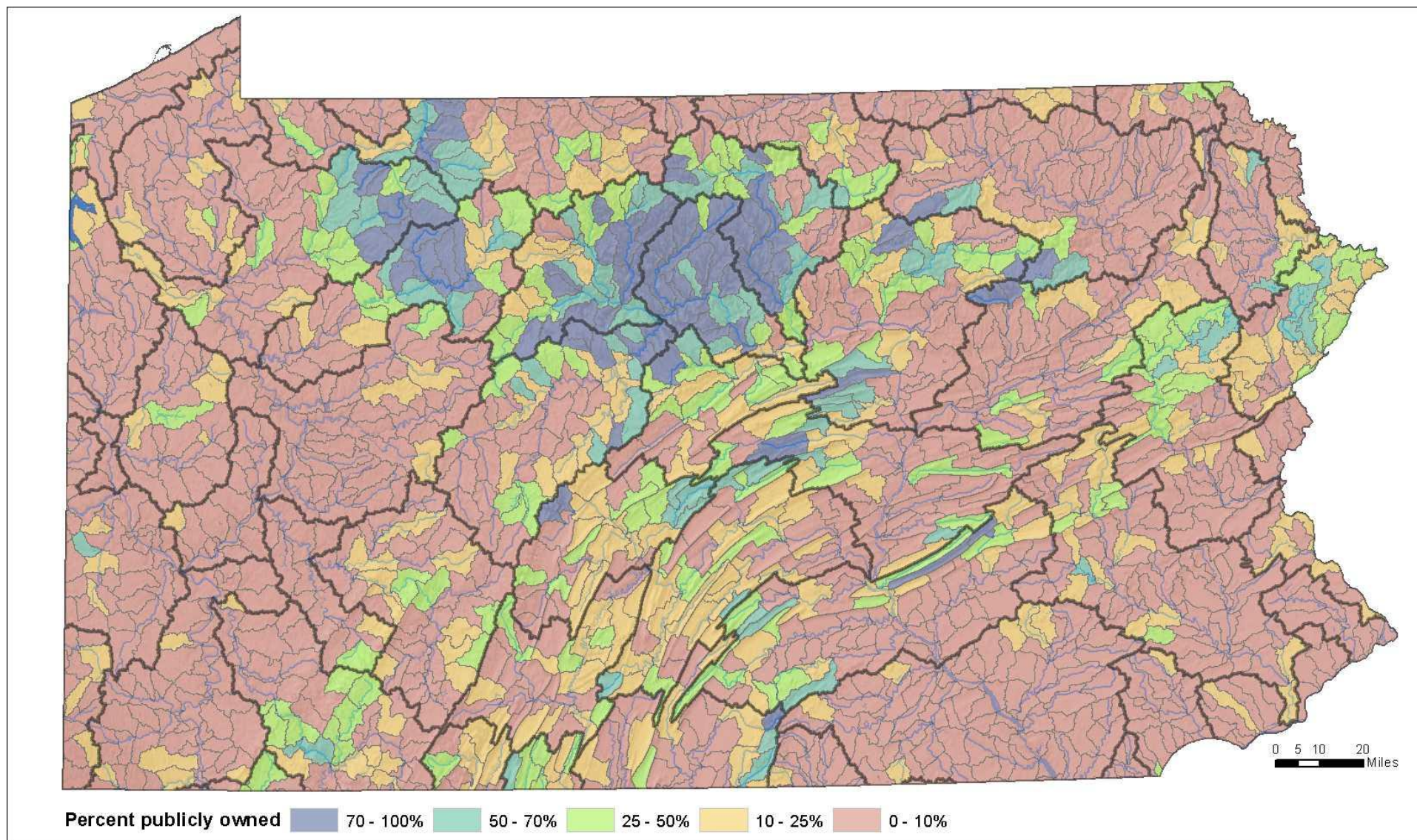


Map 10: CSI analysis for Climate



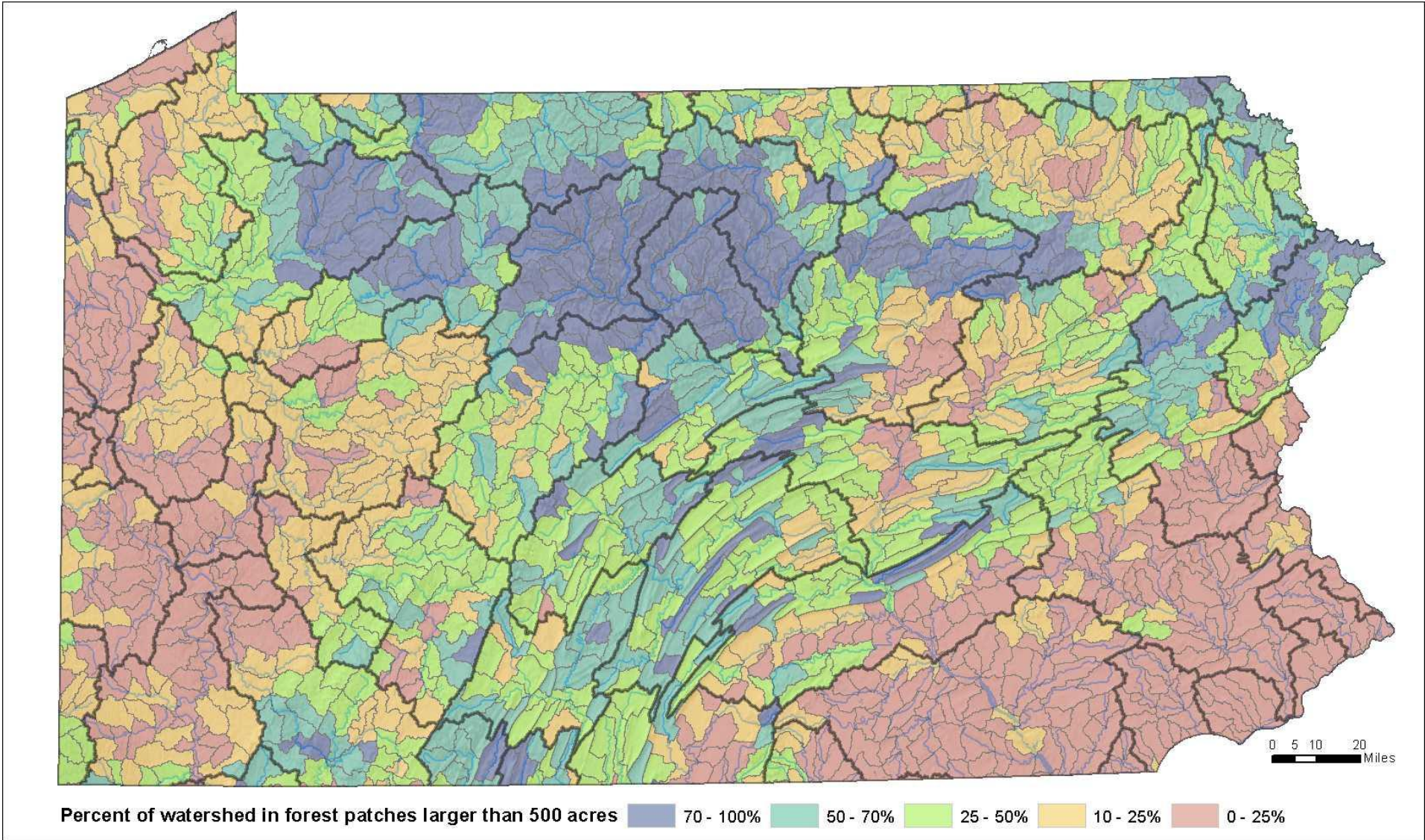


**Map 11:** Percent of watershed area in state, federal, or land trust ownership



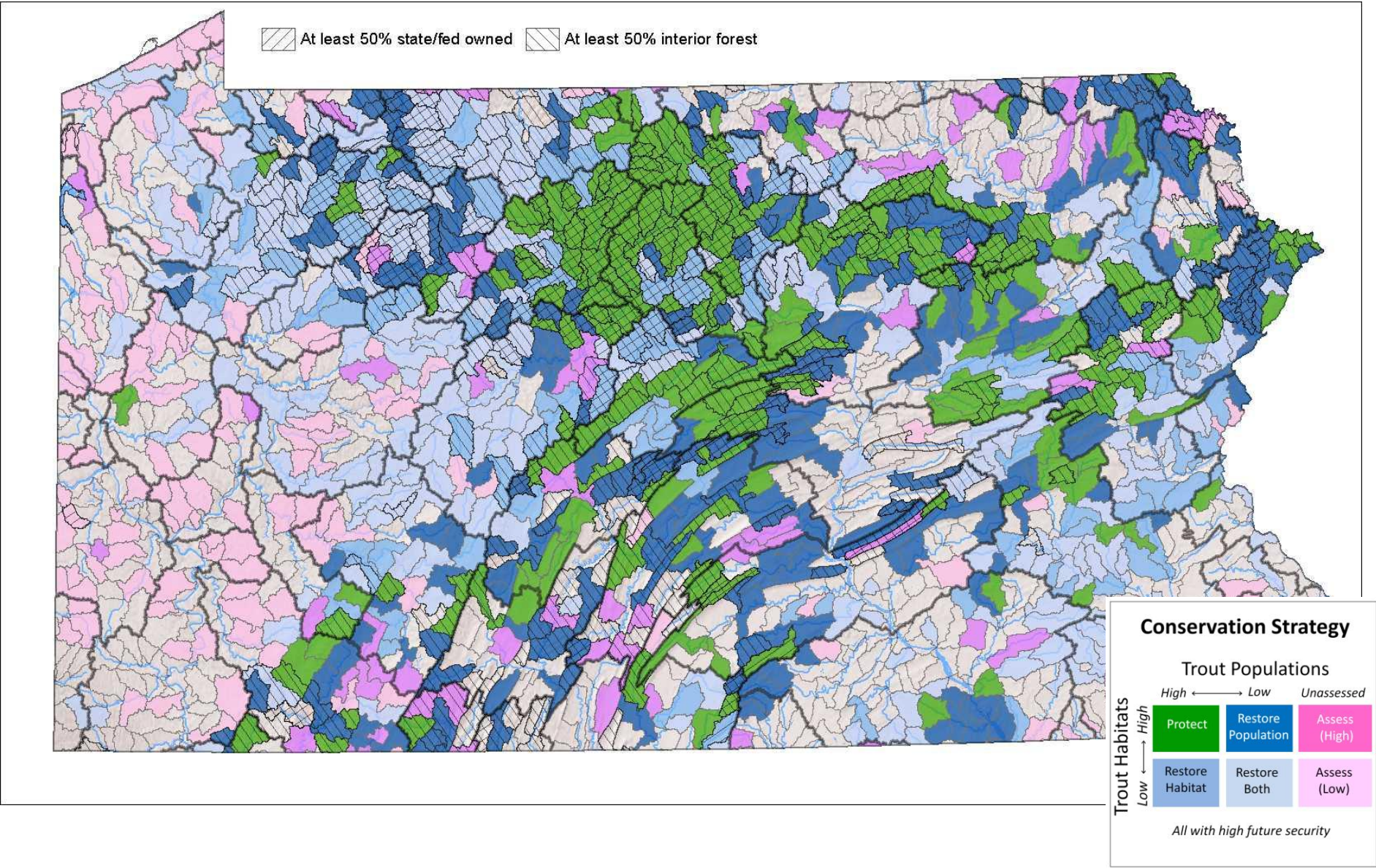


**Map 12:** Percent of watershed area in forest patches larger than 500 acres





**Map 13:** Conservation Strategies (Protection and Restoration)





Map 14: Marcellus Shale Strategies

