# Marcellus Shale Environmental Change & Impact Due to Well Pad Drilling: Lycoming & Washington Counties, Pennsylvania

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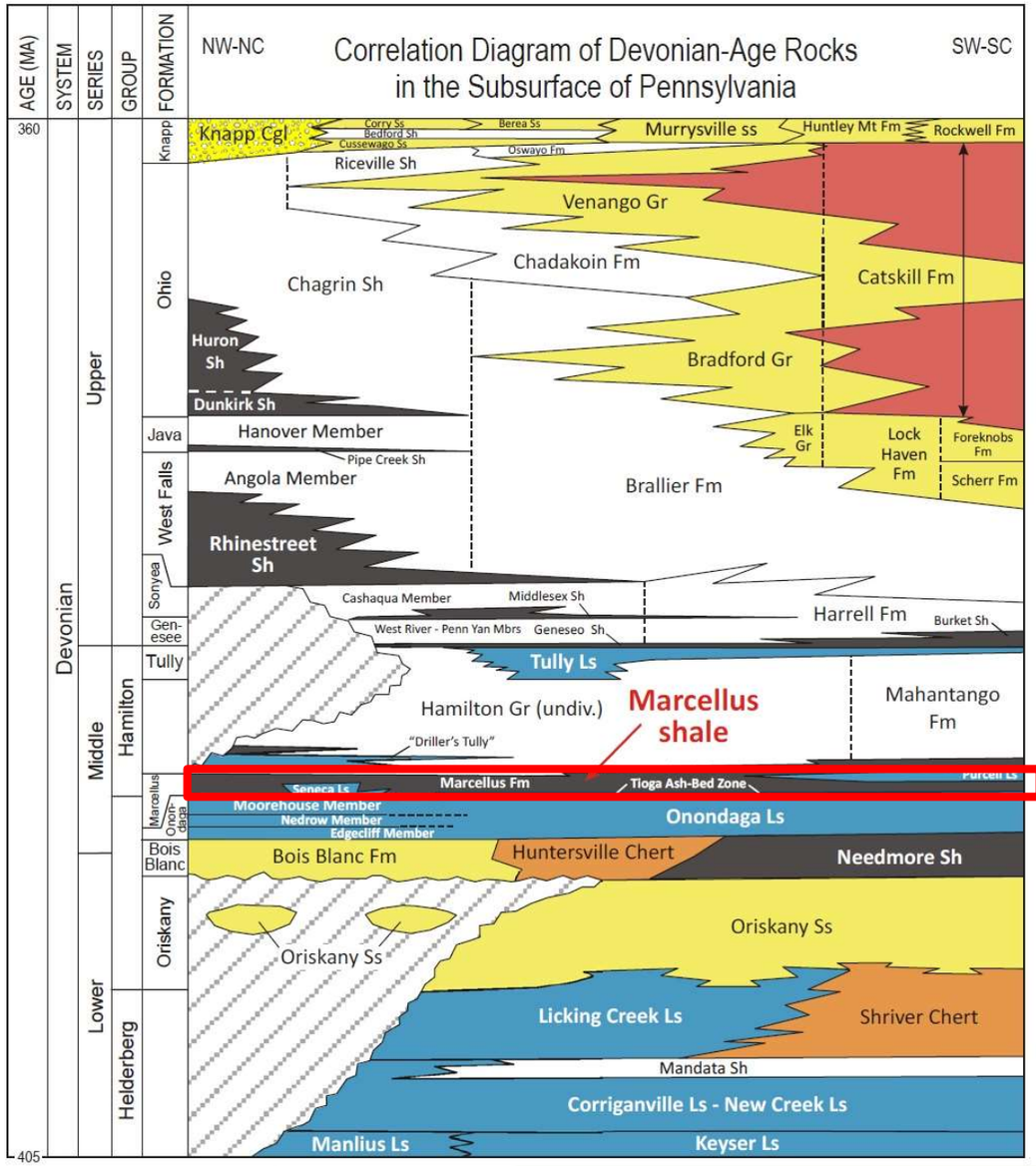
## Presentation Outline:

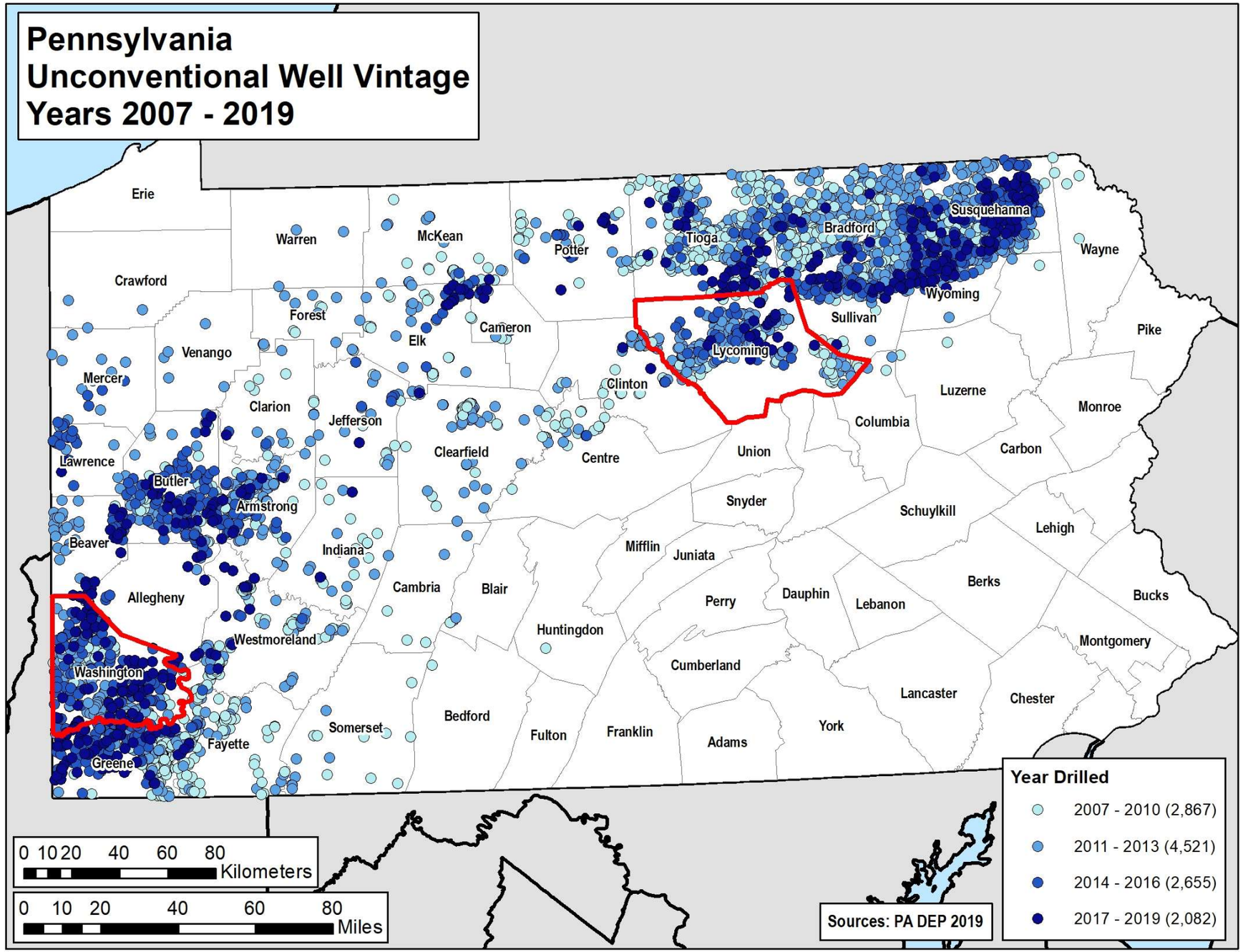
1. Background
2. Study Area
3. Goals/Objectives
4. Existing Analyses
5. Timeline
6. Data Sources
7. Methods
8. Expected Results
9. Potential Conferences

# 1. BACKGROUND

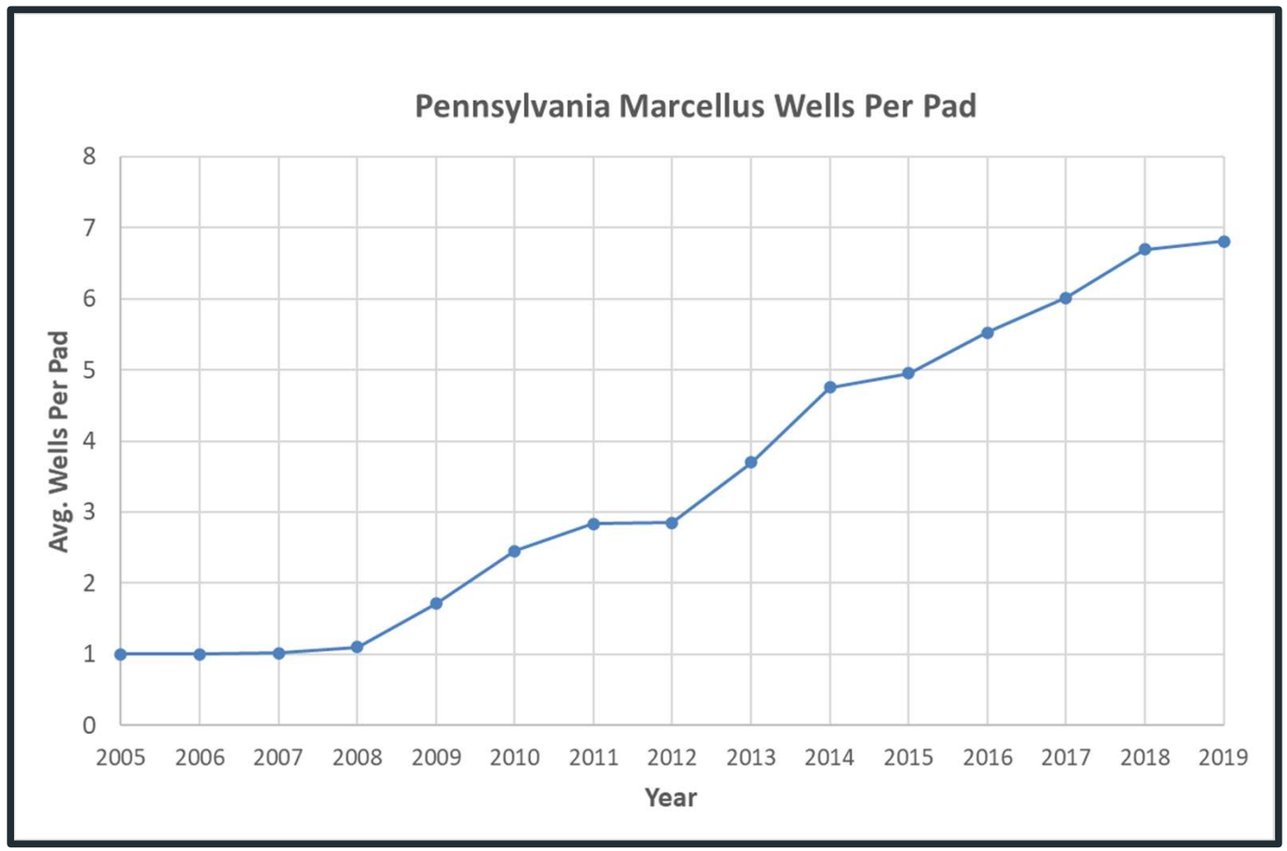
- Marcellus Shale
  - Appalachian Basin
  - Middle Devonian black shale (interbedded limestone)
  - Shallow marine depositional environment
  - Source rock to overlying conventional reservoirs
  - Shale/horizontal drilling began in 2005
  - Shift to pad drilling in 2008
  - Over 12,000 wells



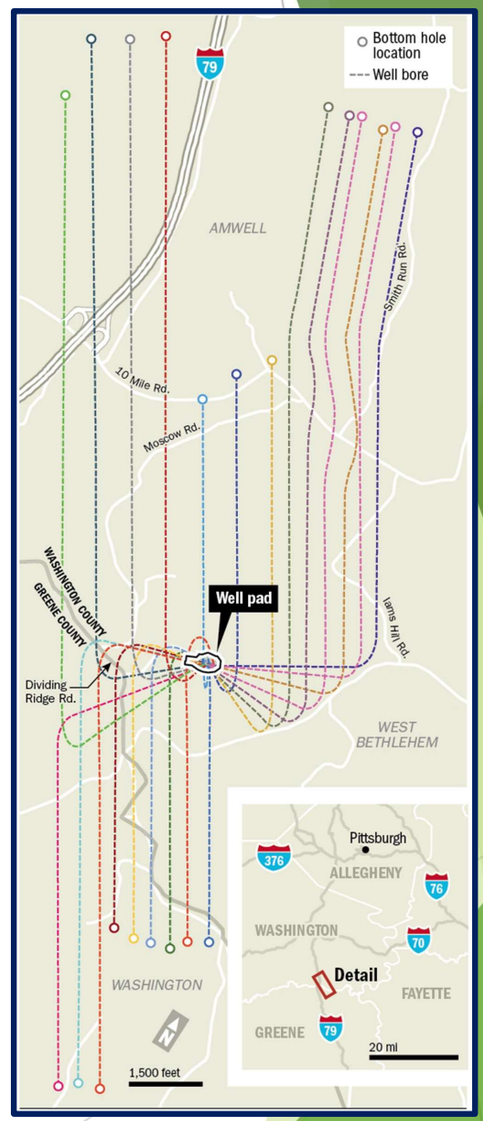

Source: DCNR 2010


Pennsylvania
Unconventional Well Vintage
Years 2007 - 2019
Erie
Warren
McKean
Potter
Tioga
Bradford
Susquehanna
Wayne
Crawford
Forest
Elk
Cameron
Wyoming
Sullivan
Pike
Venango
Lycoming
Mercer
Clinton
Luzerne
Clarion
Jefferson
Columbia
Monroe
Lawrence
Clearfield
Centre
Union
Carbon
Butler
Armstrong
Snyder
Schuylkill
Beaver
Indiana
Mifflin
Juniata
Lehigh
Allegheny
Cambria
Blair
Perry
Dauphin
Lebanon
Berks
Bucks
Westmoreland
Huntingdon
Washington
Cumberland
Montgomery
Lancaster
Chester
Somerset
Bedford
Fulton
Franklin
Adams
York
Fayette
Greene
0 10 20 40 60 80
Kilometers
0 10 20 40 60 80
Miles
Sources: PA DEP 2019
Year Drilled
2007 - 2010 (2,867)
2011 - 2013 (4,521)
2014 - 2016 (2,655)
2017 - 2019 (2,082)

# Increasing Well Pad Development




Based on 2019 PA DEP data

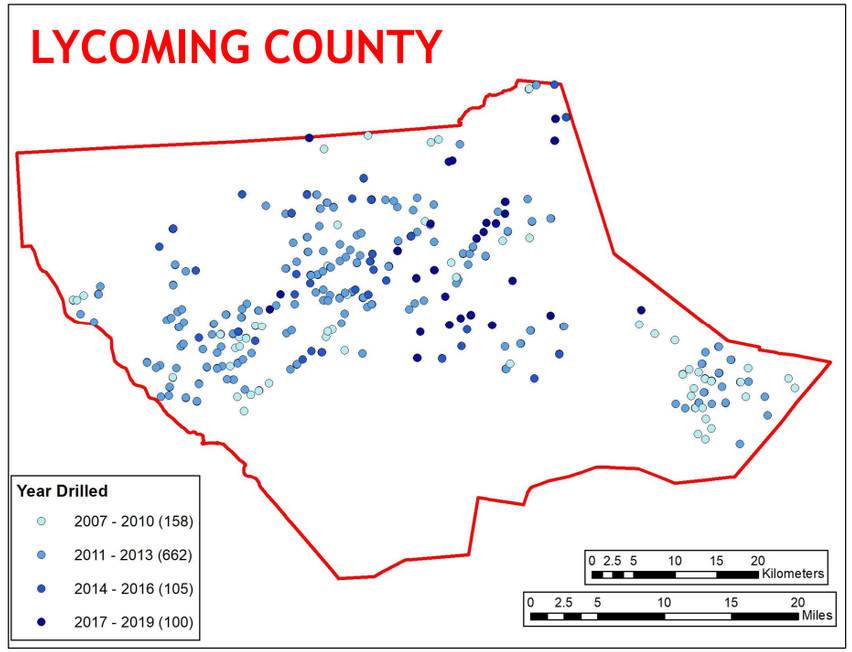


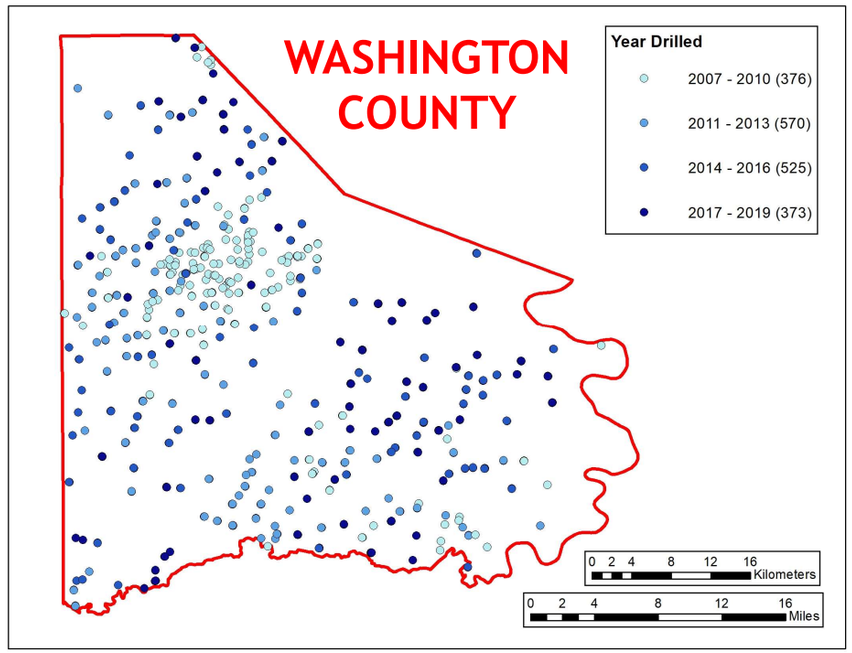

22 Hz Well Pad: Southern Washington County
Source: PA DEP/EQT Corp, 2018

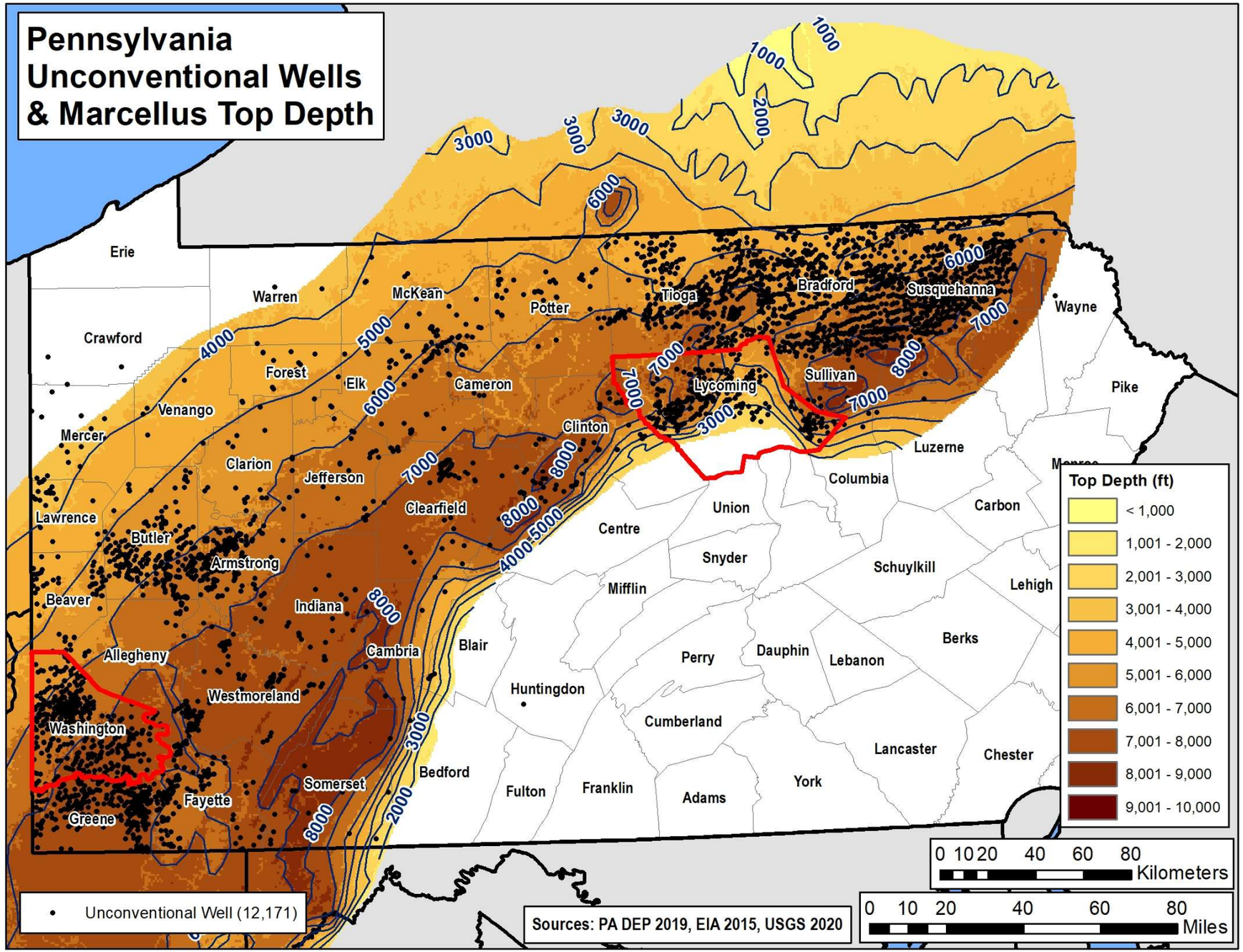
# 2. STUDY AREA

- Marcellus Shale Play = 58,000 $mi^2$ (24,000 $mi^2$ in PA)

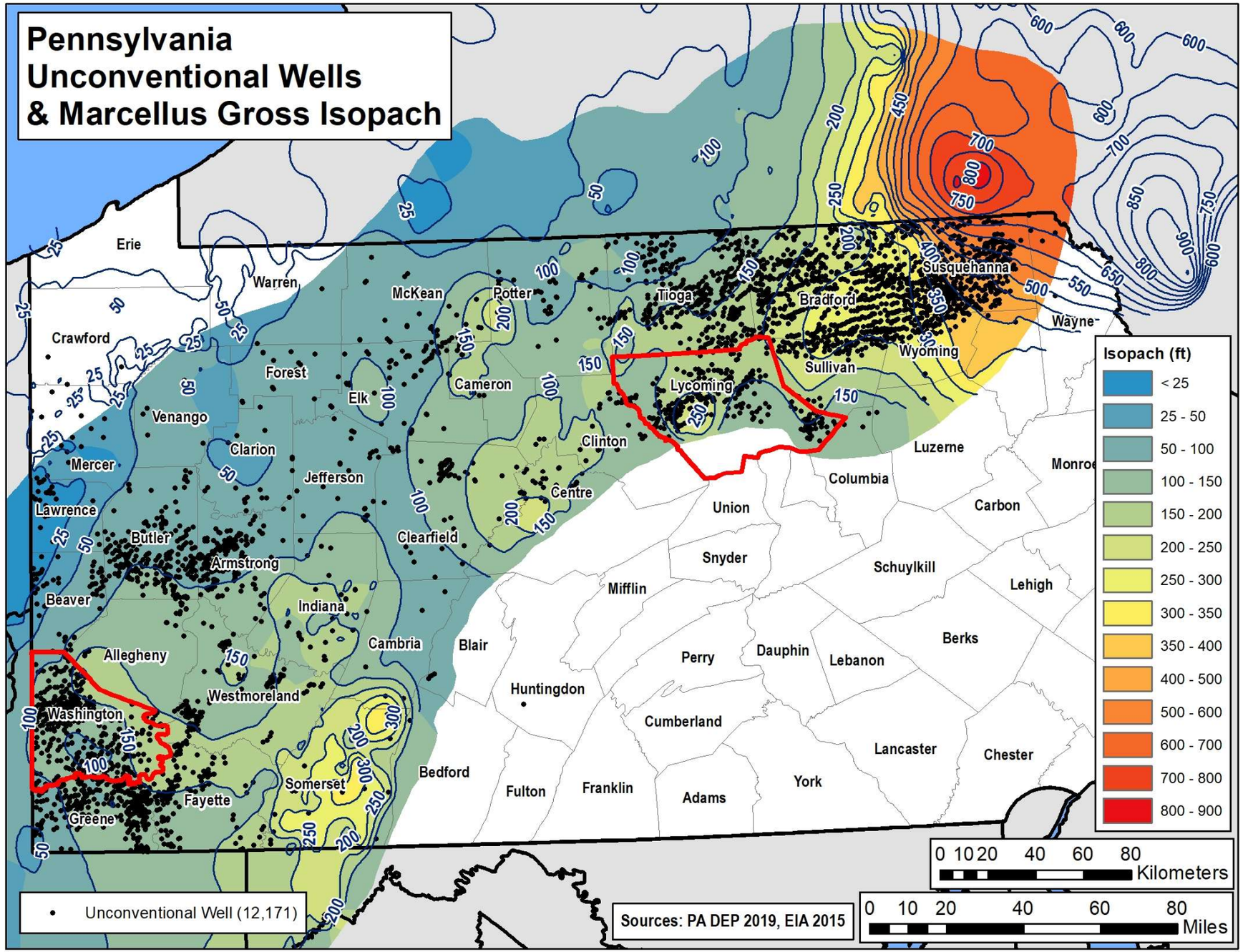
| | Lycoming County | Washington County |
|---|---|---|
| **Region** | NE PA | SW PA |
| **Area** | 1,244 $mi^2$ | 861 $mi^2$ |
| **Population Density** | 92/$mi^2$ | 243/$mi^2$ |
| **Depth** | 2,000 - 7,500 ft | 5,000 - 7,500 ft |
| **Isopach (thickness)** | 140 - 255 ft | 65 - 200 ft |
| **Total Wells** | 1,025 | 1,869 |
| **Peak Well Years** | 2011 - 2013 | 2011 - 2013 |
| **Well Pads** | 237 | 391 |
| **Avg. Wells/Pad** | 4.0 | 4.8 |
| **Main Operator** | Ard Opr LLC | Range Resources |






***Depth inferred from structure (sub-sea elevation) contours and DEM**



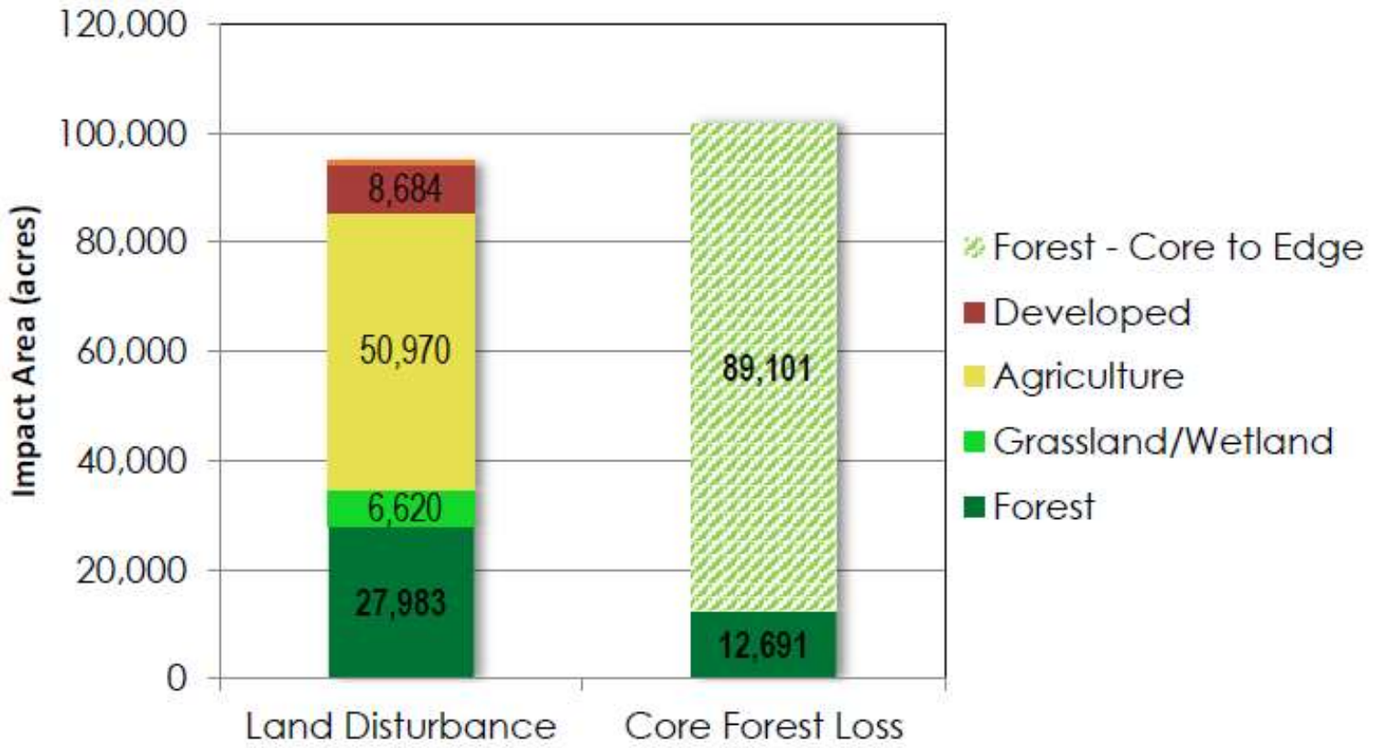

*Isopach = formation thickness

# 3. GOALS & OBJECTIVES

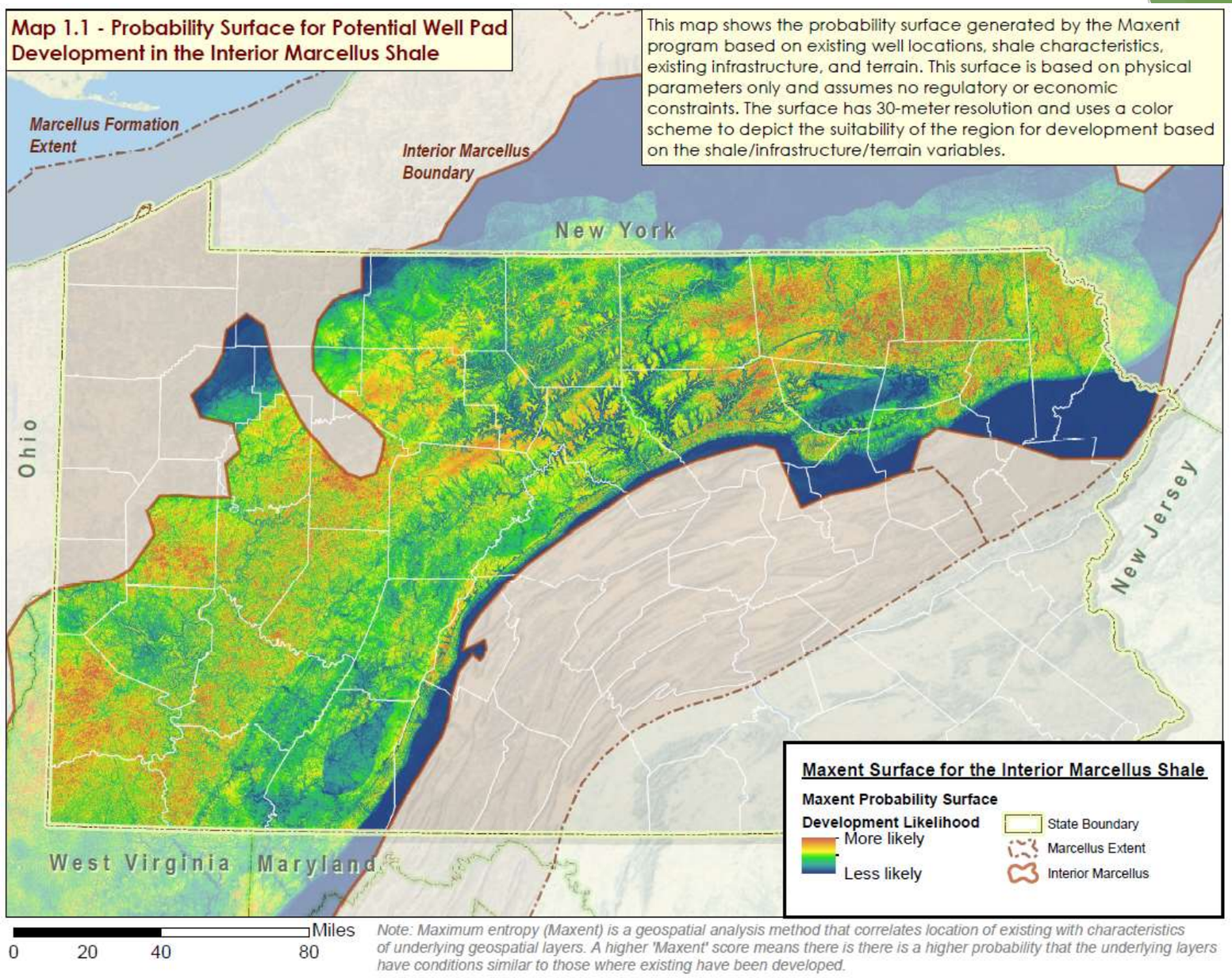
- Determine change in land cover type and amount over time near well pads
- Identify any correlations among geographical factors and well pad placement (i.e. low slope, proximity to infrastructure, soil type)
- Verify production per unit disturbed area on well pad has increased

# 4. EXISTING ANALYSES

- Predicting full production development on the environment in PA (Hanson et al 2016)

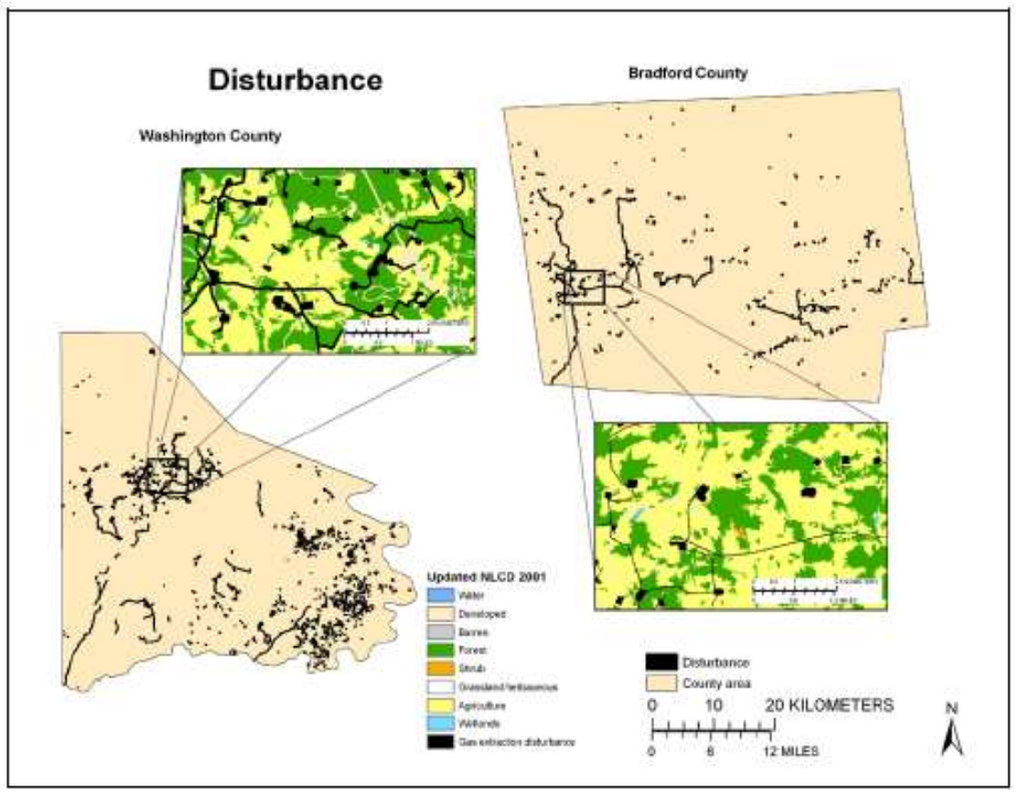



Hanson et al. 2016

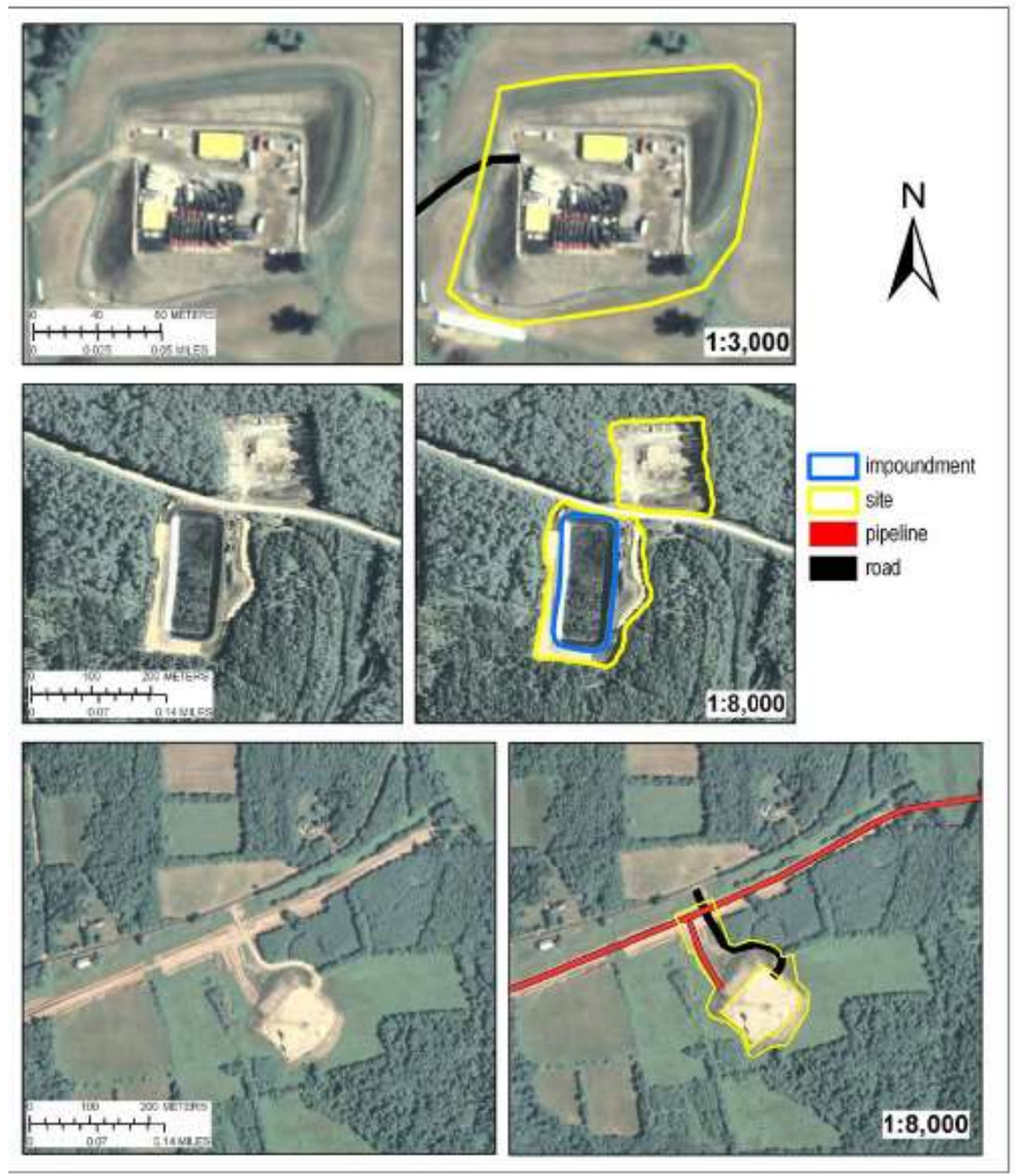



Hanson et al. 2016

- Landscape disturbance in Bradford/Washington Counties, PA (Slonecker et al. 2012)
  - Aerial imagery classification




Slonecker et al. 2012



# OTHER ANALYSES

- Habitat and species effects due to Marcellus drilling (Keller et al. 2017)
- Maximizing net present value based on well placement and well pad parameters (Abramov 2019)
- Well site extraction using Landsat-5 imagery using object- and pixel-based image analysis (Salehi et al. 2014)
- Quantifying land cover change in the Haynesville Shale (Unger et al. 2015)
- Social and economic change in PA due to the Marcellus (Brasier et al. 2014)

# 5. TIMELINE

**Data Acquisition**
- March – May 2020

**Preprocessing**
- May – June 2020

**Data Analysis**
- July – September 2020

**Report & Presentation**
- September – December 2020

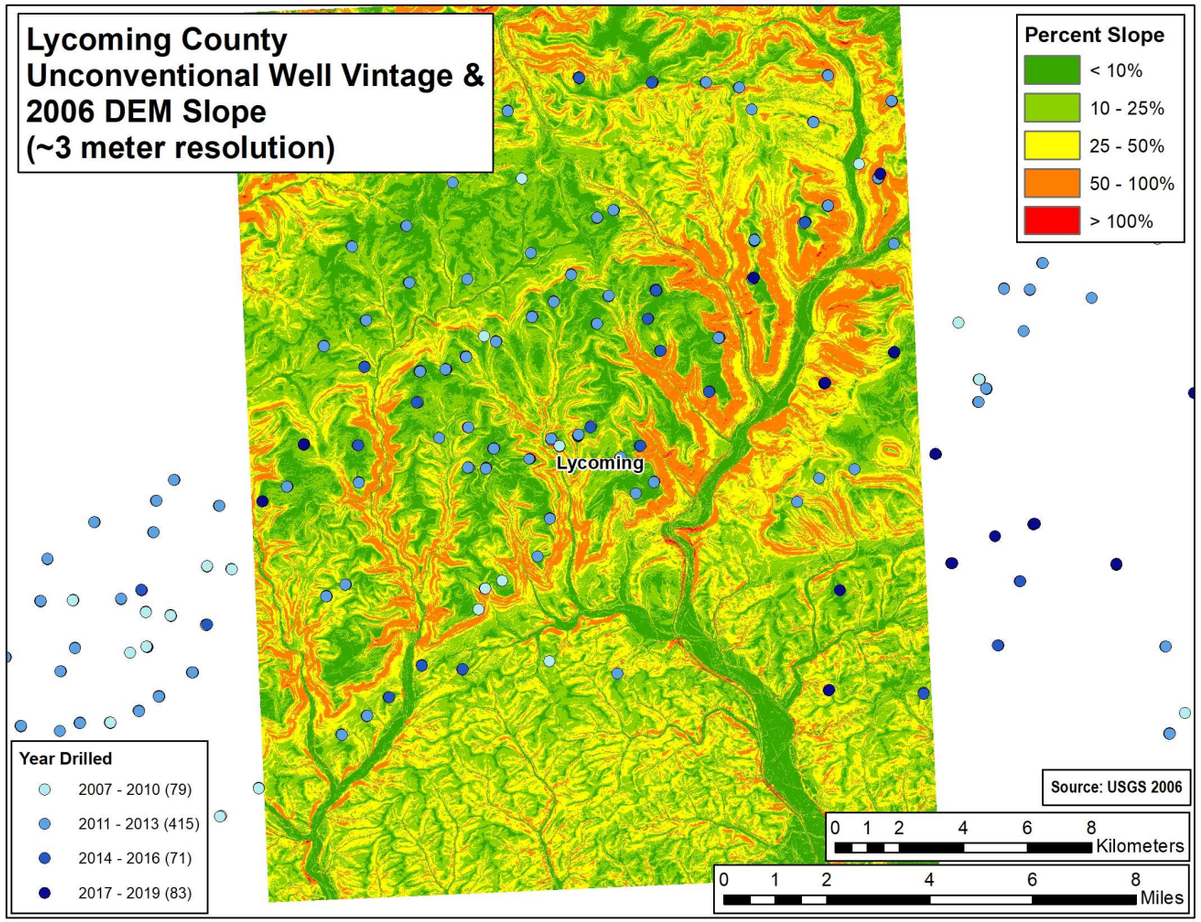
# 6. DATA SOURCES

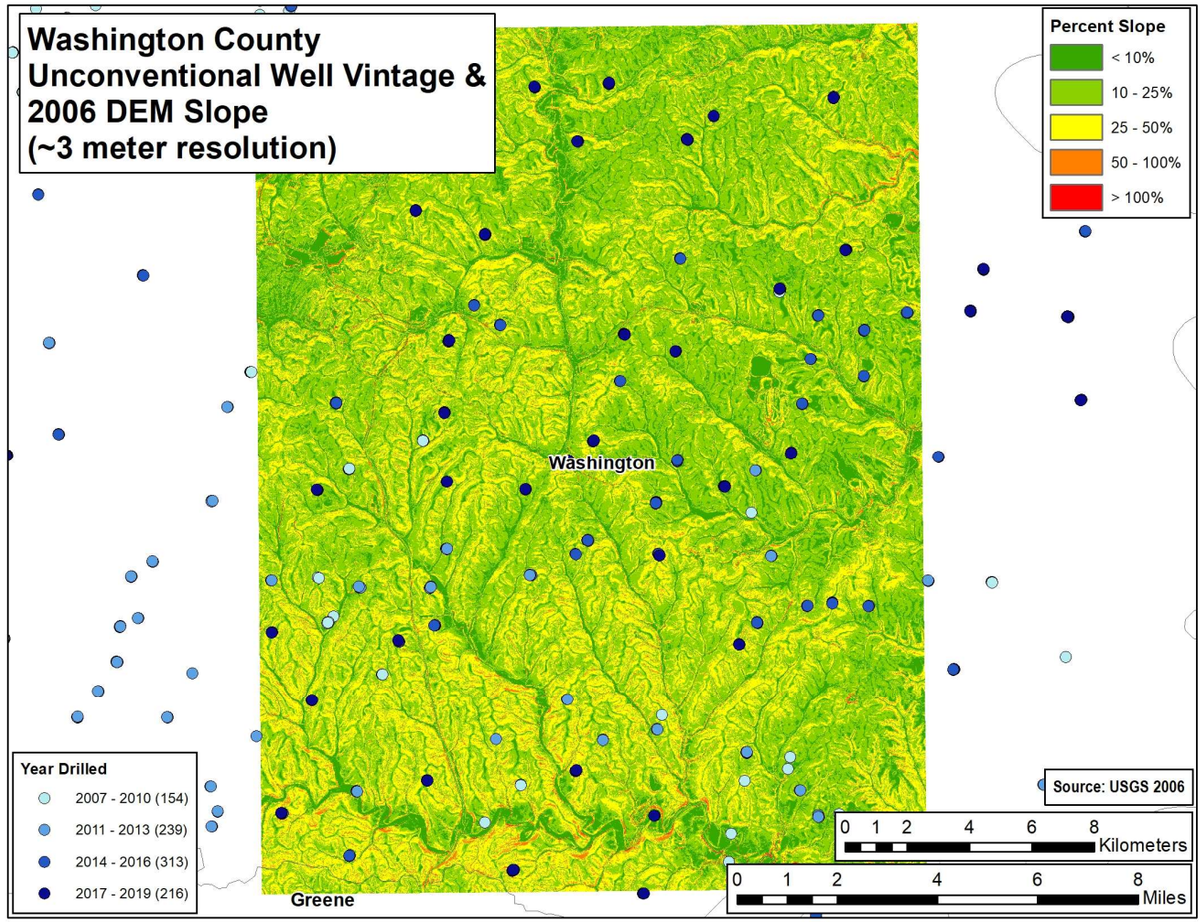
## 6.1 Unconventional Well Data

- 2005-2019 (PA Department of Environmental Protection)
- ~12,000 wells drilled
- Surface hole locations
- Well pad identification
- Operator
- Spud/first production dates
- Monthly production/days on

# 6.2. LiDAR (DEM) Data

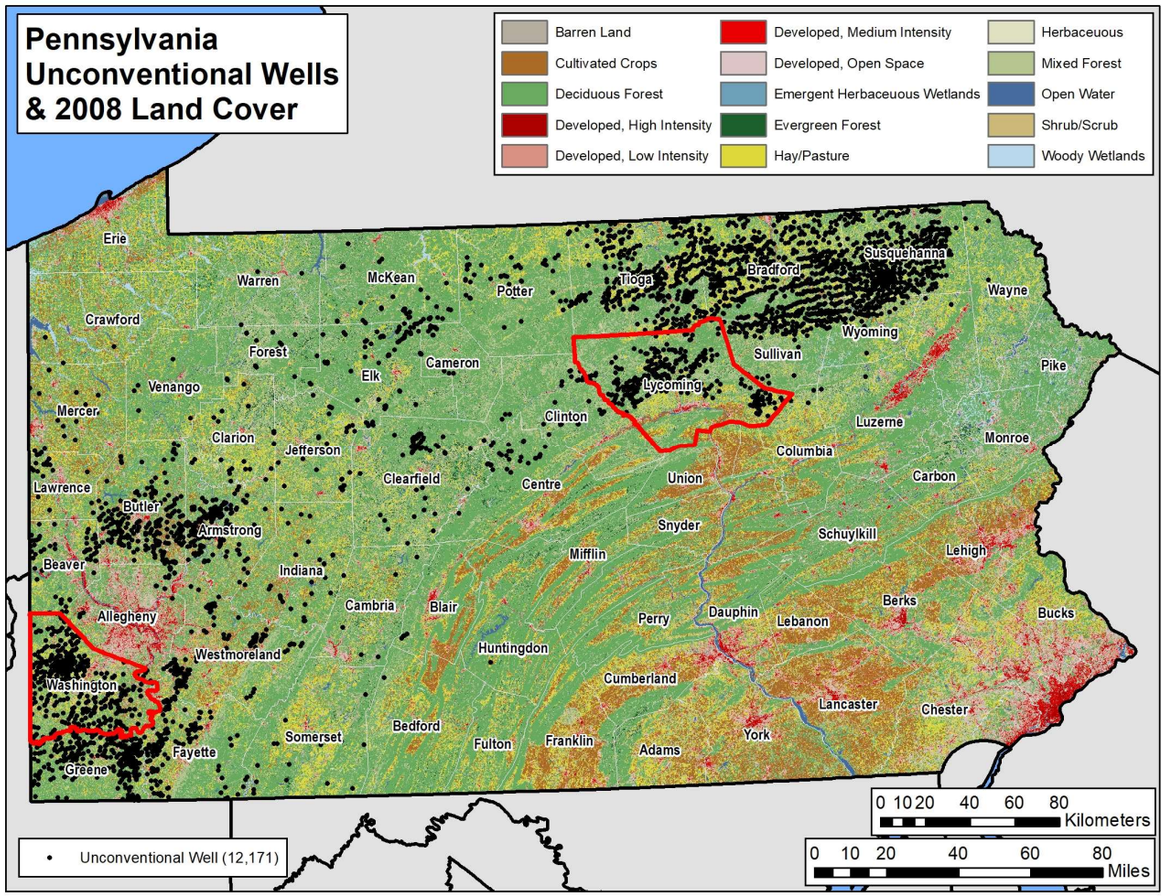
- 1/9 arc second (~3 meter resolution)
- Slope calculations/comparison

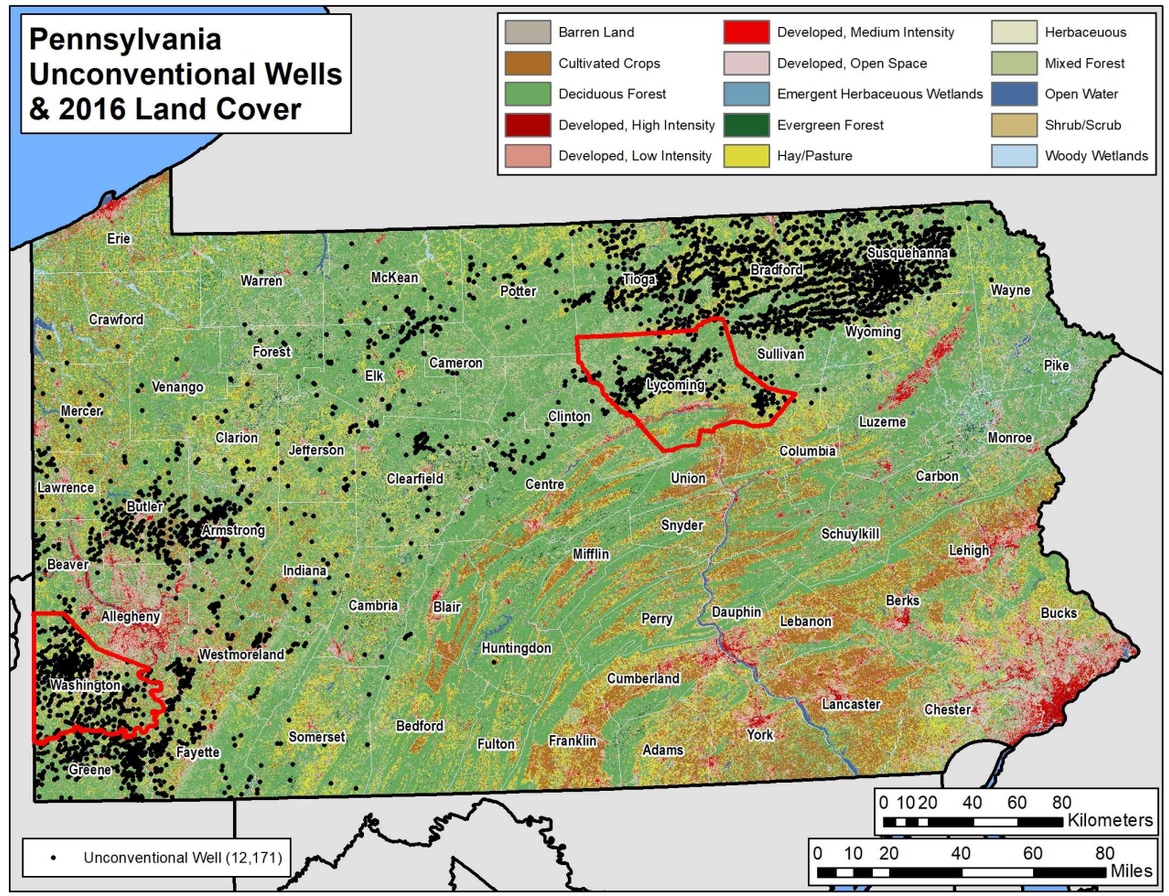


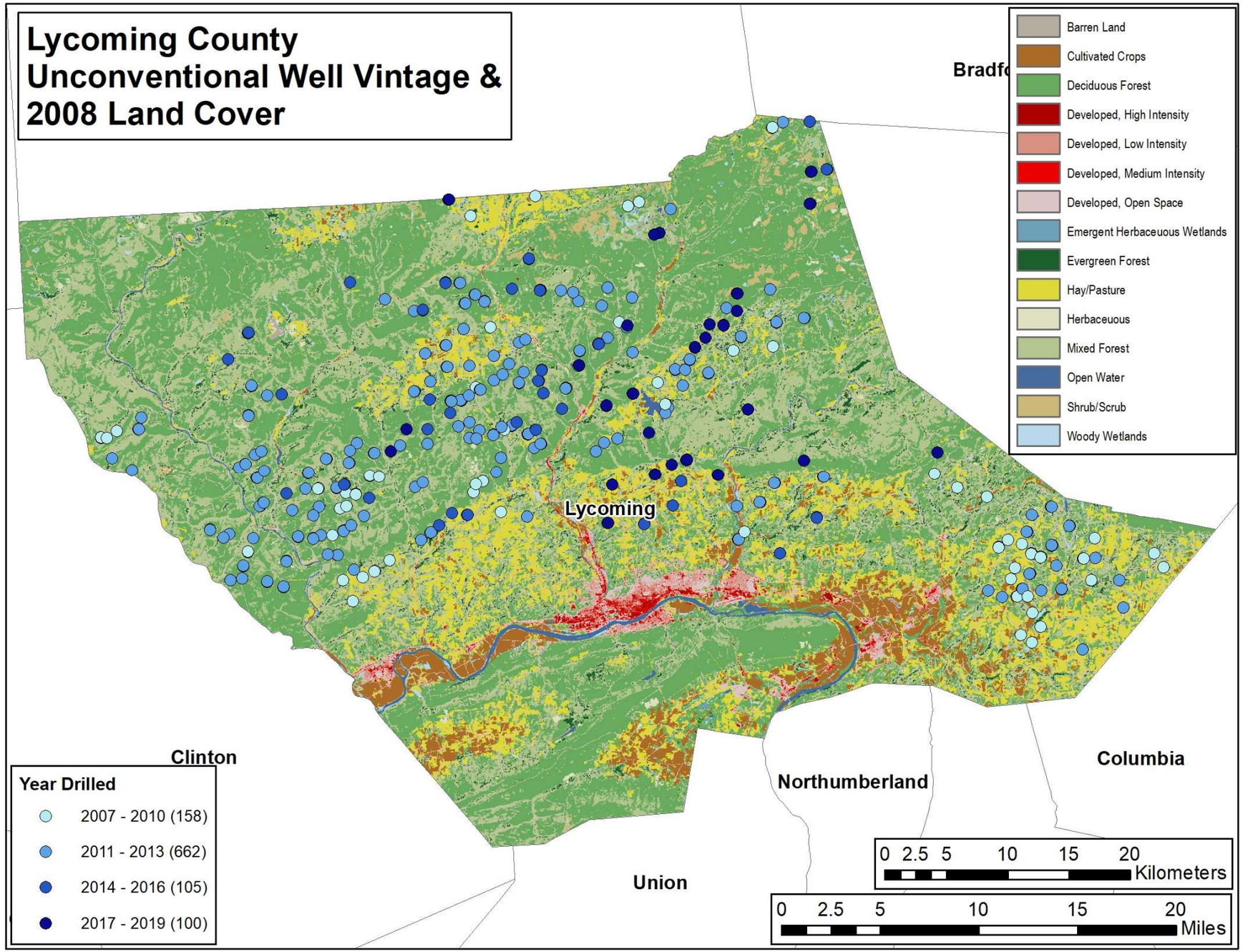



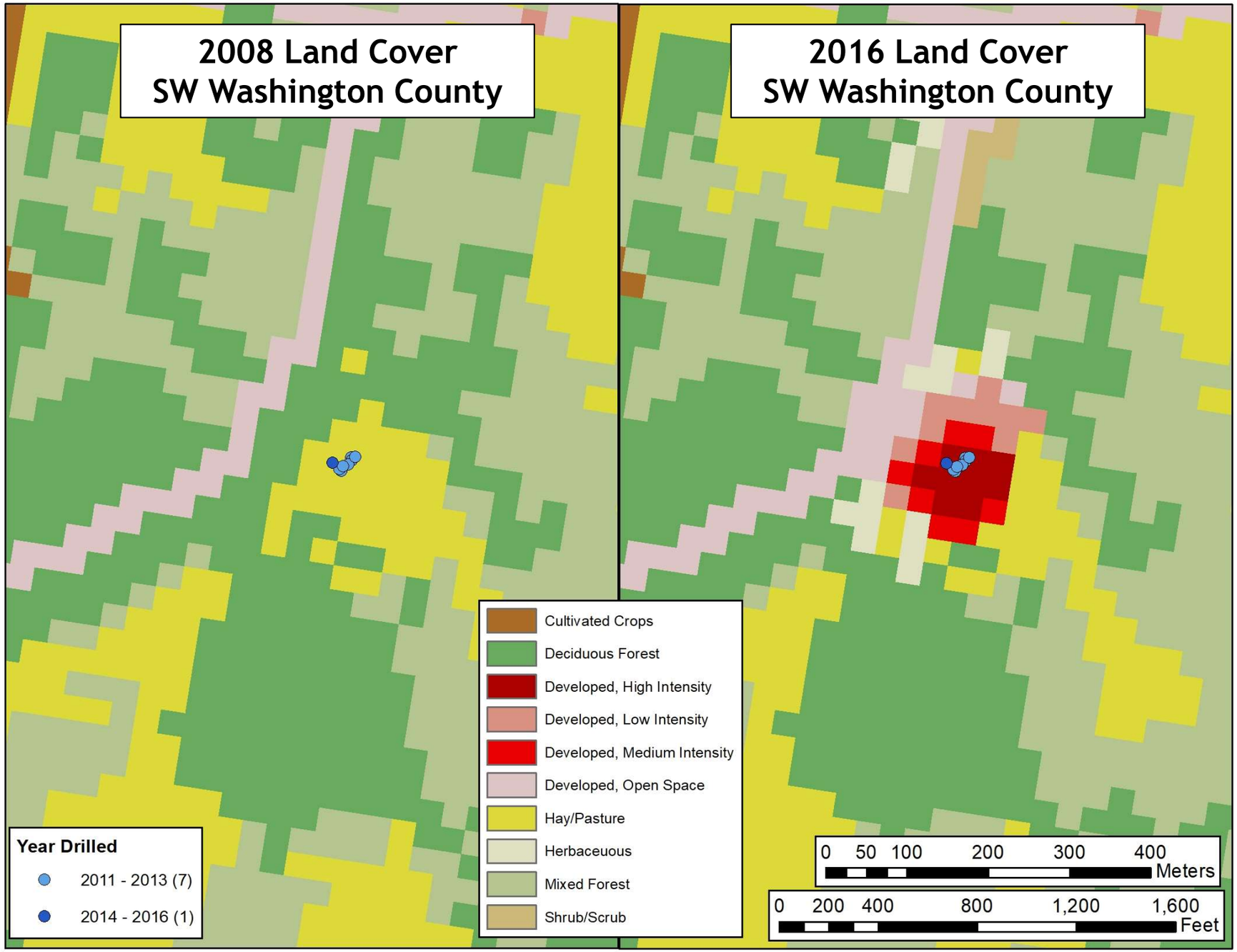
# 6.3. Land Cover/Land Use

- 2004, 2008, 2011 & 2016 NLCD Datasets (30 meter)
- Determine land cover change near wells (e.g. forest to developed)



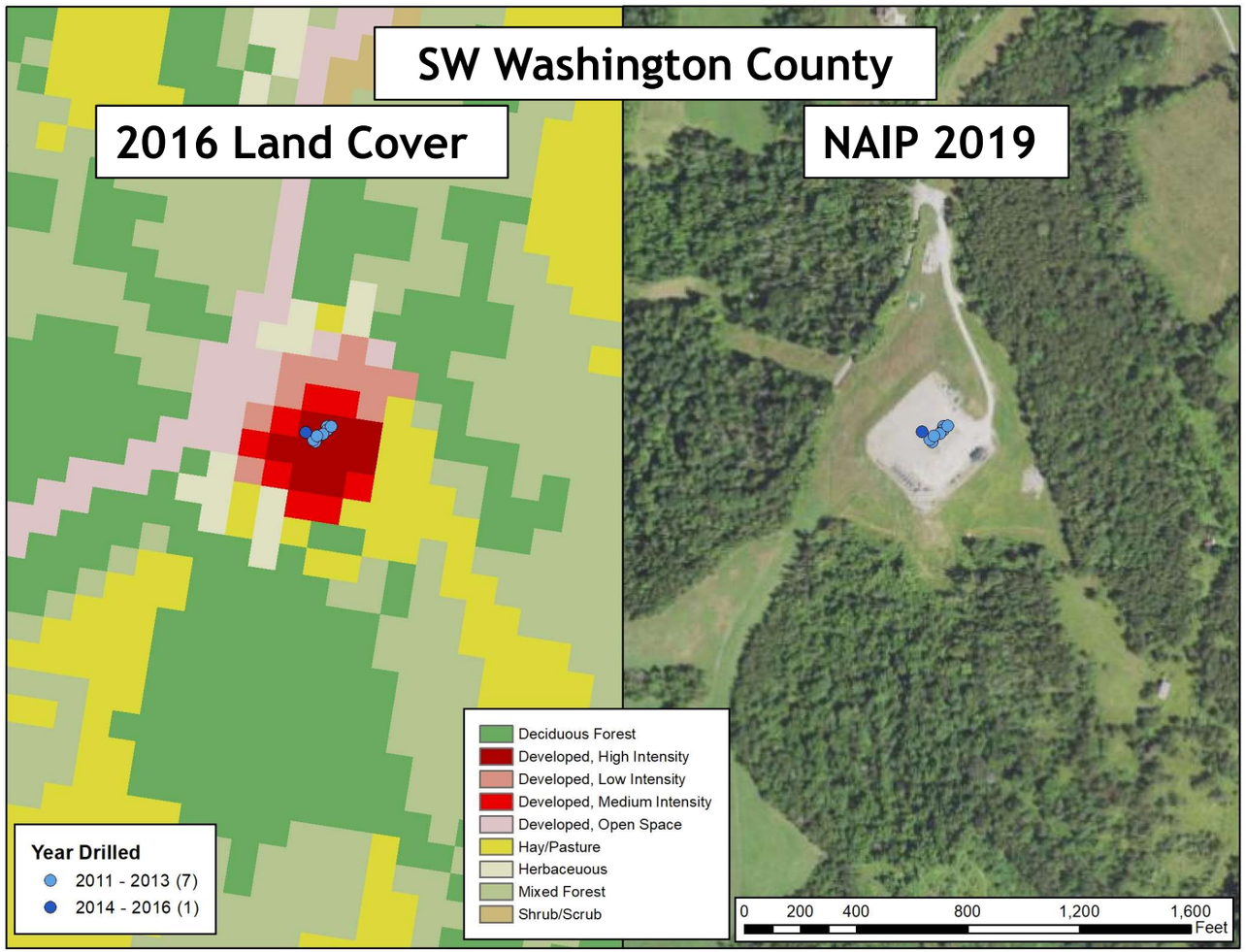




Lycoming County
Unconventional Well Vintage &
2008 Land Cover
Barren Land
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Emergent Herbaceuous Wetlands
Evergreen Forest
Hay/Pasture
Herbaceuous
Mixed Forest
Open Water
Shrub/Scrub
Woody Wetlands
Lycoming
Clinton
Union
Northumberland
Columbia
Year Drilled
2007 - 2010 (158)
2011 - 2013 (662)
2014 - 2016 (105)
2017 - 2019 (100)
0 2.5 5 10 15 20
Kilometers
0 2.5 5 10 15 20
Miles


2008 Land Cover
SW Washington County
2016 Land Cover
SW Washington County
Cultivated Crops
Deciduous Forest
Developed, High Intensity
Developed, Low Intensity
Developed, Medium Intensity
Developed, Open Space
Hay/Pasture
Herbaceuous
Mixed Forest
Shrub/Scrub
Year Drilled
2011 - 2013 (7)
2014 - 2016 (1)
0 50 100 200 300 400
Meters
0 200 400 800 1,200 1,600
Feet

# 6.4. Aerial Imagery

- NAIP (latest is 2019)
  - PA County Years = 2005, 2008, 2010, 2013, 2015, 2017, 2019

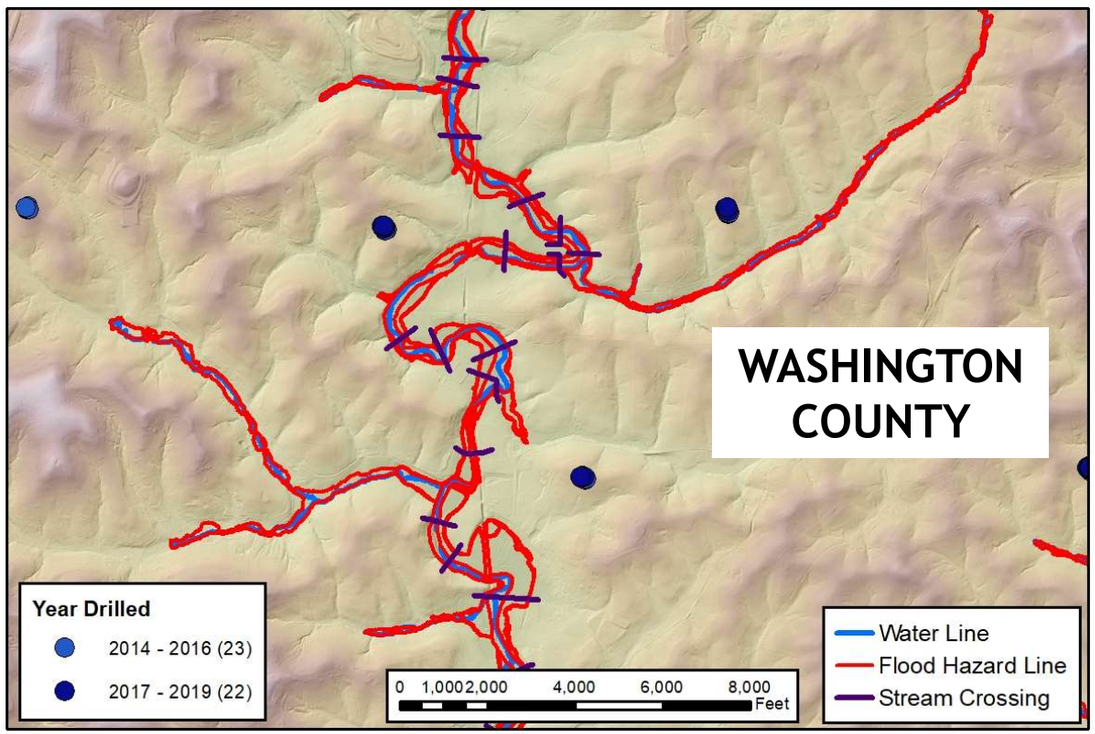


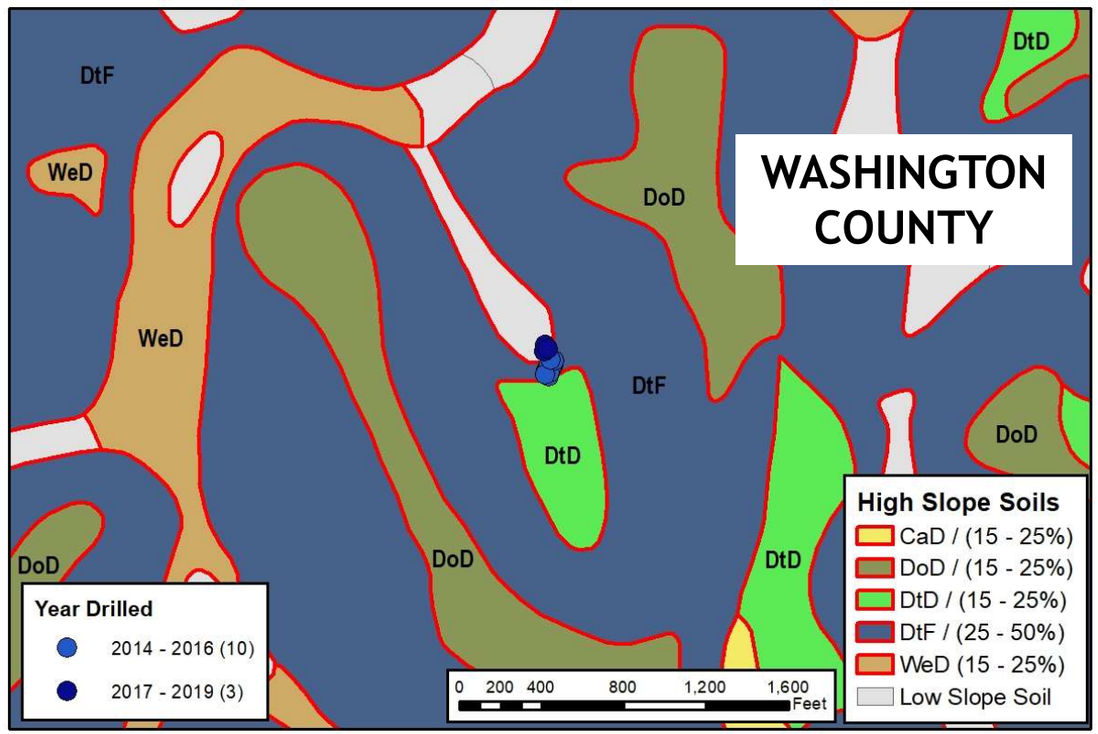

**Washington County NAIP Imagery (2019) 1 meter resolution**

- Will use to confirm land cover grids are accurate

# 6.5. Other Data

- Roads (Paved & Unpaved)
- Streams
- Soils
- Oil & Gas Water Pollution Control Facilities
- Storage Tank Locations



# 8. METHODS

## Subset Data

- Buffer well pad area
- Clip land cover and other datasets to well pad areas
- Determine average disturbed area (~5 acres)

## Quantify Land Change

- Calculate land cover area changes by category for each time interval

## Analyze Correlations

- Identify trends over time between both counties
- Compare geographic factors (proximity to infrastructure/environmental hazards, slope, soils)

## Production

- Compute production at well pad
- Calculate production efficiency per unit disturbed area

# 8. EXPECTED RESULTS

- Early wells in “easier” areas (low slope, close to existing roads, minimal land prepping)?
- More efficient production per unit disturbed area
- Identify most disturbed land cover type

***LIMITATIONS**

- Lack of high-res (1 m) and recent LiDAR data in Washington County (10 m still adequate)
- Land Cover data only through 2016 (30 meter), but have multiple prior years

# 9. POTENTIAL CONFERENCES

- AAPG Eastern Section Meeting: Champaign, IL - September 13, 2020
- Geological Society of America: Montreal, QB - October 25, 2020
- PA Geography Society: York, PA - November 6, 2020

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# QUESTIONS?