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Shale Oil and Gas Development: Potential Ecological Impacts in the Appalachians

HEALTH EFFECTS INSTITUTE WORKSHOP
SPECIAL SCIENTIFIC COMMITTEE ON POTENTIAL IMPACTS OF UNCONVENTIONAL OIL/GAS DEVELOPMENT
Pittsburgh, Pennsylvania June 10, 2014

Nels Johnson, Pennsylvania Deputy State Director

POTENTIAL ENVIRONMENTAL IMPACTS

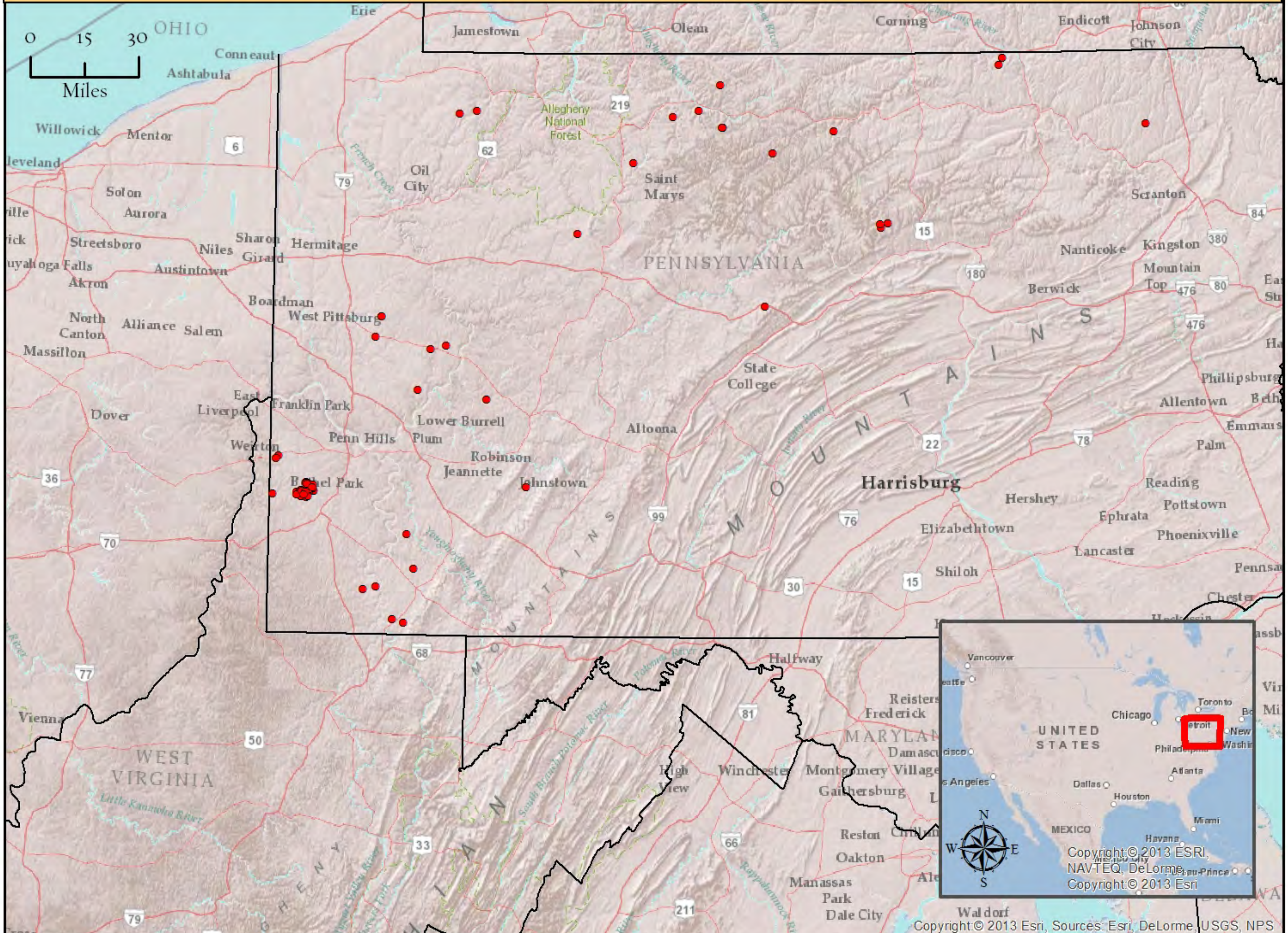
Air and Water Quality

- *Surface Water Pollution*
- *Groundwater Pollution*
- *Air Pollution - VOCs, Ozone, Particulates*
- *Air Pollution - Methane and CO_2 Emissions*

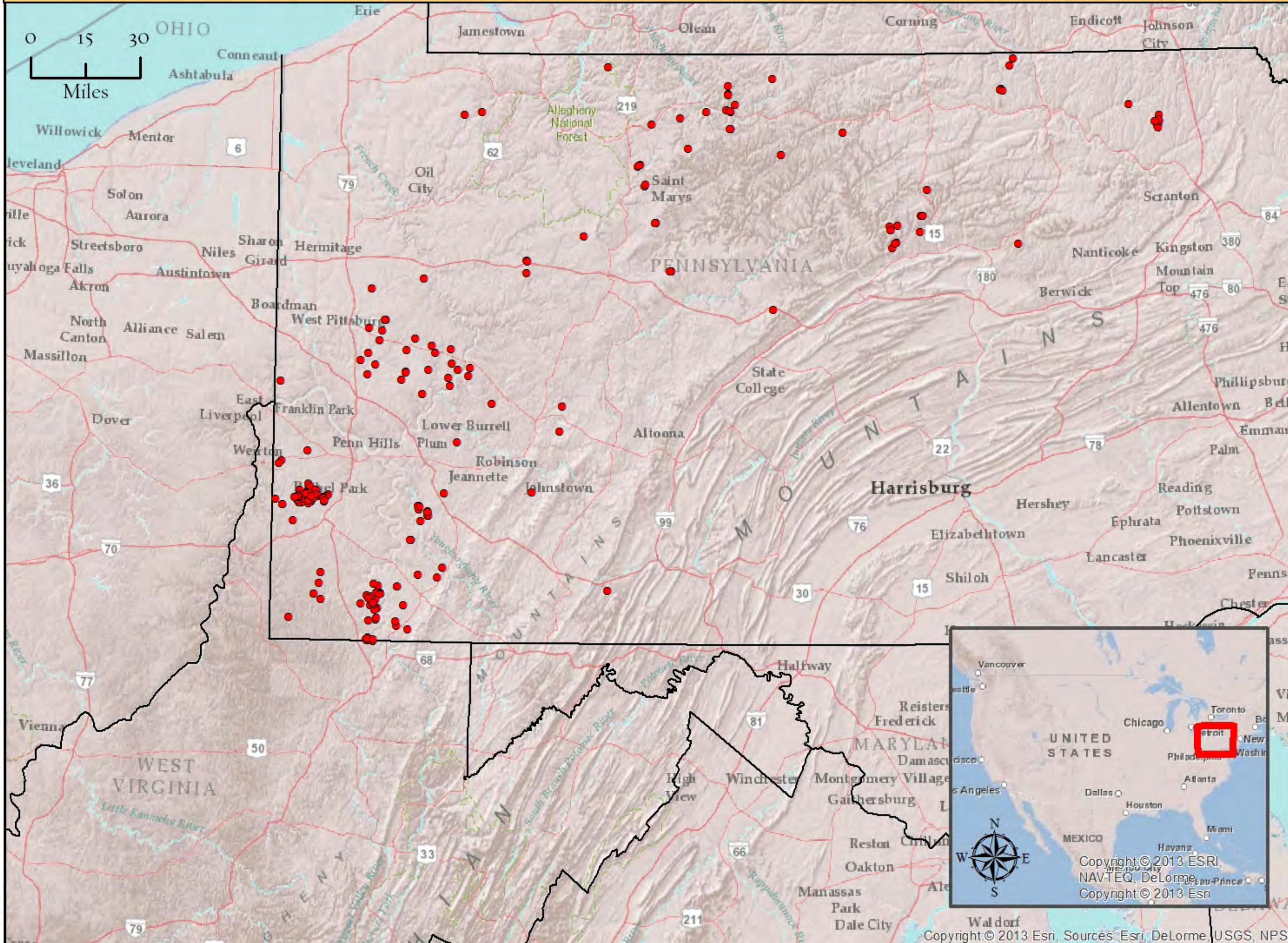
Ecological Condition

- *Water Use – Quantity, Location, and Timing of Withdrawals*
- *Water Quality – Sedimentation and Nutrients*
- *Land Use Change – Habitat Loss, Fragmentation, Species Impacts*

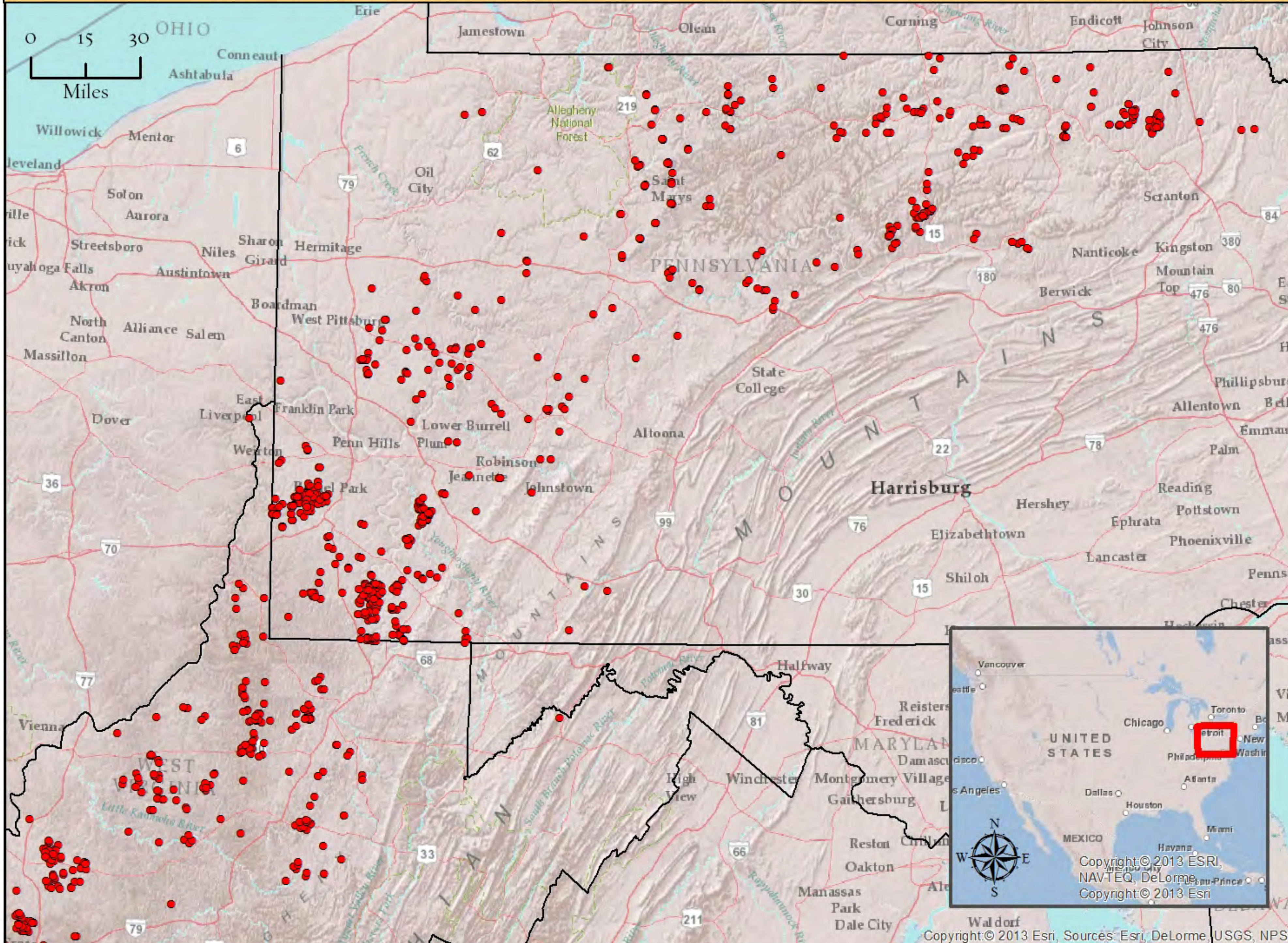
Unconventional Gas Wells Permitted by 2006



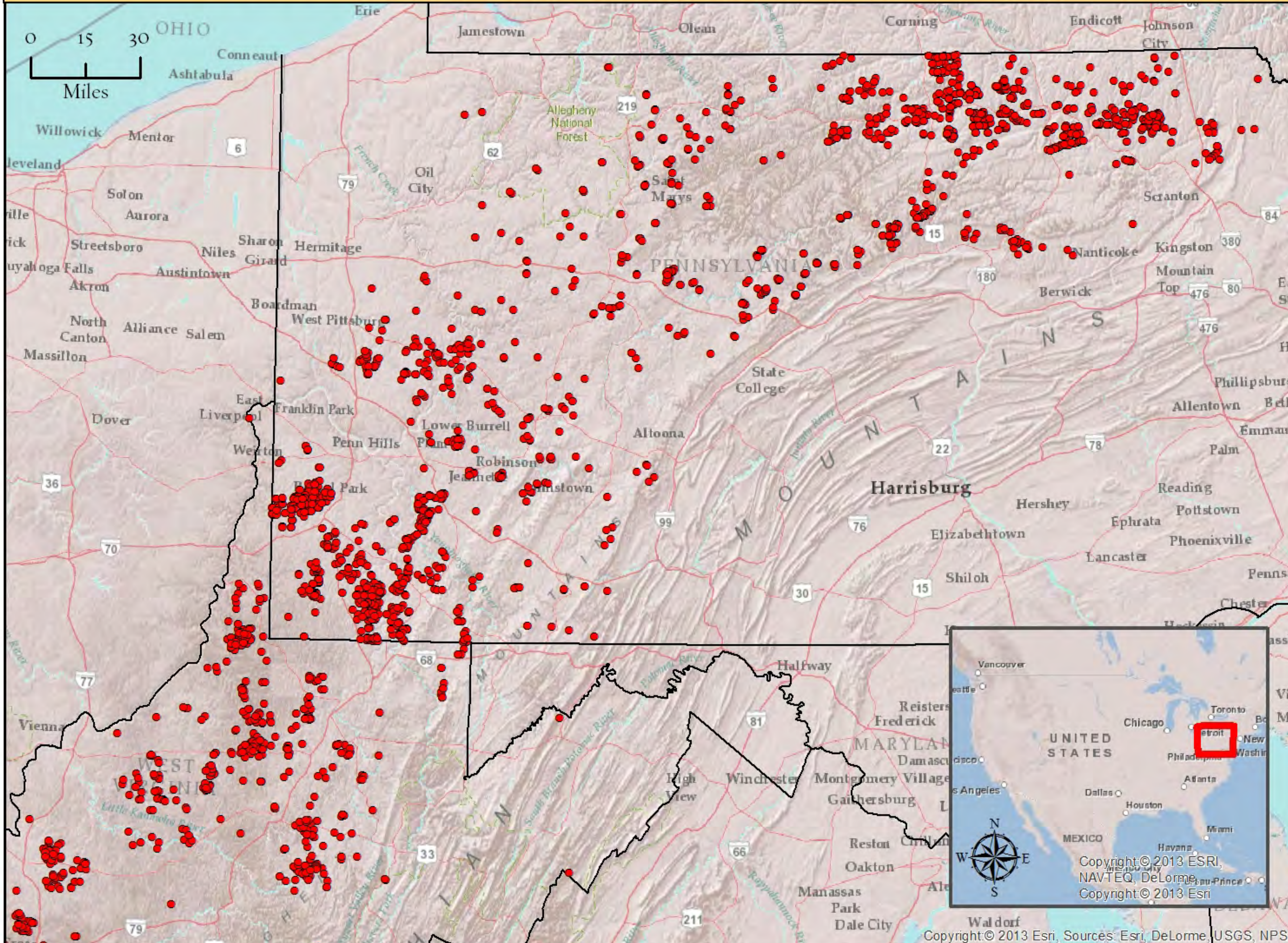
Unconventional Gas Wells Permitted by 2007



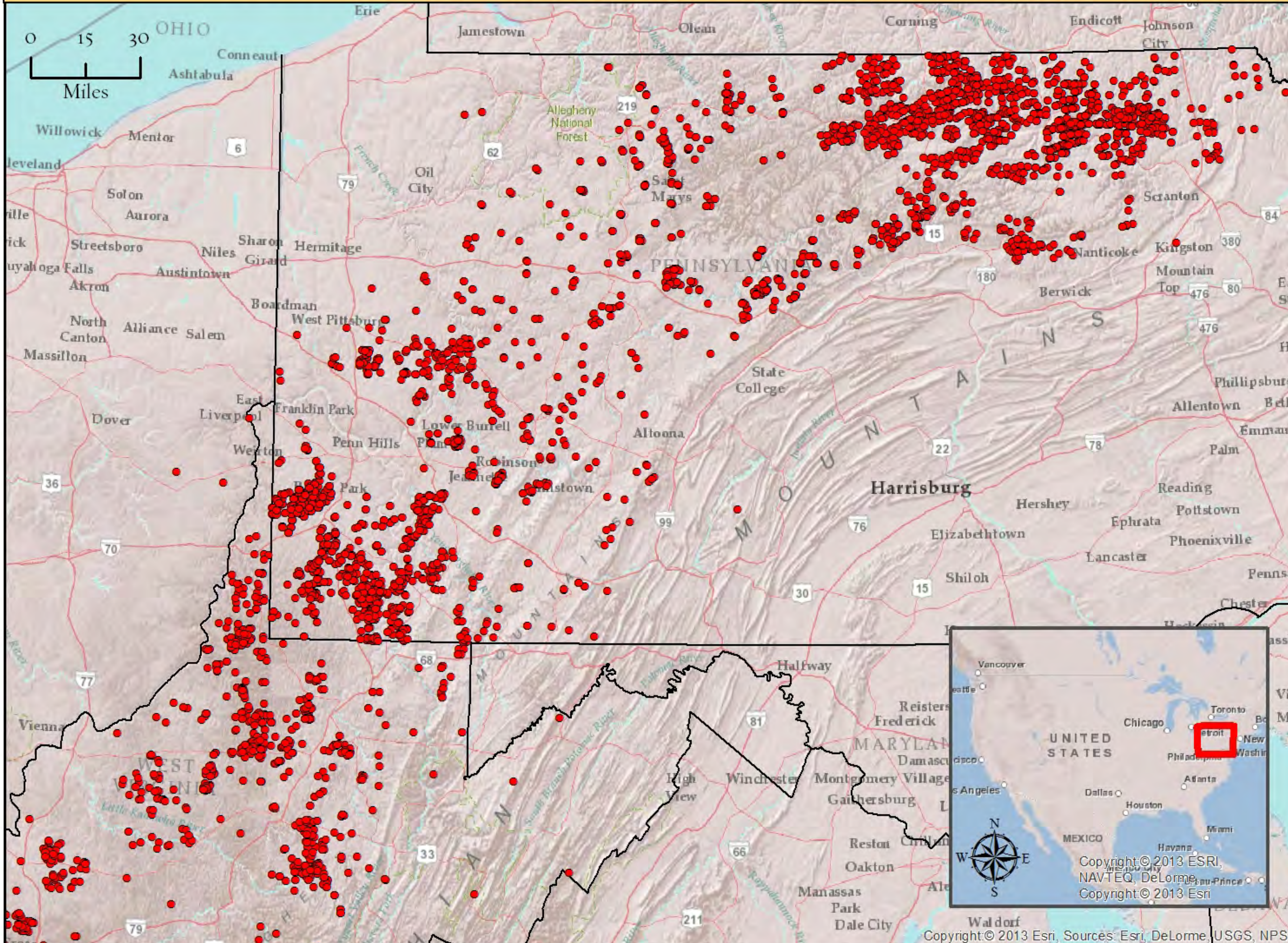
Unconventional Gas Wells Permitted by 2008



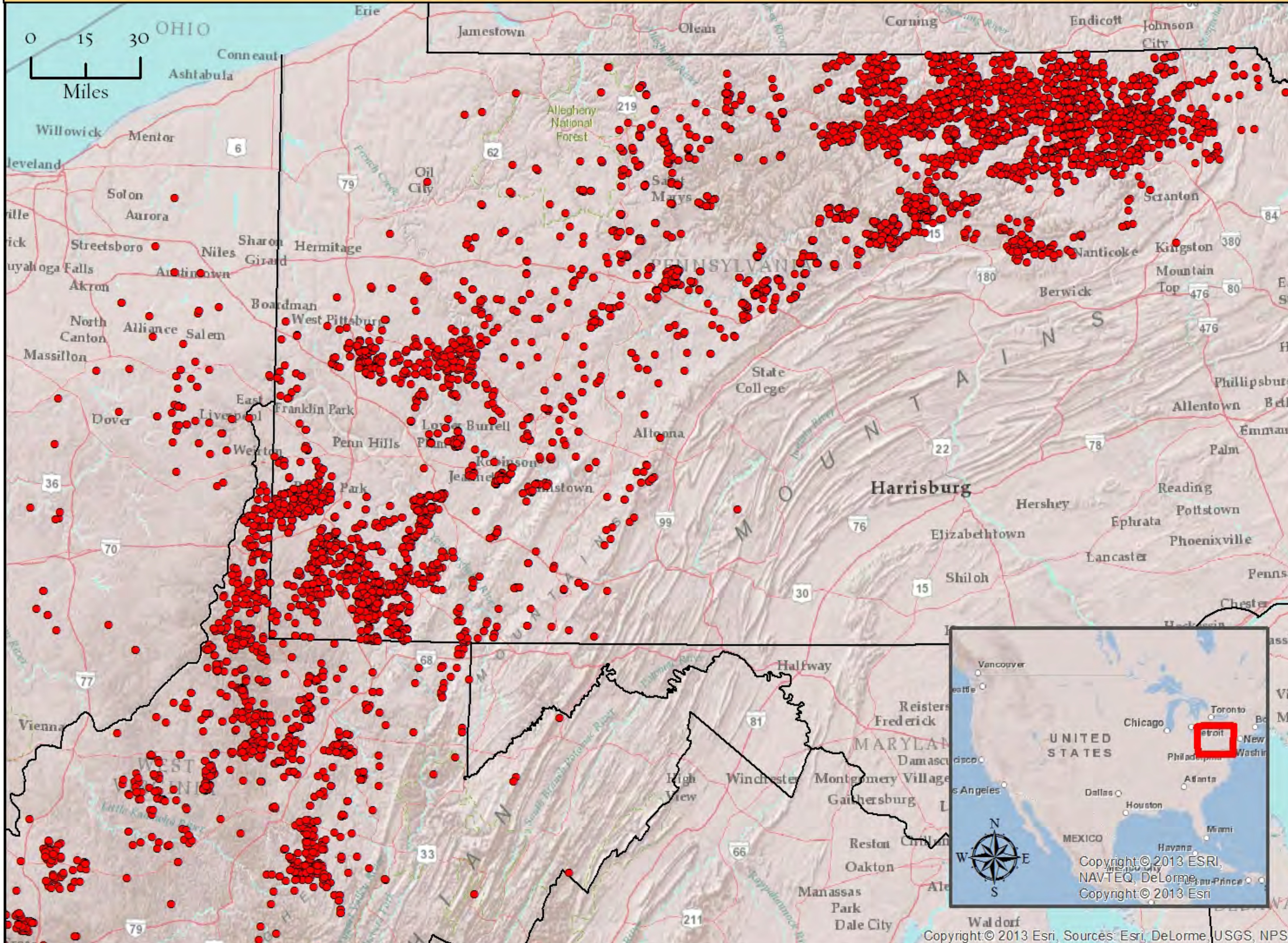
UNCONVENTIONAL GAS WELLS PERMITTED BY 2009



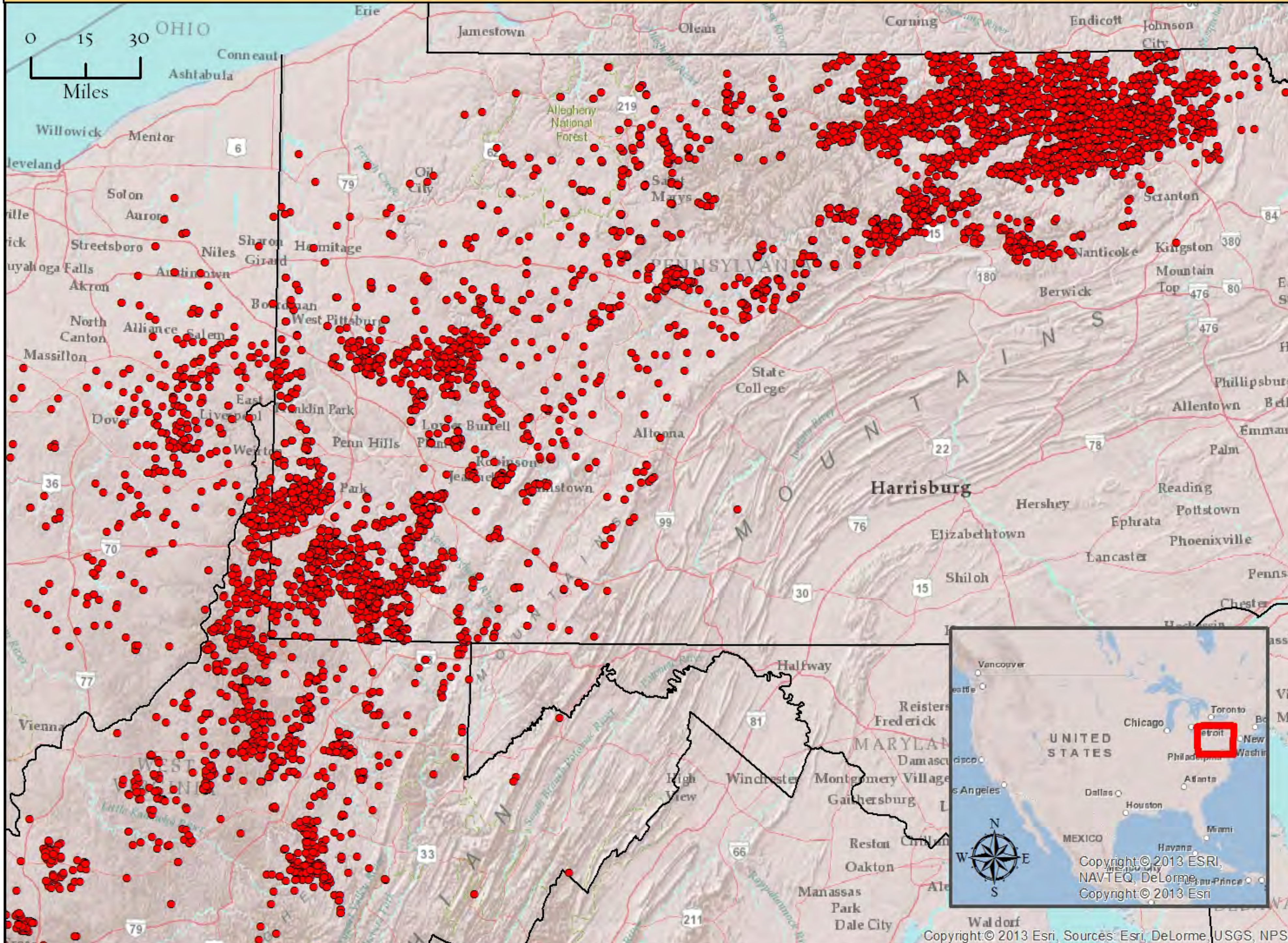
UNCONVENTIONAL GAS WELLS PERMITTED BY 2010



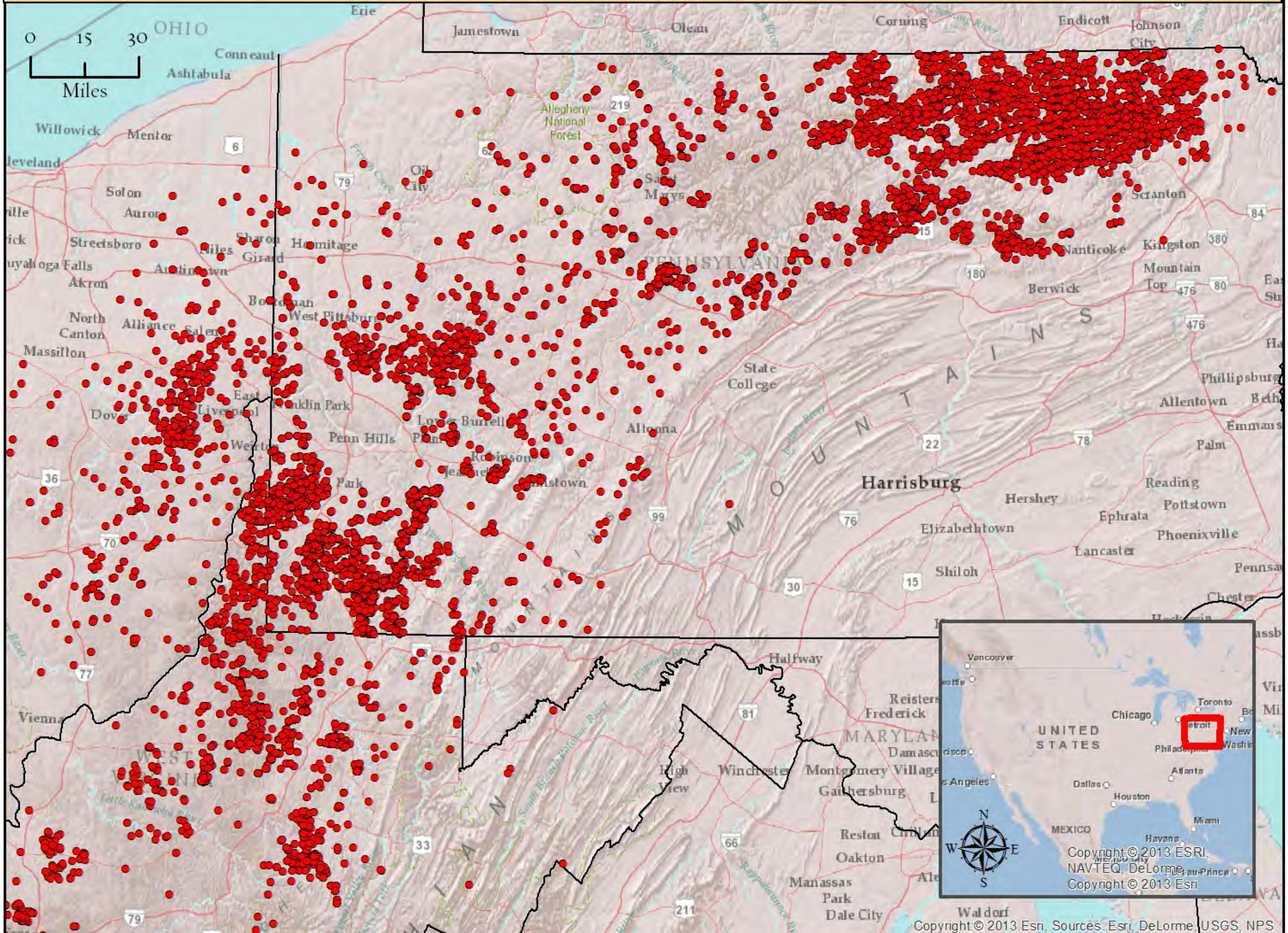
Unconventional Gas Wells Permitted by 2011



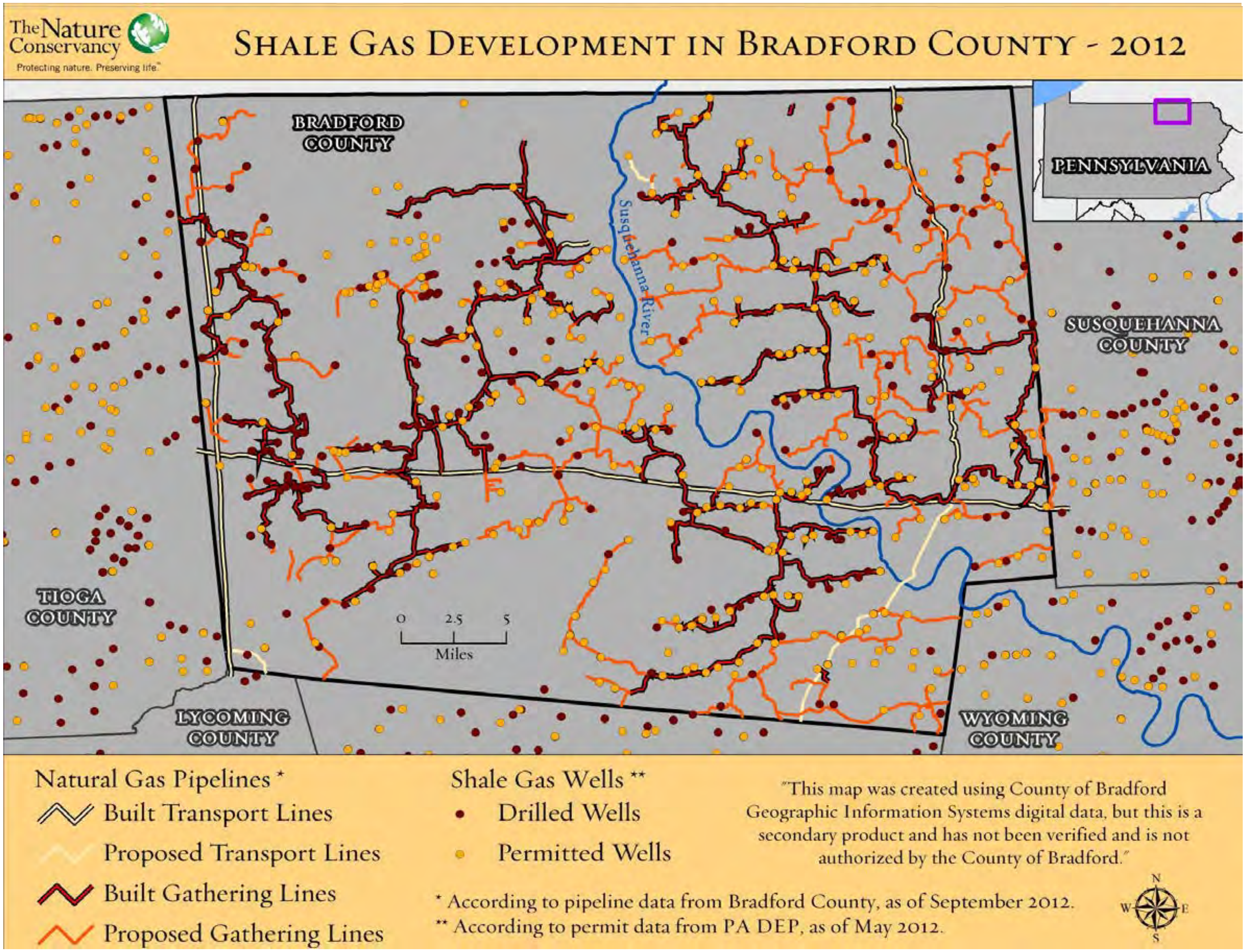
UNCONVENTIONAL GAS WELLS PERMITTED BY 2012



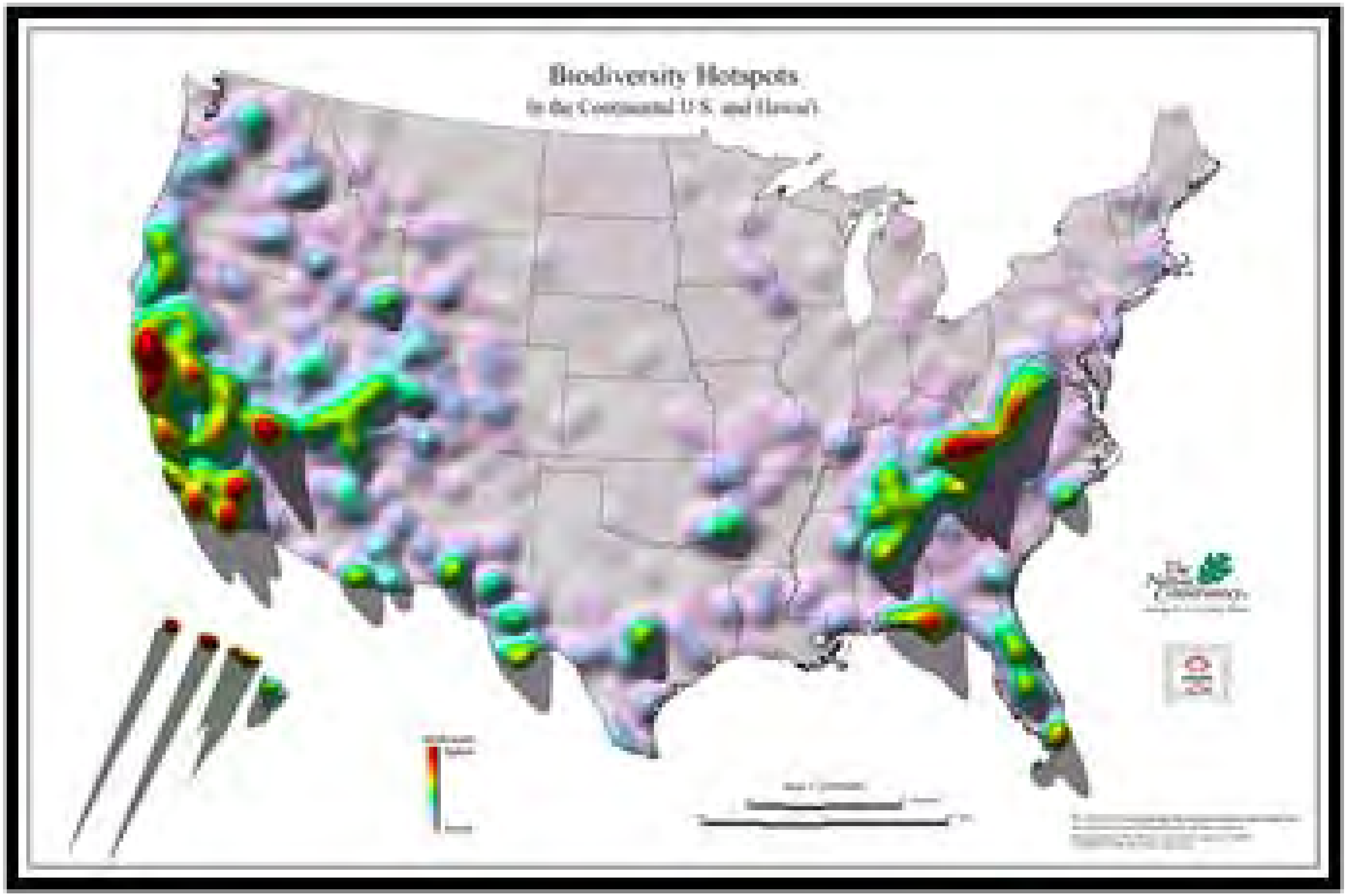
Unconventional Gas Wells Permitted by June 2013



Rapid Rate of Development



Central Appalachians – Biodiversity Hotspot



ECOLOGICAL CONDITION

Water Use

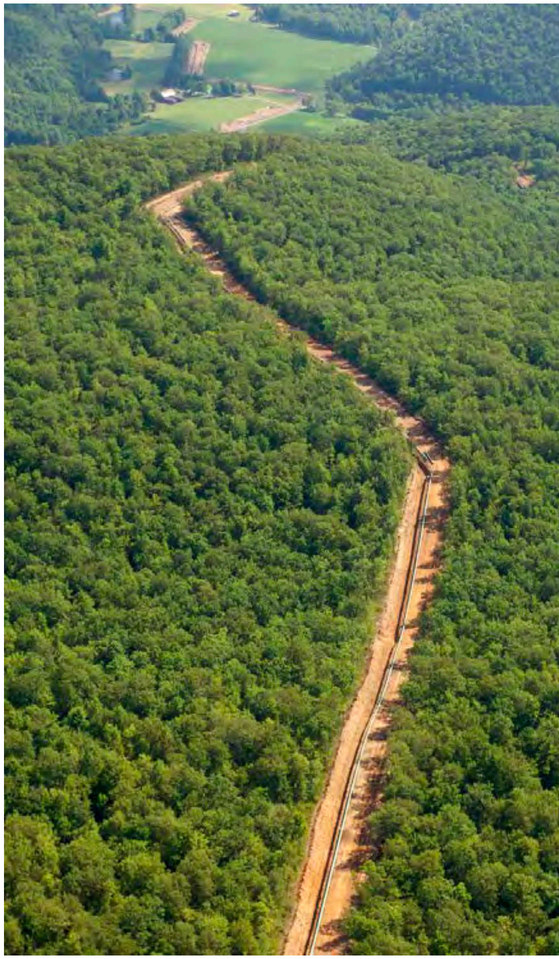
- Quantity
- Location
- Timing

Water Quality

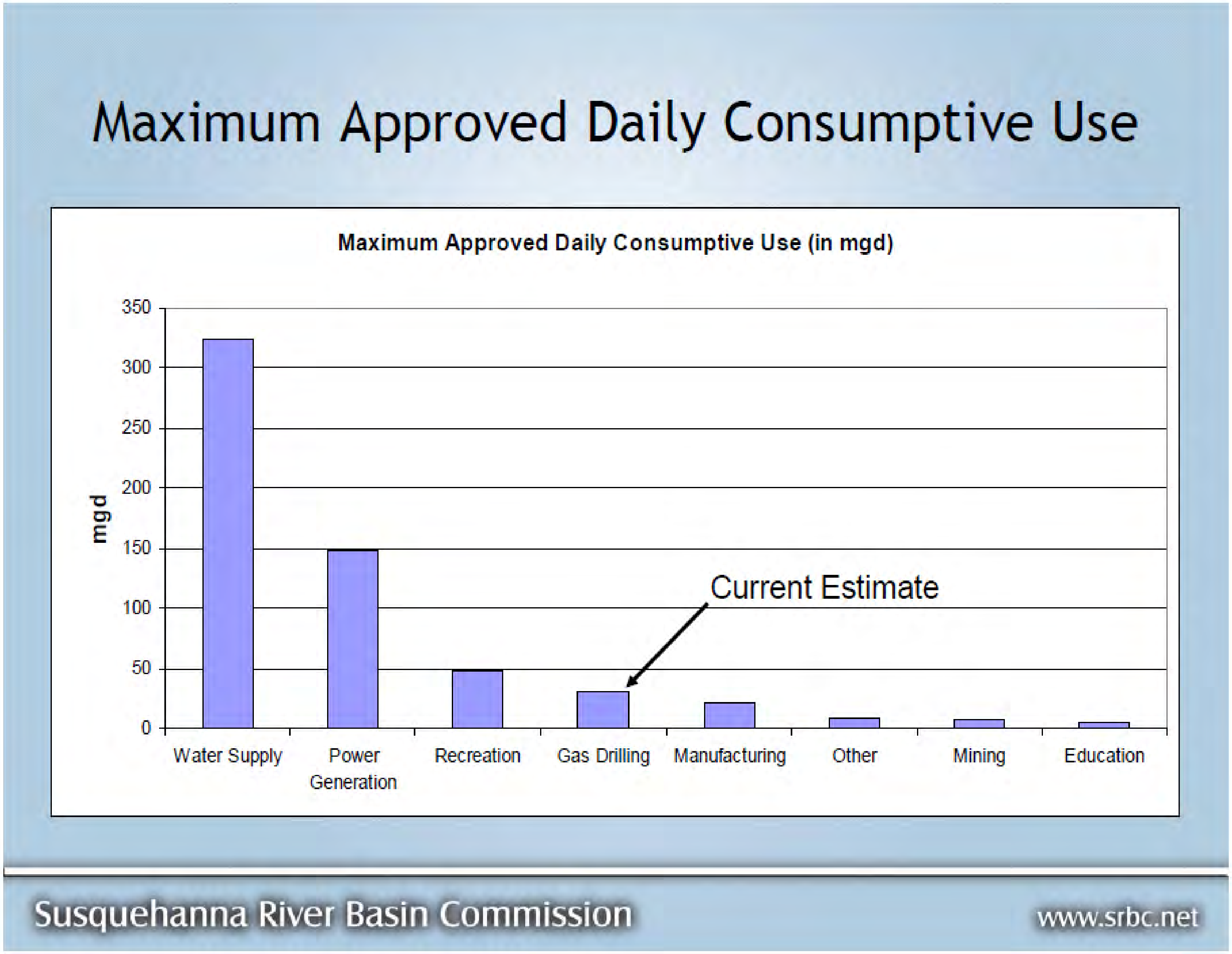
- Sediment
- Nutrients

Land Use

- Direct Habitat Impacts
- Indirect Habitat Impacts
- Species Impacts



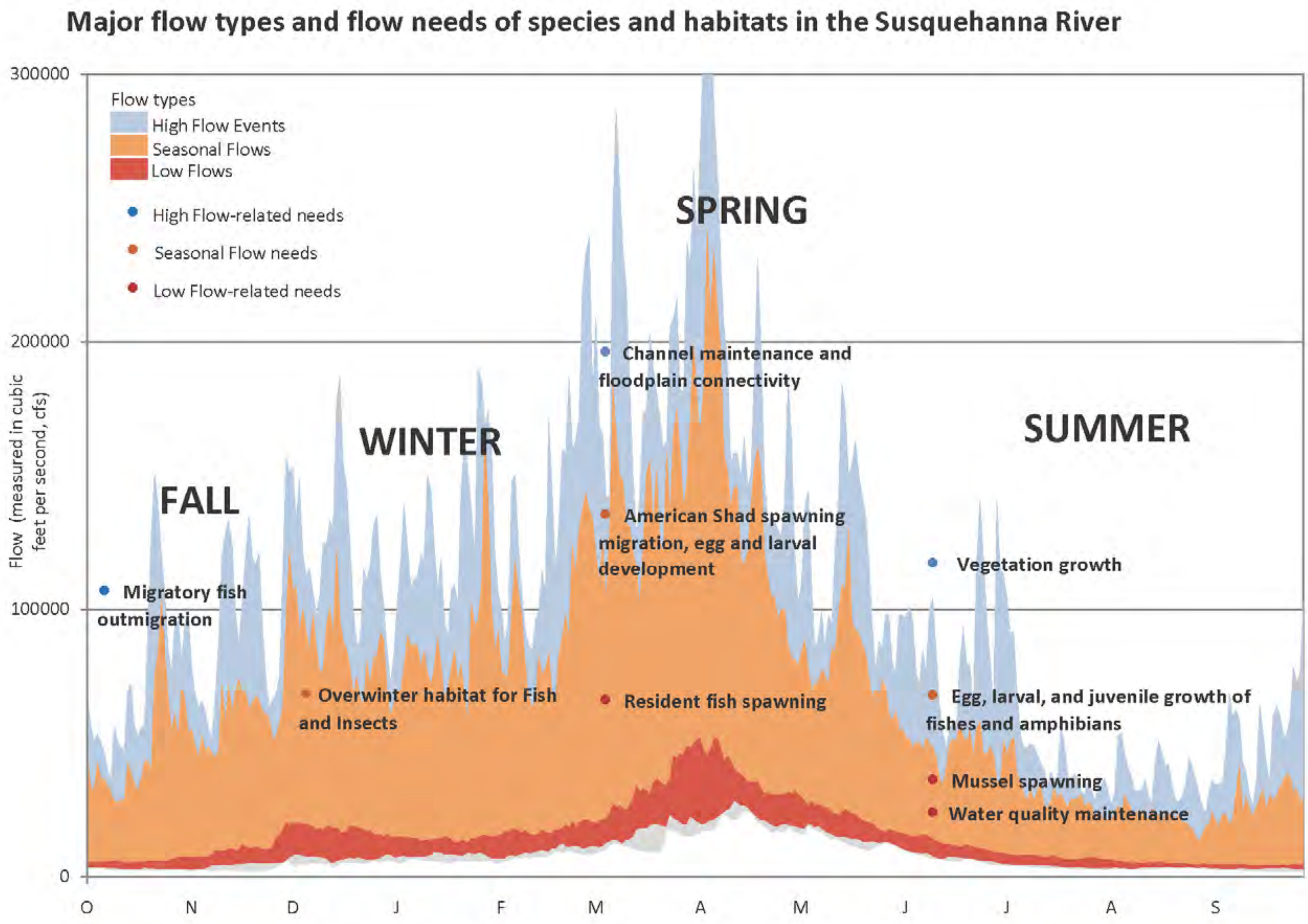
Water Use – Quantity of Withdrawals



Water Use – Location of Withdrawals

Photo: SRBC

Water Use – Timing of Withdrawals



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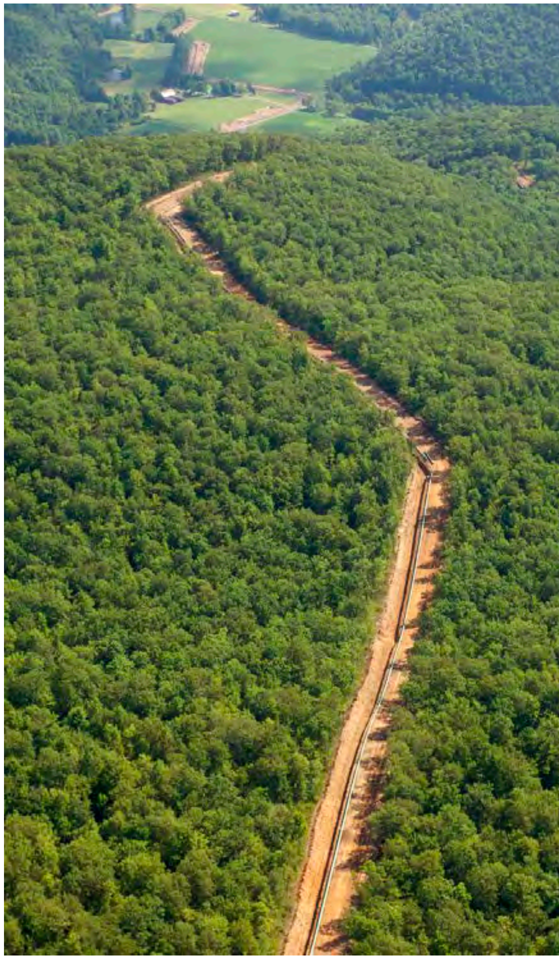

Water Quality – Sediment and Nutrients

Photo: Patrick Drohan – Penn State

Photo: Josh Parrish – TNC

Water Quality – Sediment and Nutrients

Projections (Evans and Kiesecker, 2014)

- Shale development in Appalachians could increase impervious cover 1.5 million acres
- “Sensitive” category watersheds would decrease from 83% to 65% in Marcellus region while “Impacted” watersheds would increase from 13.5% to 25% and “Non-supporting” from 3% to 10%
- Not aware of any projections or observations on nutrients

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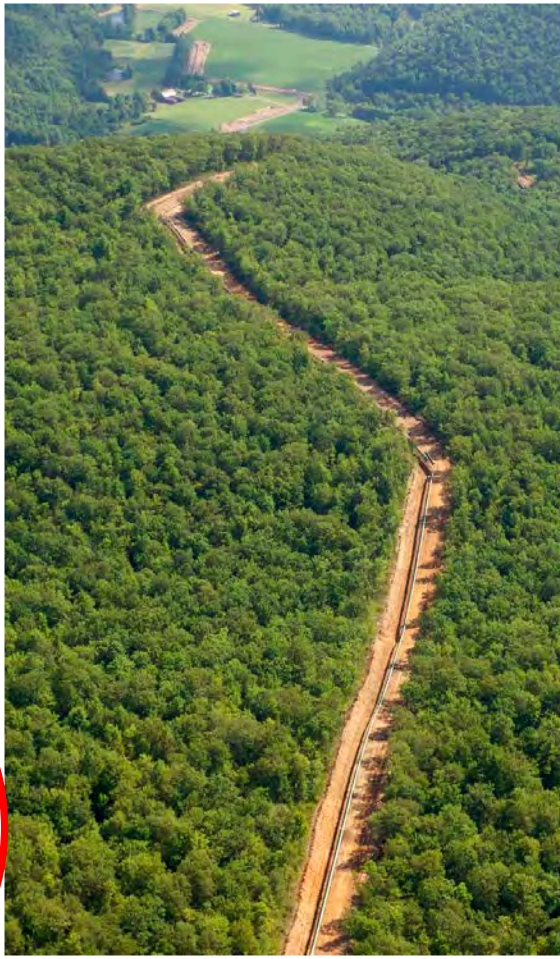
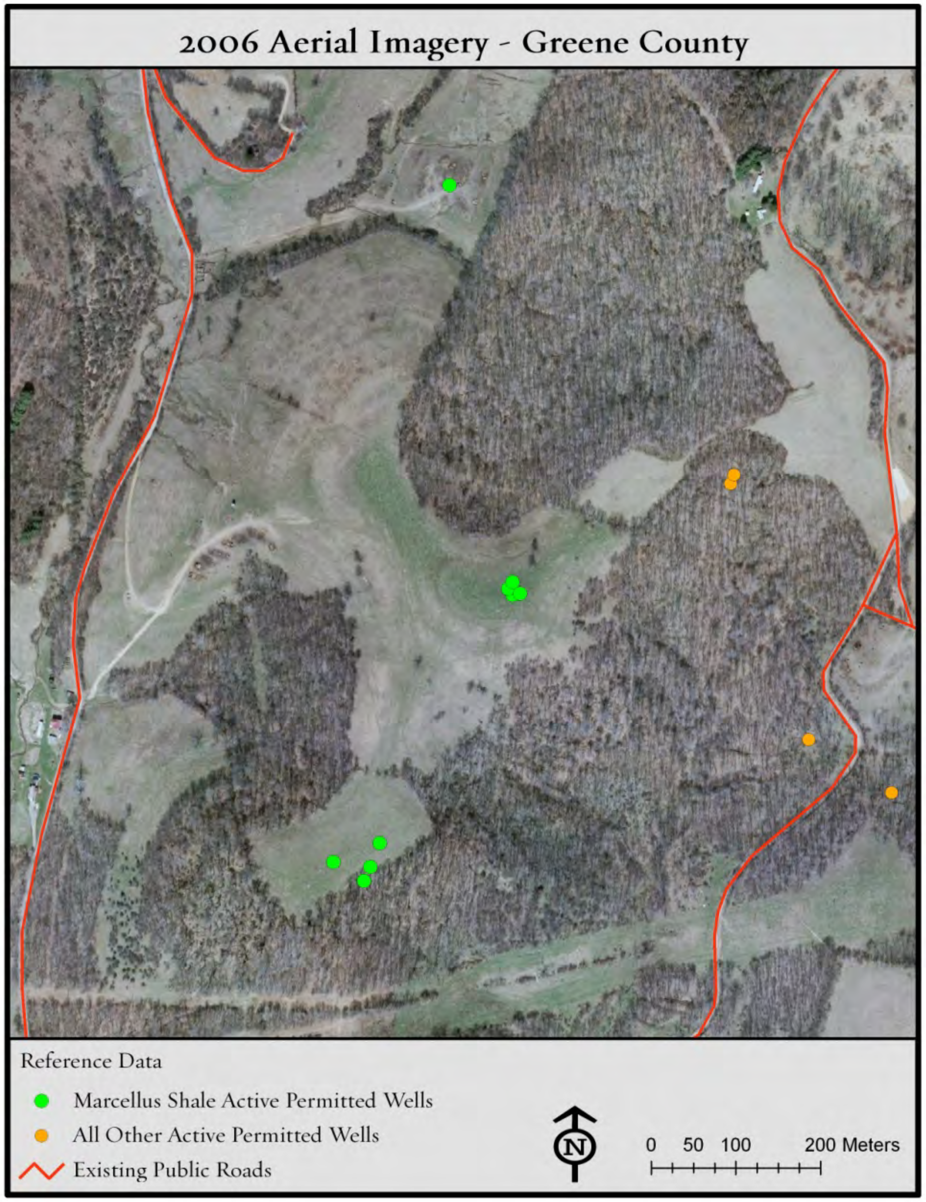
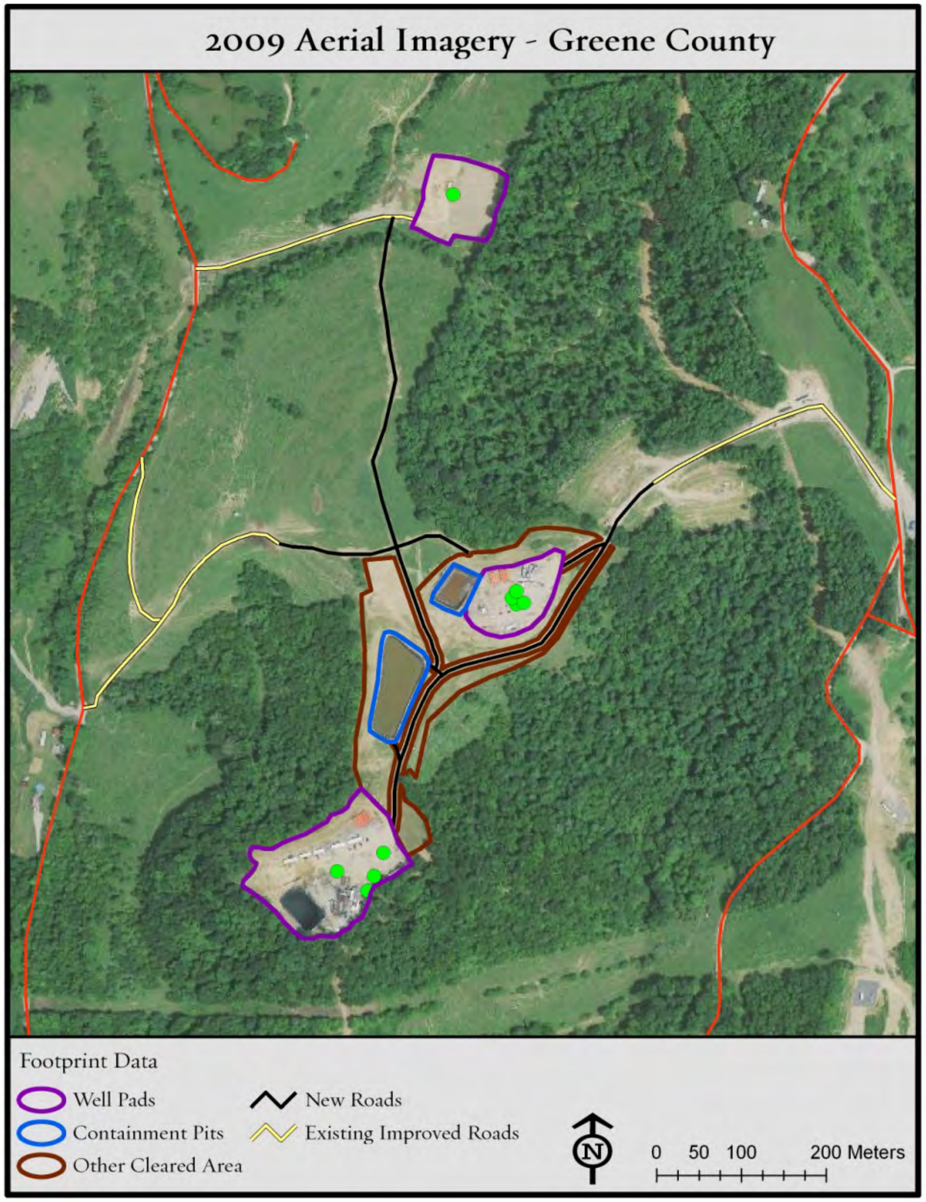


Measuring Land Use Change

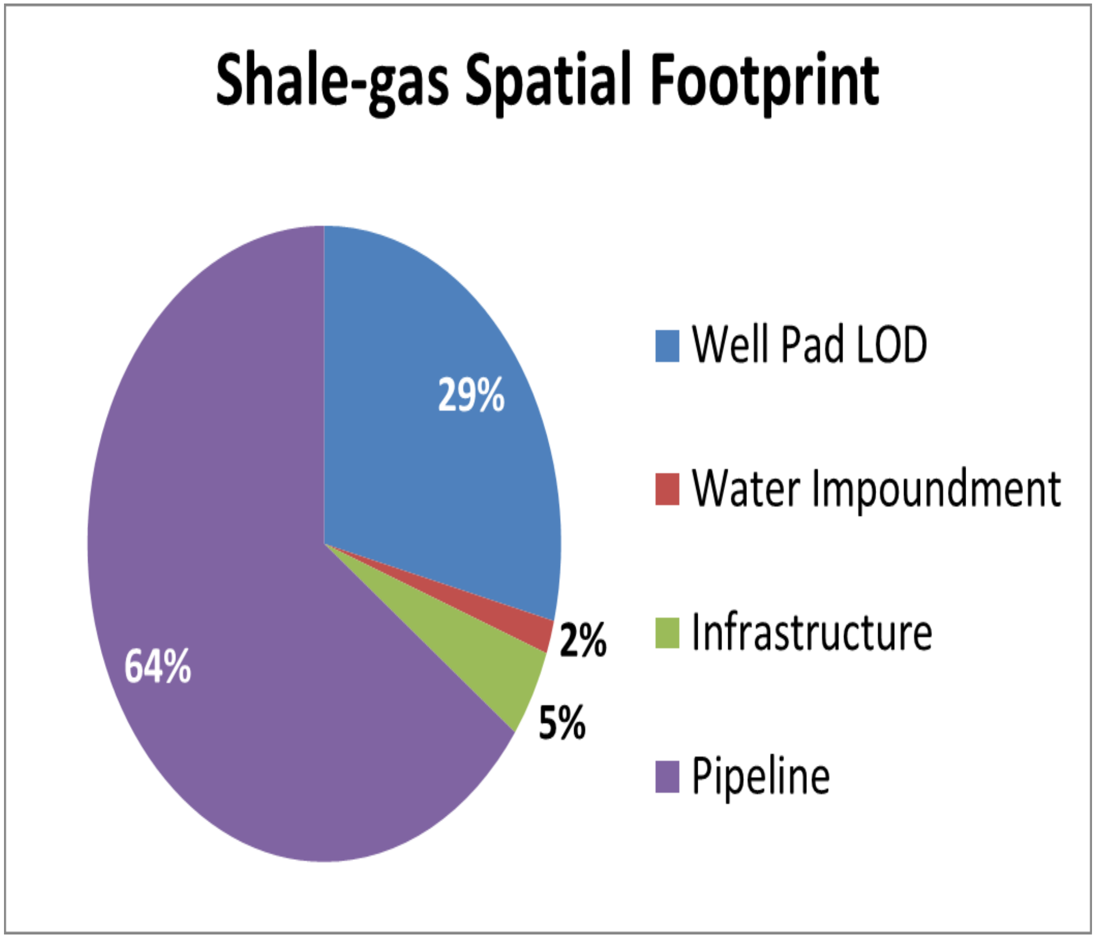




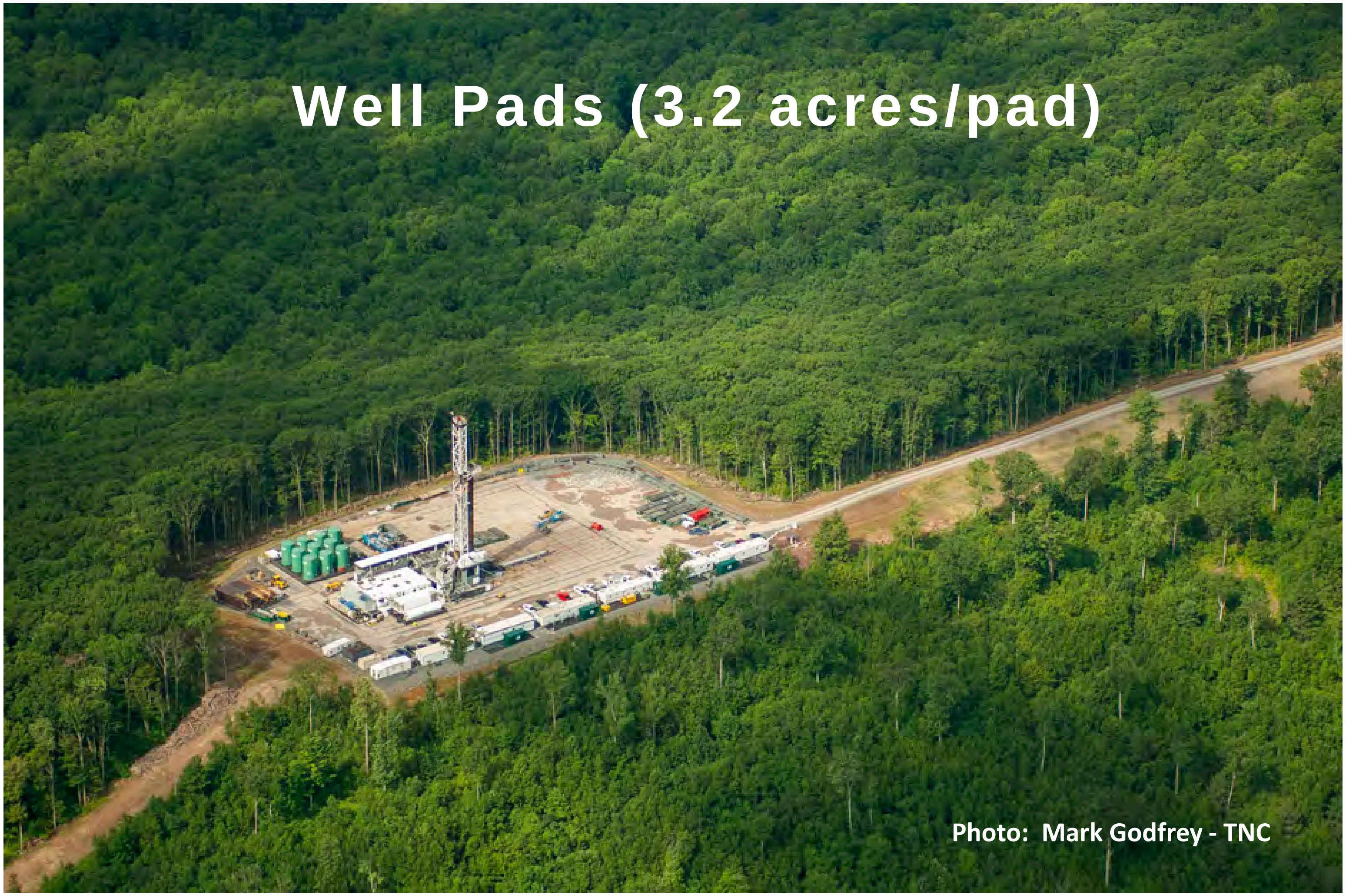
Measuring Land Use Change

Brittingham et al. 2013

- 4617 pads built or permitted
- 59% forest, 40% agriculture
- 31% in core forest
- Core forest declined from 43.5% to 33.5% in surveyed PA bird atlas census blocks



Land Use – Habitat Loss



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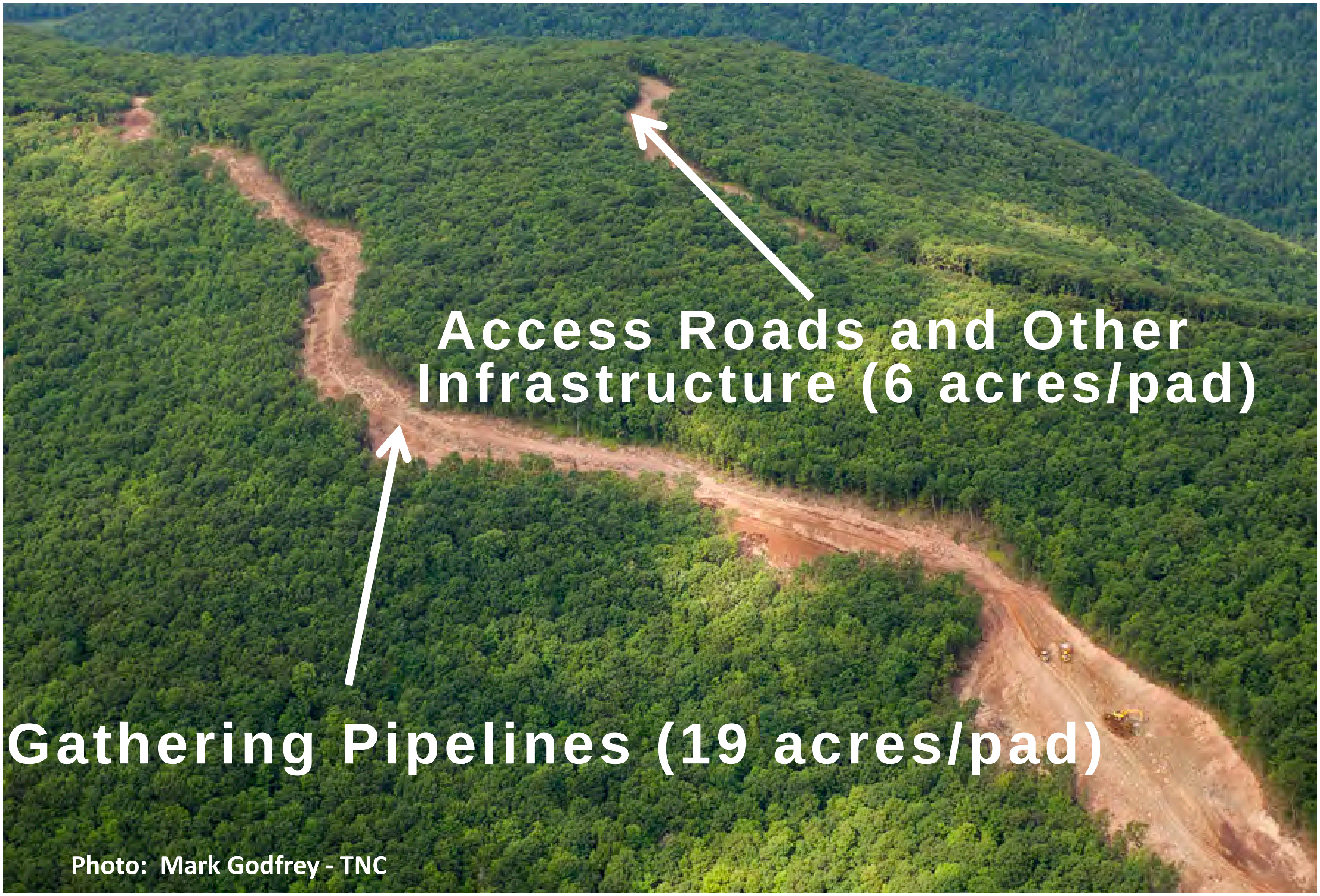


Land Use – Habitat Loss

Land Use – Habitat Loss

Land Use – Other Direct Impacts

- Between 50-70% of pads built on soils and/or slopes prone to erosion
- 21% built on potentially wet soils with risk of drainage problems
- Alteration of acidic soils by application of fertilizer and lime may exacerbate invasive species spread and abundance

(Drohan and Brittingham, 2012)

Direct Forest Habitat Loss/Well Pad

Average Habitat Loss Per Well Pad in Forest Areas (acres)		
Forest cleared for Marcellus Shale well pad	3	TOTAL 28
Forest cleared for associated infrastructure (roads, water impoundments, etc.)	6	
Forest cleared for gathering pipeline/well pad (1.6 miles)	19	

Source: Johnson et al. 2010; Johnson 2011

Land Use – Direct and Indirect Habitat Loss

Edge Effects on Forest Interior Species

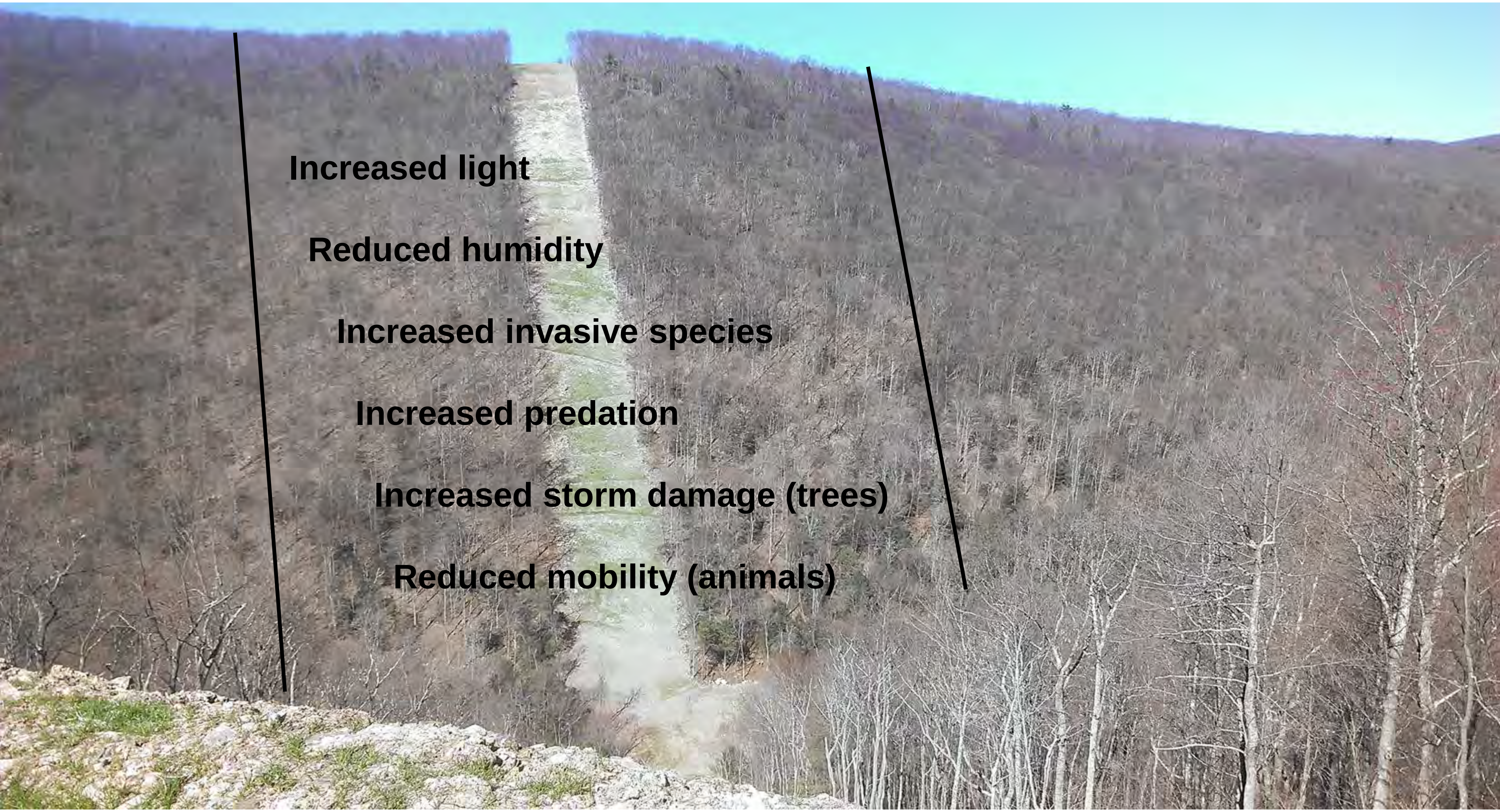
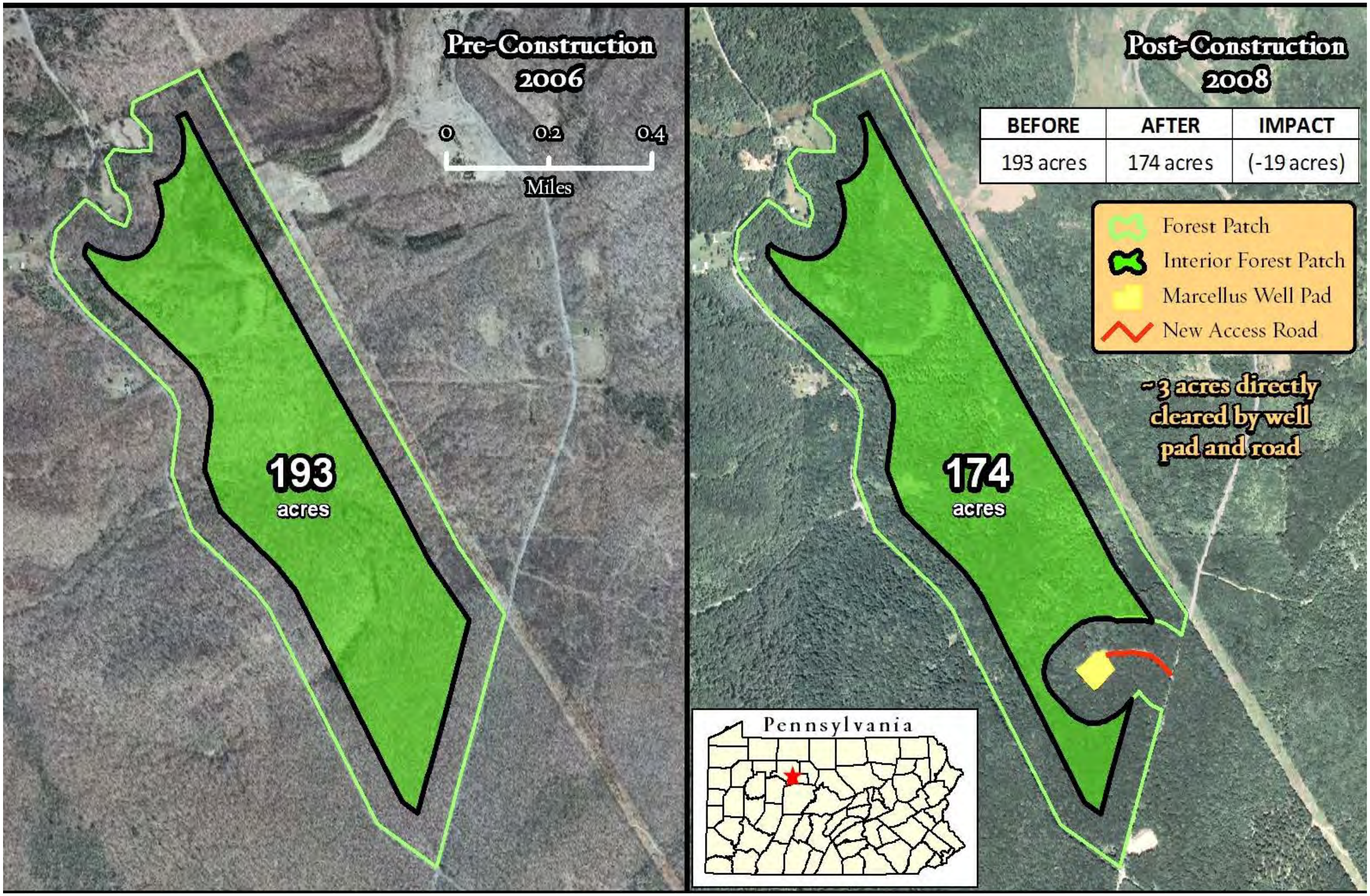


Photo: Josh Parrish – TNC

Measuring Indirect Forest Impacts – Edge Effect



Indirect Forest Habitat Impacts/Well Pad

Average Edge Effect Per Well Pad in Forest Areas (acres)		
Forest edge habitat created by pads, roads, and water impoundments	21	TOTAL 136
Forest edge habitat created by gathering pipelines	115	

Source: Johnson 2011

Total Forest Impacts/Well Pad

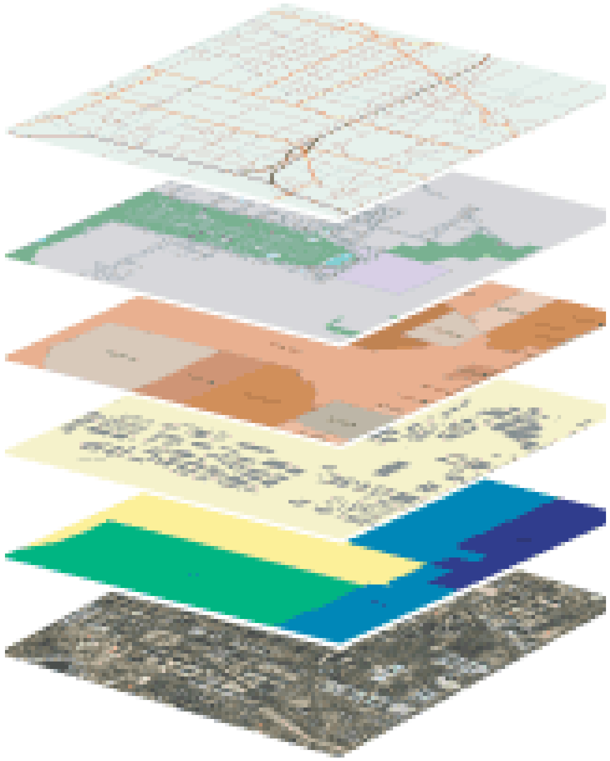
Average Total Habitat Impact Per Well Pad in Forest Areas (acres)	
Forest cleared for pads, roads, water storage and gathering pipelines	28
Forest edge habitat created by pads, roads, water storage, and gathering pipelines	136
TOTAL FOREST HABITAT IMPACT PER WELL PAD	164

Source: Johnson et al. 2010; Johnson 2011

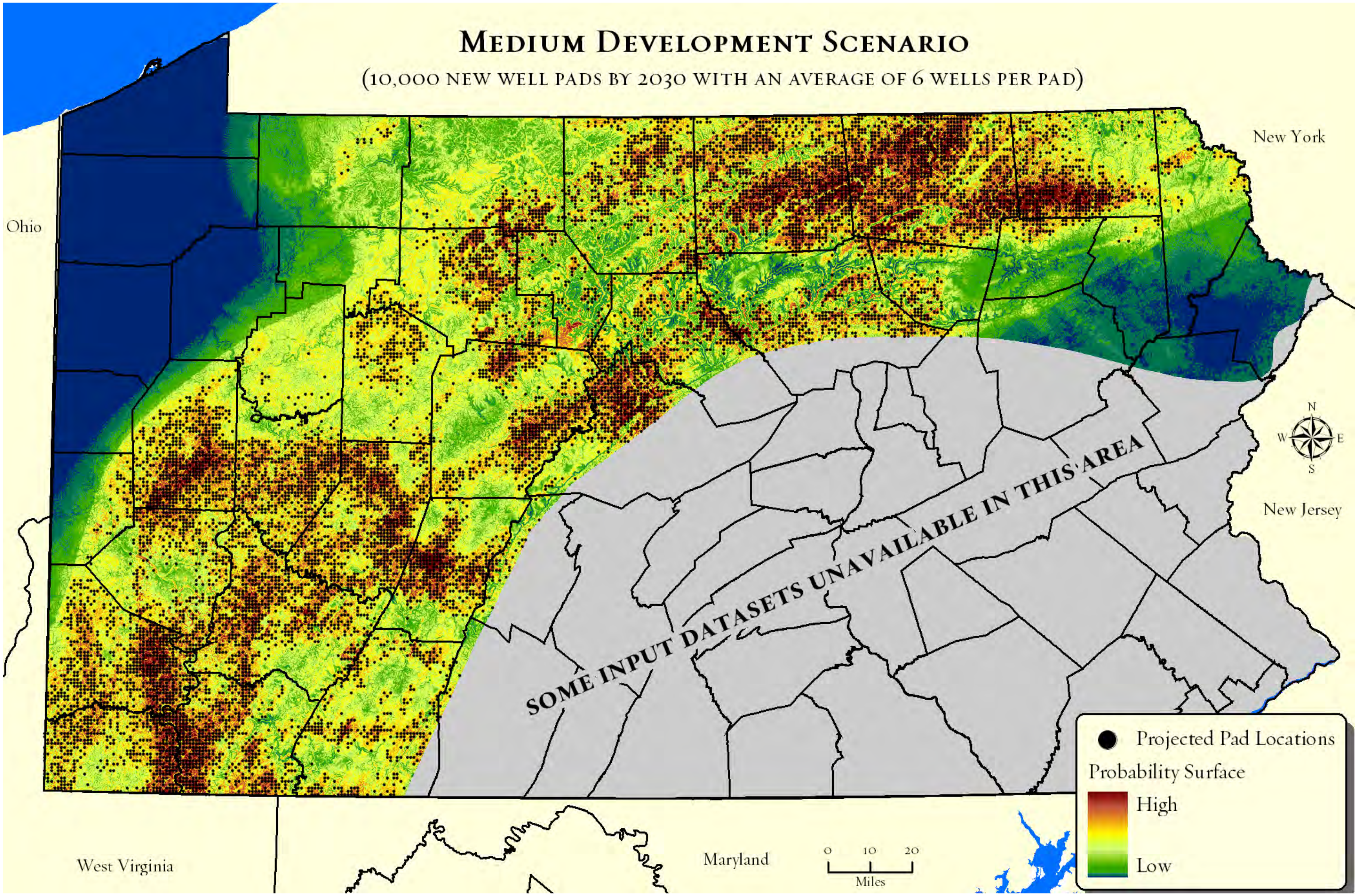
Geographic Projections for Marcellus Development

Modeled the relationship between:

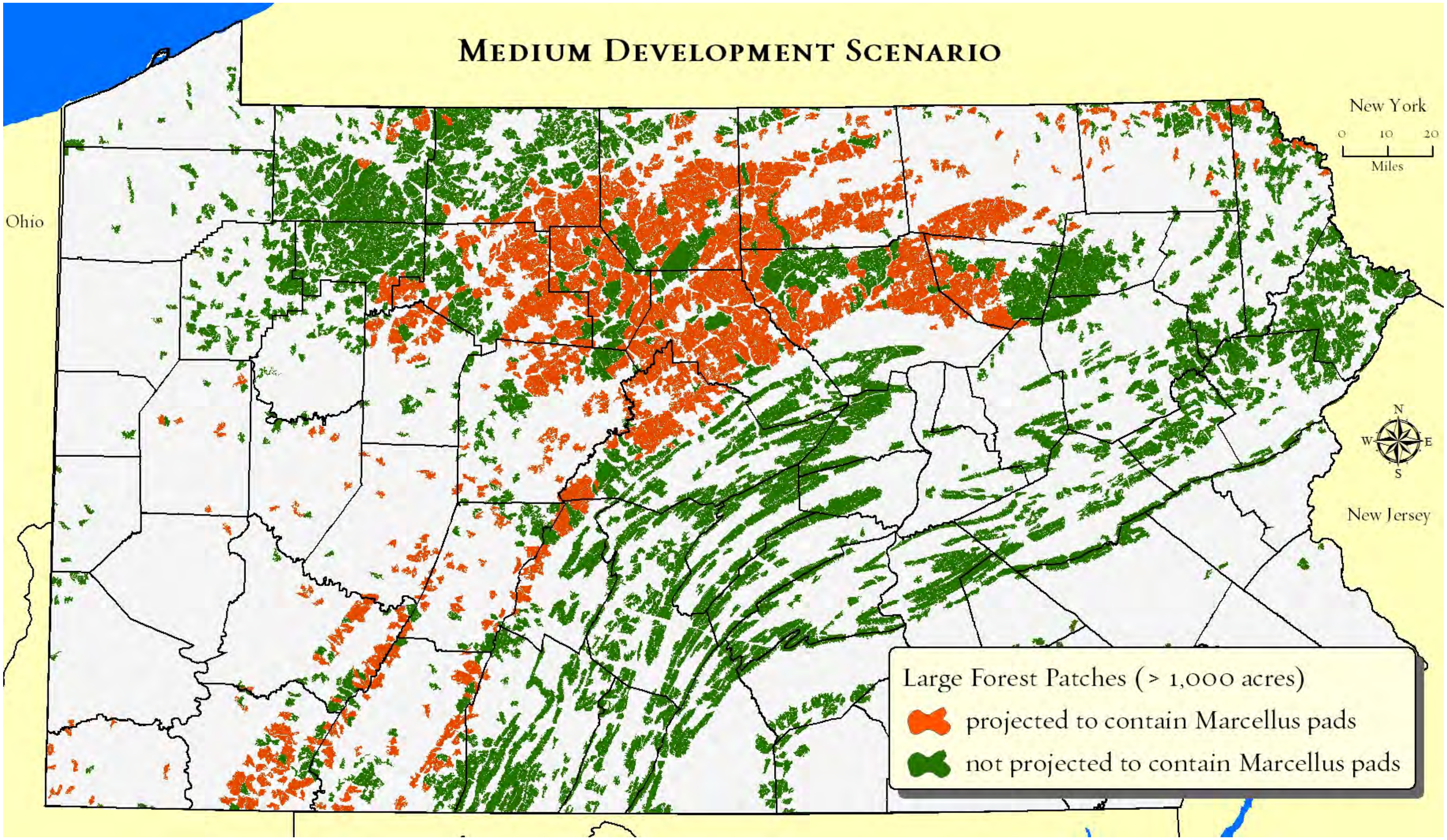
- Drilled and permitted Marcellus wells (from PA-DEP data)
- Spatial variables related to geology and infrastructure:
    - Thermal Maturity
    - Shale Depth
    - Shale Thickness
    - Percent Slope
    - Distance to Roads
    - Distance to Pipelines



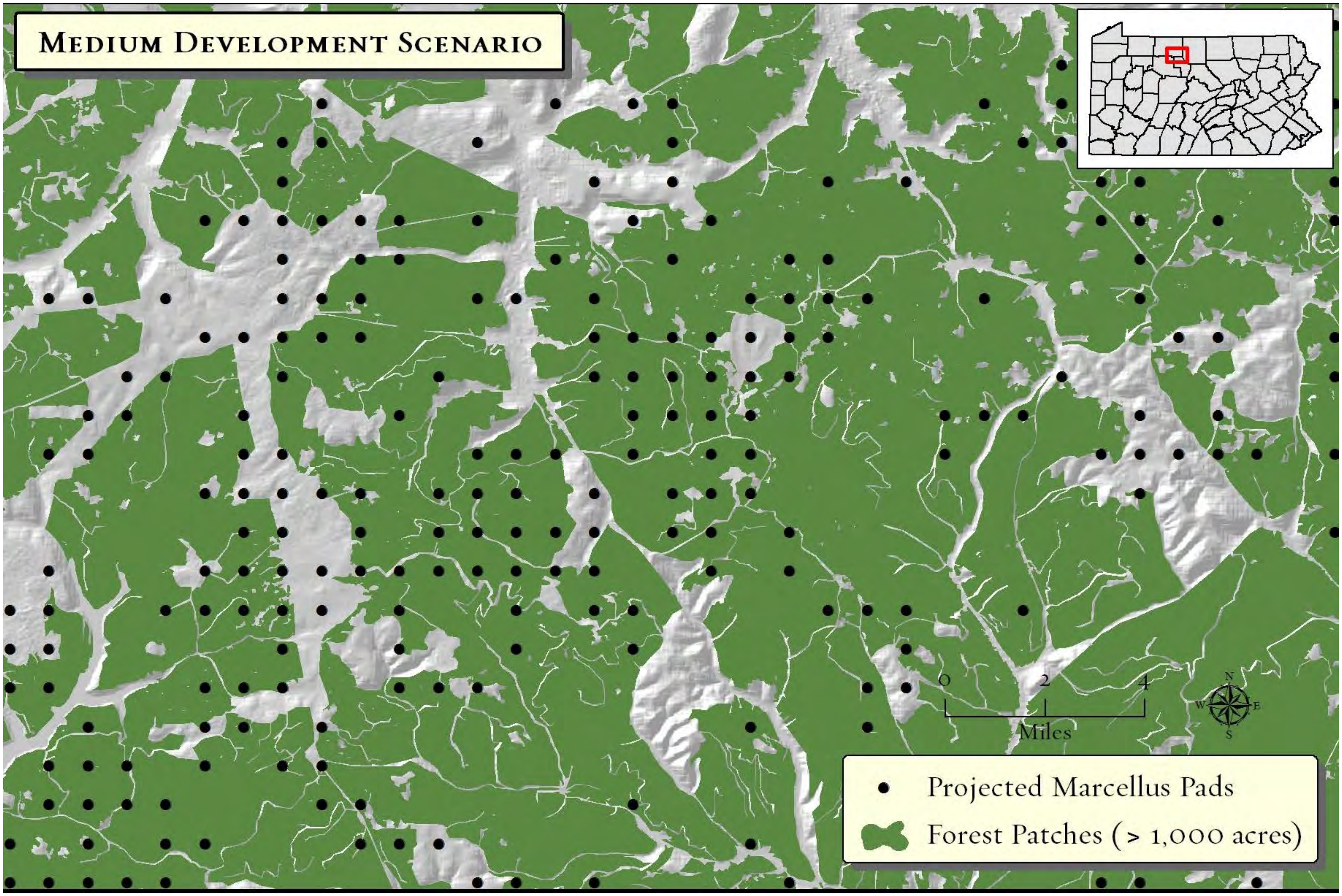
Geographic Projections for Marcellus Development



Projected Fragmentation of Large Patches



Projected Fragmentation of Large Forest Patches



Projected Total Forest Habitat Impacts in PA

Projected Total Forest Habitat Impacts in Pennsylvania by 2030 (acres) Assumes 7,000 – 15,000 well pads, 12,000 – 25,000 miles of gathering lines	
DIRECT **Forest cleared for pads, roads, water storage and gathering pipelines**	**100,000 – 250,000**
INDIRECT **Forest edge habitat created by pads, roads, water storage, and gathering pipelines**	**600,000 – 1,500,000**
TOTAL POTENTIAL FOREST HABITAT IMPACT	**700,000 – 1,750,000**

Note: Gathering Pipelines Will Cause Approximately 70 Percent of Projected Impacts *Unless They are Co-located with Roads or Existing Utility ROWs*

Observed Forest Habitat Impacts

Slonecker et al. 2012

- Bradford County lost 2,200 acres of forest due to Marcellus development between 2004-2010. 306 new forest patches created. Average patch size decreased by 11.2 acres to 102 acres.

- Washington County lost 2,600 acres of forest due to Marcellus development between 2004-2010. 984 new forest patches created. Average patch size decreased by 19 acres to 93 acres

- **Pipelines responsible for most new patches**. Unpublished CMU research shows that constraining pipelines to road ROWs dramatically reduces forest fragmentation (by up to 94%)

Projected Species Impacts – Rare Species

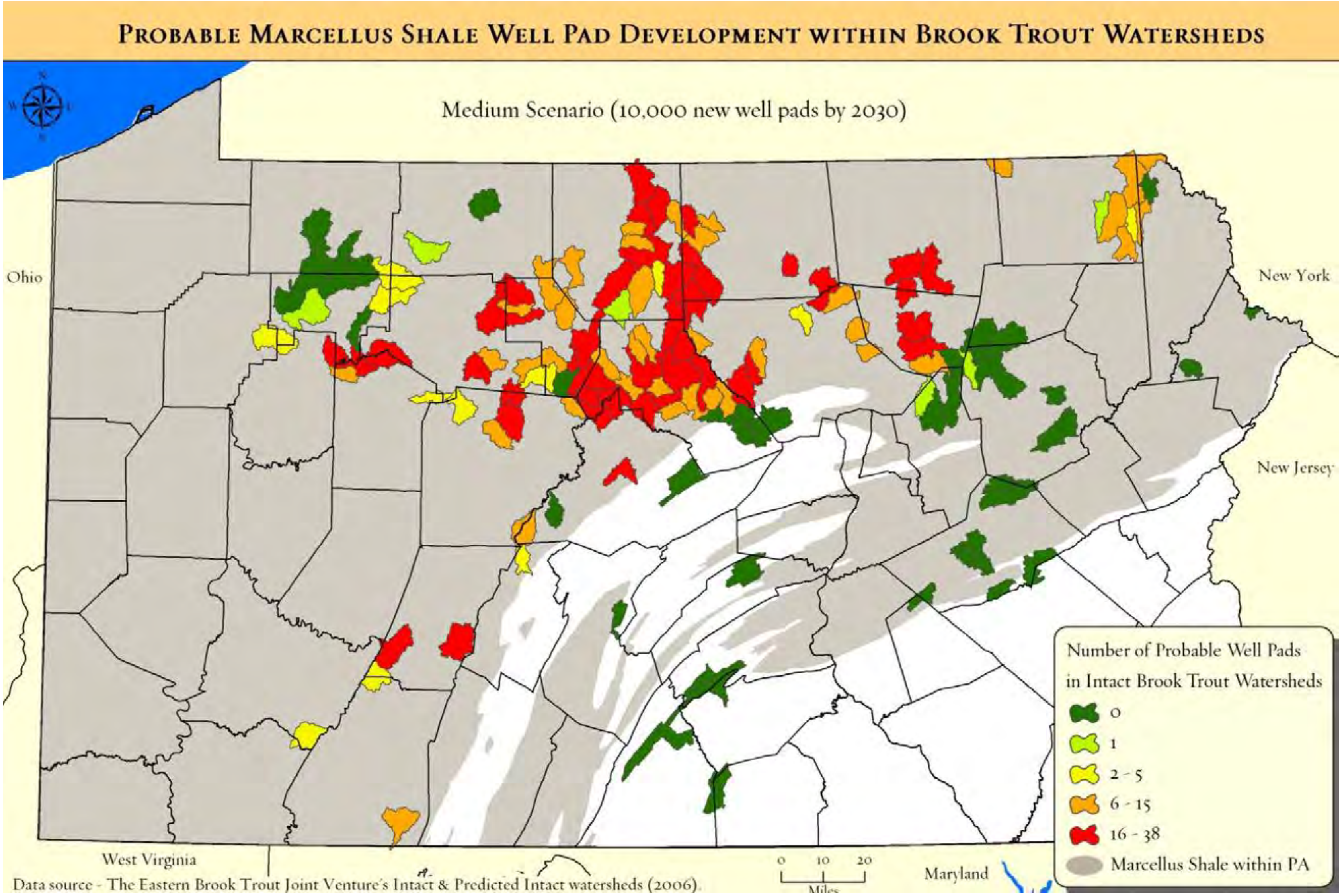
- 329 species tracked by the PA Natural Heritage Program have populations in areas with high probability of Marcellus development.
- 40% of those species are globally rare
- Some of those species are critically endangered or imperiled in Pennsylvania

Examples of species at risk:

Snow trillium (*Trillium nivale*)
73% of known populations

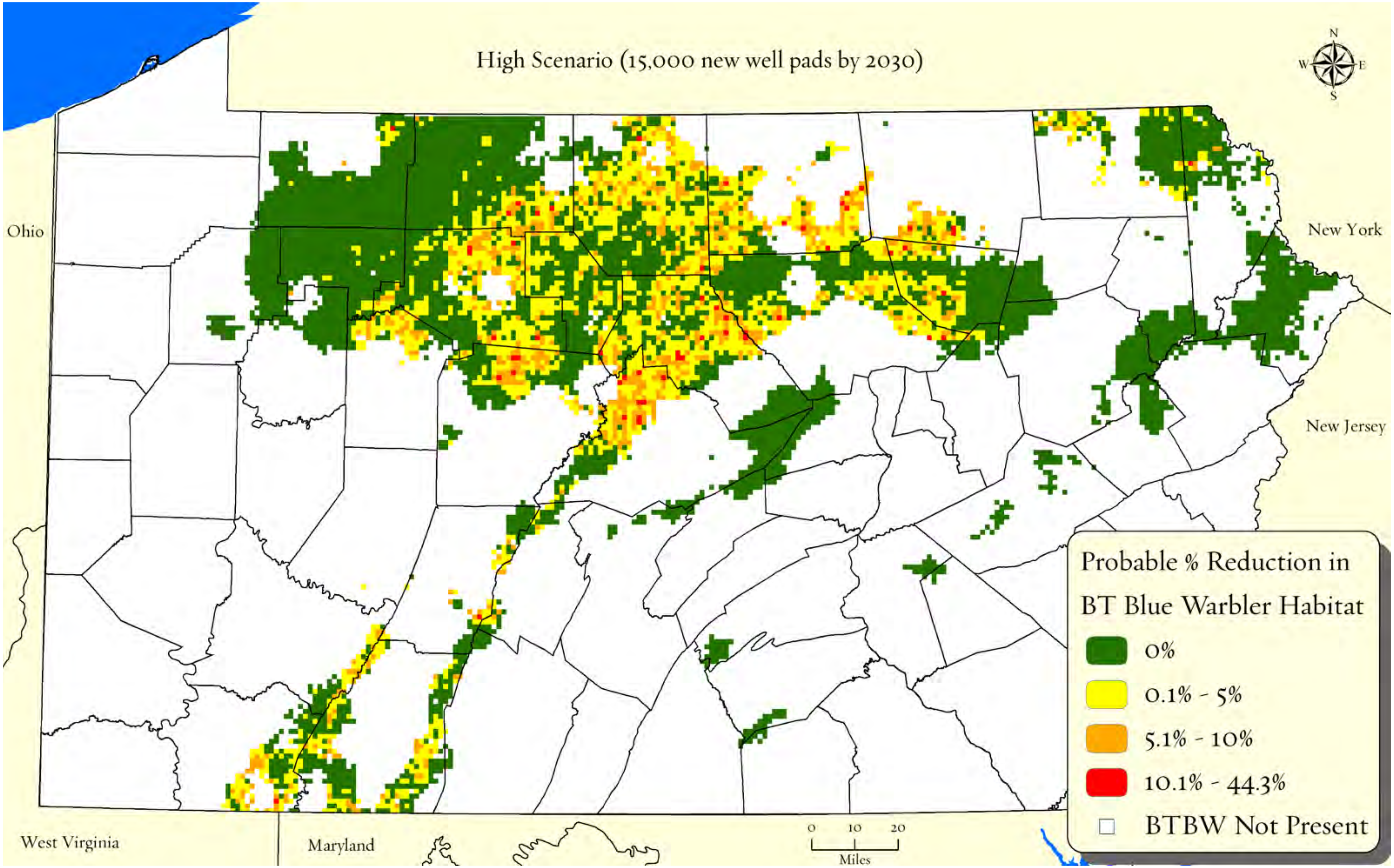
Green salamander (*Aniedes aeneus)*
100% of known populations

Projected Species Impacts – Eastern Brook Trout



Projected Species Impacts - Birds

Black-Throated Blue Warbler



Mechanisms For Terrestrial Species Impacts

Temporary Impacts
(Construction)

- Noise
- Light
- Traffic

Long Term Impacts
(Occupancy)

- Habitat Loss
- Edge Effects
- Invasive Species

Observed Species Impacts - Birds

Human-associated species were more abundant in proximity to Marcellus development (robins, goldfinch, mourning dove, common grackle, house wren)

Forest interior species were less abundant near Marcellus development (black-throated blue warbler, magnolia warbler, red eyed vireo, oven bird, scarlet tanager)

Langlois and Brittingham(2013)

Mechanisms For Aquatic Species Impacts

Temporary Impacts
(Construction)

- Water withdrawals
- Leaks/spills of flowback water
- Sediment and nutrient delivery

Long Term Impacts
(Occupancy)

- Sediment
- Connectivity
- Shallow groundwater contamination
- Surface water contamination
- Invasive species

Observed Freshwater Species Impacts

- No statistical change in cold water fish, salamanders, and crayfish in 27 Susquehanna watersheds (Horowitz et al. 2013)
- Diatom abundance unchanged in higher conductivity streams but species composition changed significantly (Cohen, 2010)
- More than half of all individuals from 3 mayfly families died after 20-30 day exposure to concentrations of <0.5% produced water (Jackson et al. 2014)
- Survey of Eastern brook trout show no regional changes in population density between 1975-2011 but some watersheds with increased land development did show significant declines
- Eastern brook trout affected by low flows, sediment, barriers, and chemicals including TDS, metals, and surfactants (Weltman-Fahs et al., 2013)

Observed Habitat and Species Impacts

DCNR Monitoring Report (PA DNCR 2014)

- 568 of 3,000 projected shale wells (19%) have been drilled on DCNR State Forest lands.
- 191 new well pads, 104 miles of new pipelines, 30 miles of new roads, constructed on DCNR State Forest Lands between 2008-2012.
- 1,486 acres of forest cleared and 4,355 acres of edge habitat created, and loss of 9,242 acres of core forest patches greater than 500 acres.
- Invasive plants found at 77% of pad sites including 11 species. Most abundant was Japanese stilt grass (*Microstegium vimineum*).
- Stream monitoring at 300 locations showed no significant impacts on pH or conductance.
- Approximately 25% of pads, roads, and pipelines constructed on wet or erosive soils.

Ecological Impacts Summary

- Few observed impacts reported as of 2014 – and they are mixed – but monitoring results should start to build soon
- Projected impacts give us primary insights into possible ecological outcomes (though technology advances could change assumptions)
- Habitat fragmentation rather than habitat loss is the primary mechanism of ecological impacts
- Habitat generalists likely to prosper, habitat specialists likely to decline
- Pipelines (especially gathering lines) are the most important threat to terrestrial and aquatic habitats

Ecological Impacts – Research Priorities

ESTABLISH ECOLOGICAL THRESHOLDS TO MINIMIZE CUMULATIVE IMPACTS

- Forest Loss and Fragmentation
- Sedimentation
- Surface Hydrologic Alterations
- Noise and Light
- Well Density (relationship to air and water quality)

DEVELOP/TEST TOOLS FOR REDUCING ECOLOGICAL IMPACTS

- Habitat and Species Risk Assessment (Mitigation Frameworks?)
- Optimization of Infrastructure Siting
- Recommendations for Leading Practices
- Evaluate Effectiveness of Leading Practices

ECONOMICS OF LANDSCAPE VS SITE PLANNING/PERMITTING

- Permitting/Regulatory Delays Site vs. Landscape
- Allocated Financial Cost of Site vs. Landscape Approach

Discussion

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Photo: Martha Rial