Geothermal Play Fairway Analysis of the Appalachian Basin: Lessons Learned in Reservoir Mapping and Characterization

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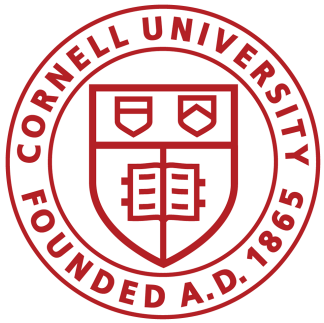

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GSA 2015, Baltimore, Maryland

Department of Energy Acknowledgement and Disclaimer

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1. MOTIVATION

2. FAIRWAY RESULTS

3. RESERVOIRS

"Combination of geologic factors that leads to the concentration of a desired resource"

Play Fairway Analysis

"Conducted during the early phases of resource exploration in order to highlight areas where more detailed exploration would be productive."

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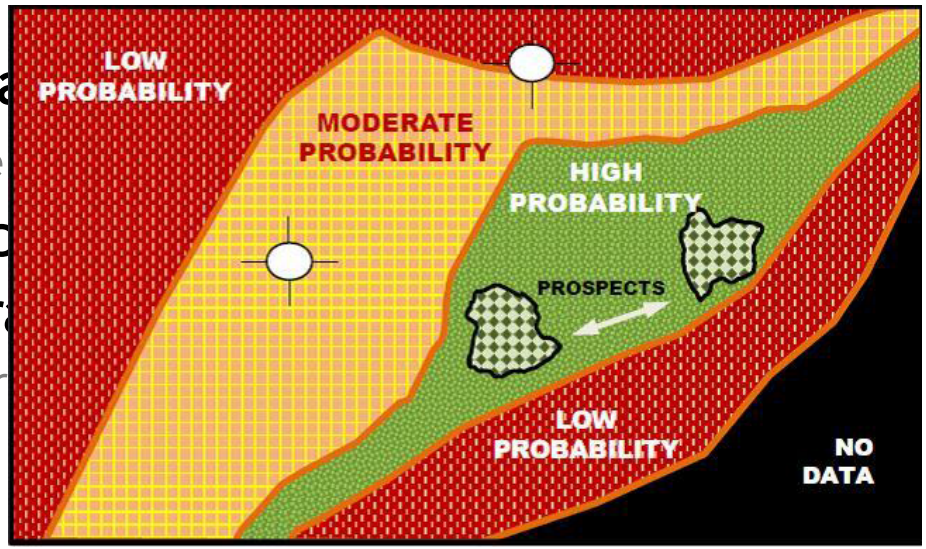
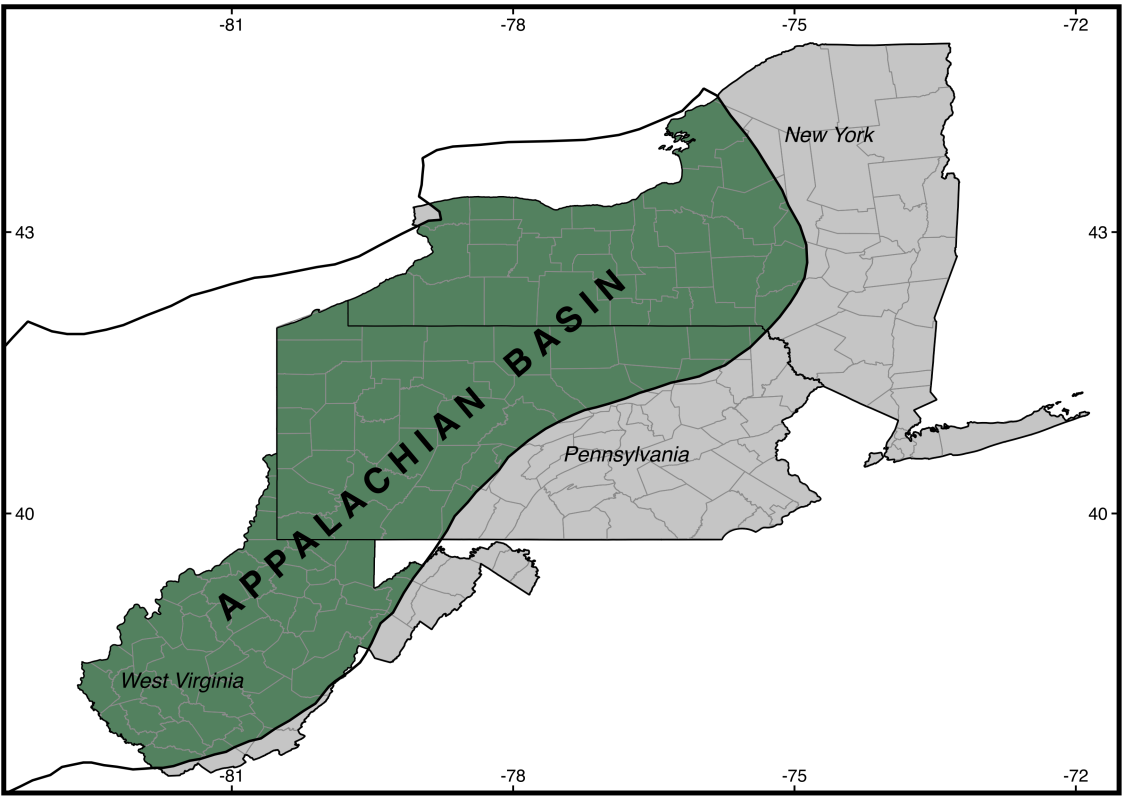
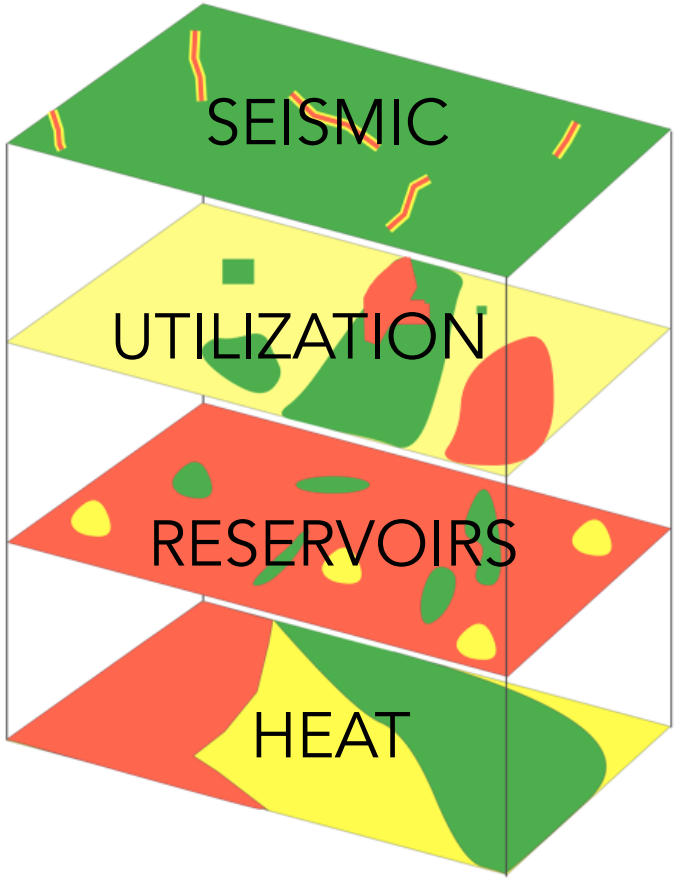


Source:
U.S. Department of Energy
EERE Geothermal Play Fairway Analysis Webinar Feb. 6, 2014

Geothermal Play Fairway Analysis

Sedimentary Basin
Hydrocarbon Reservoir
Low-temperature
Direct Use





PROJECT RESULTS

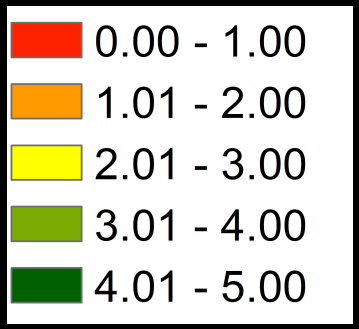
Thermal Resource

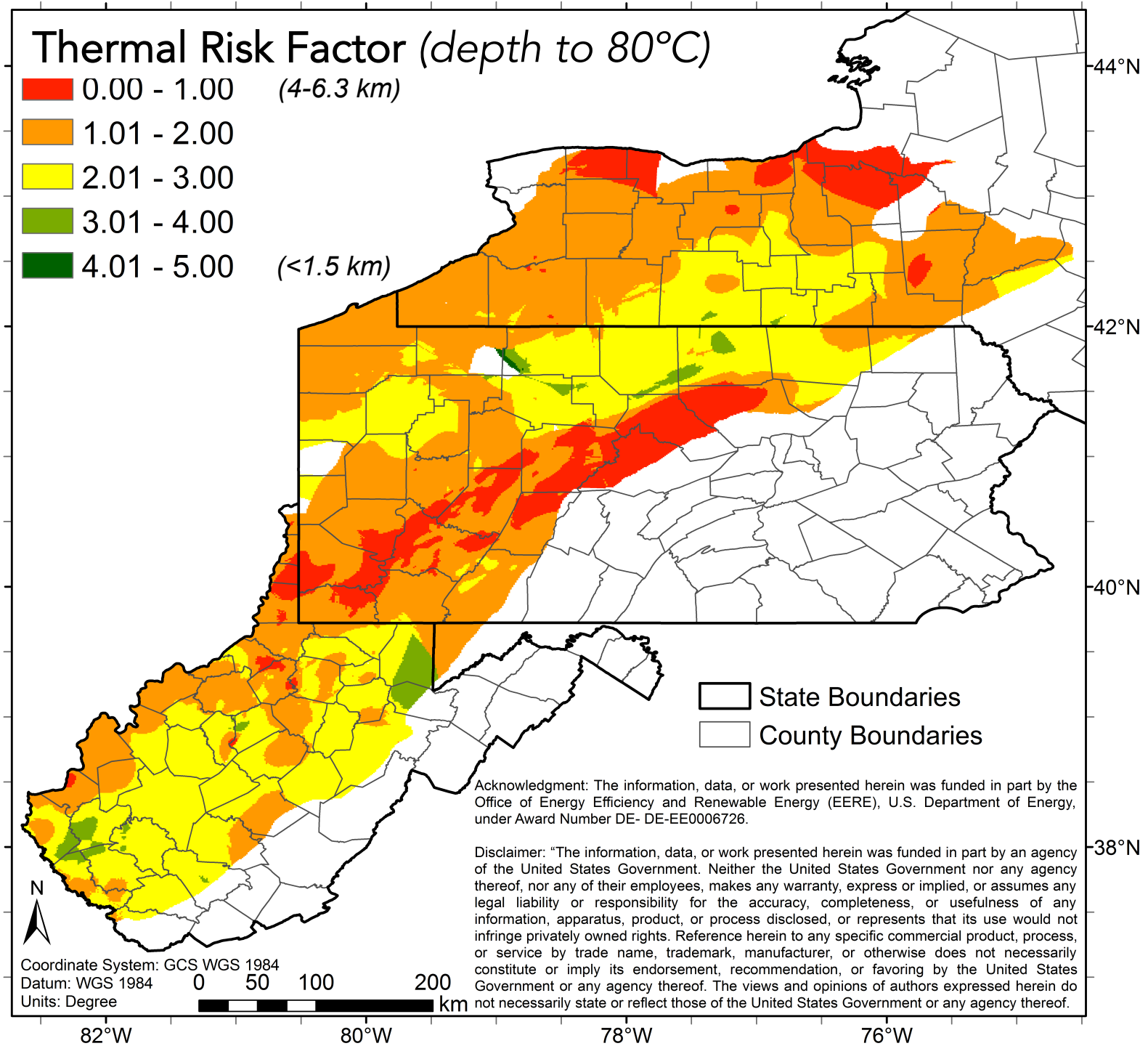
Natural Reservoirs

Seismic Risk

Utilization (Demand)

Combined





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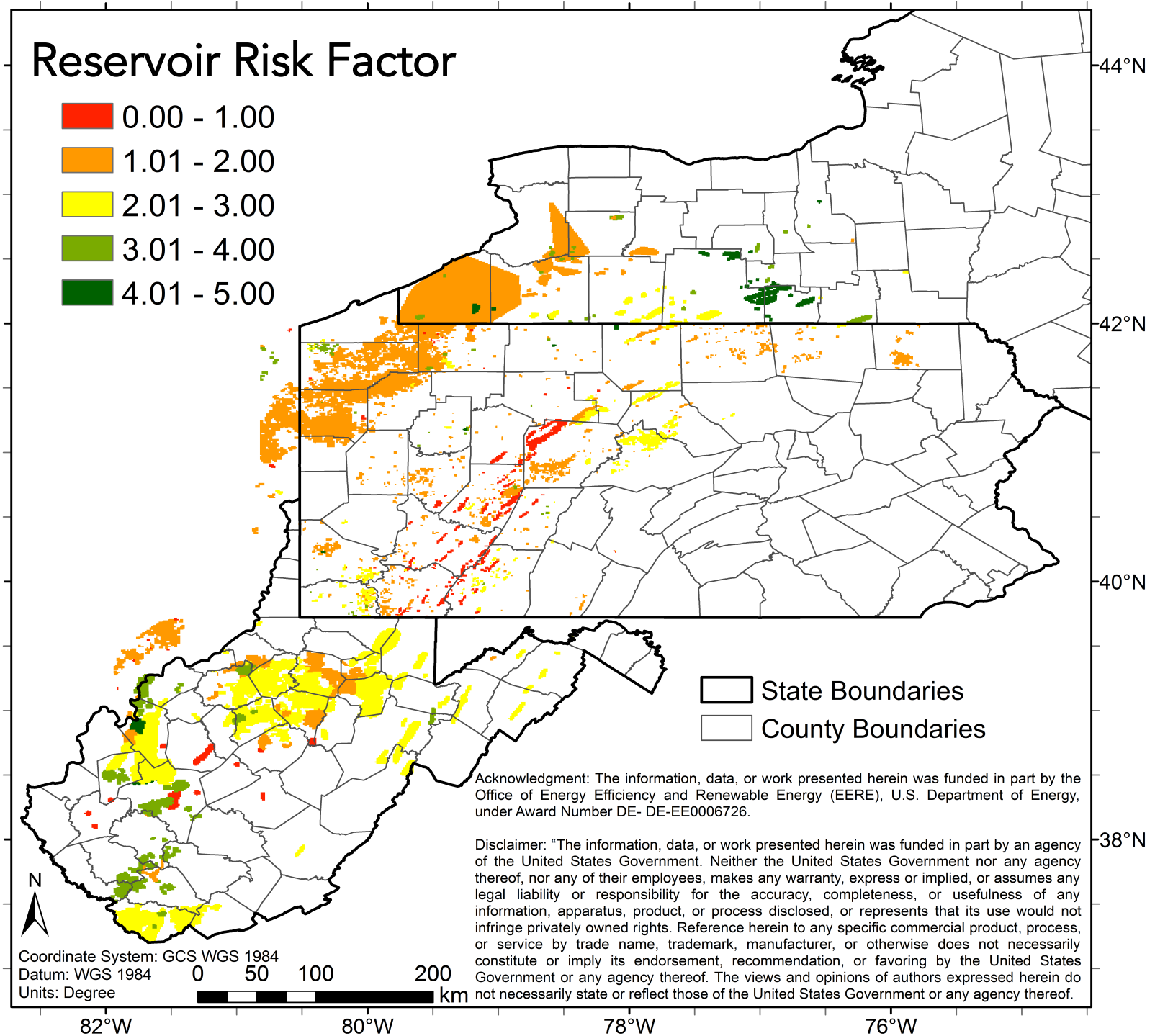
THERMAL

RESERVOIRS

SEISMIC

UTILIZATION



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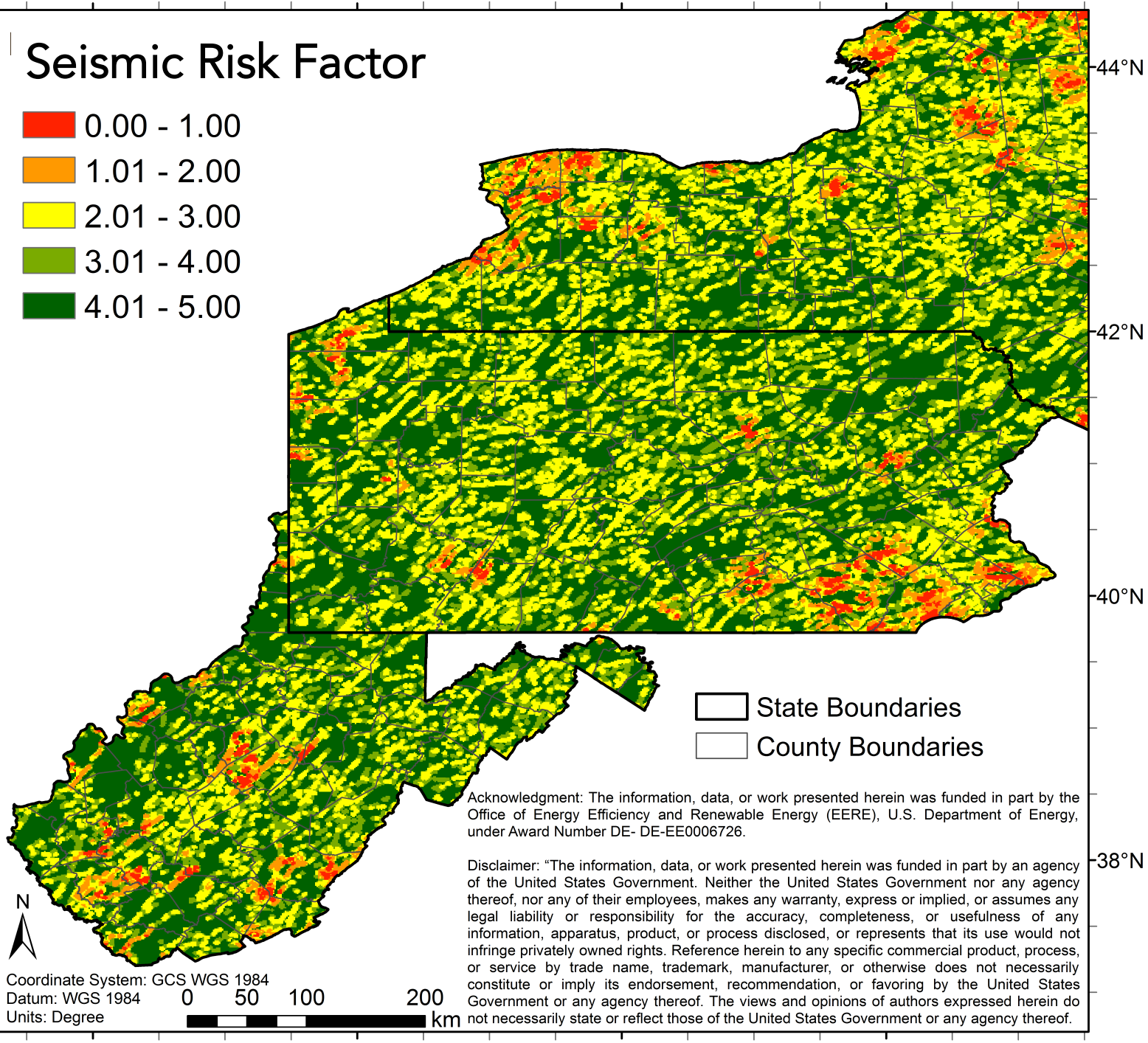
THERMAL

RESERVOIRS

SEISMIC

UTILIZATION

Seismic Risk Factor



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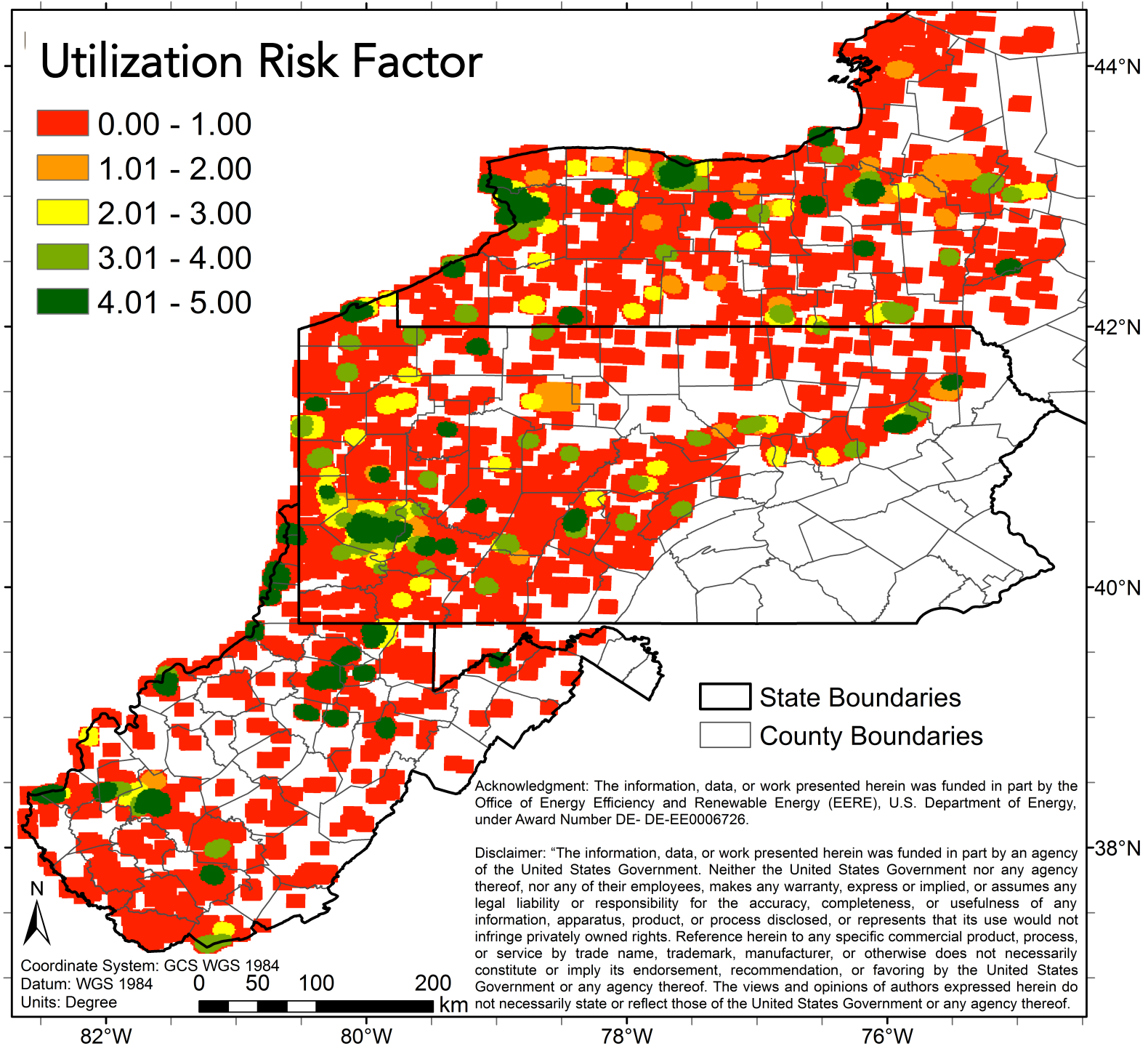
THERMAL

RESERVOIRS

SEISMIC

UTILIZATION



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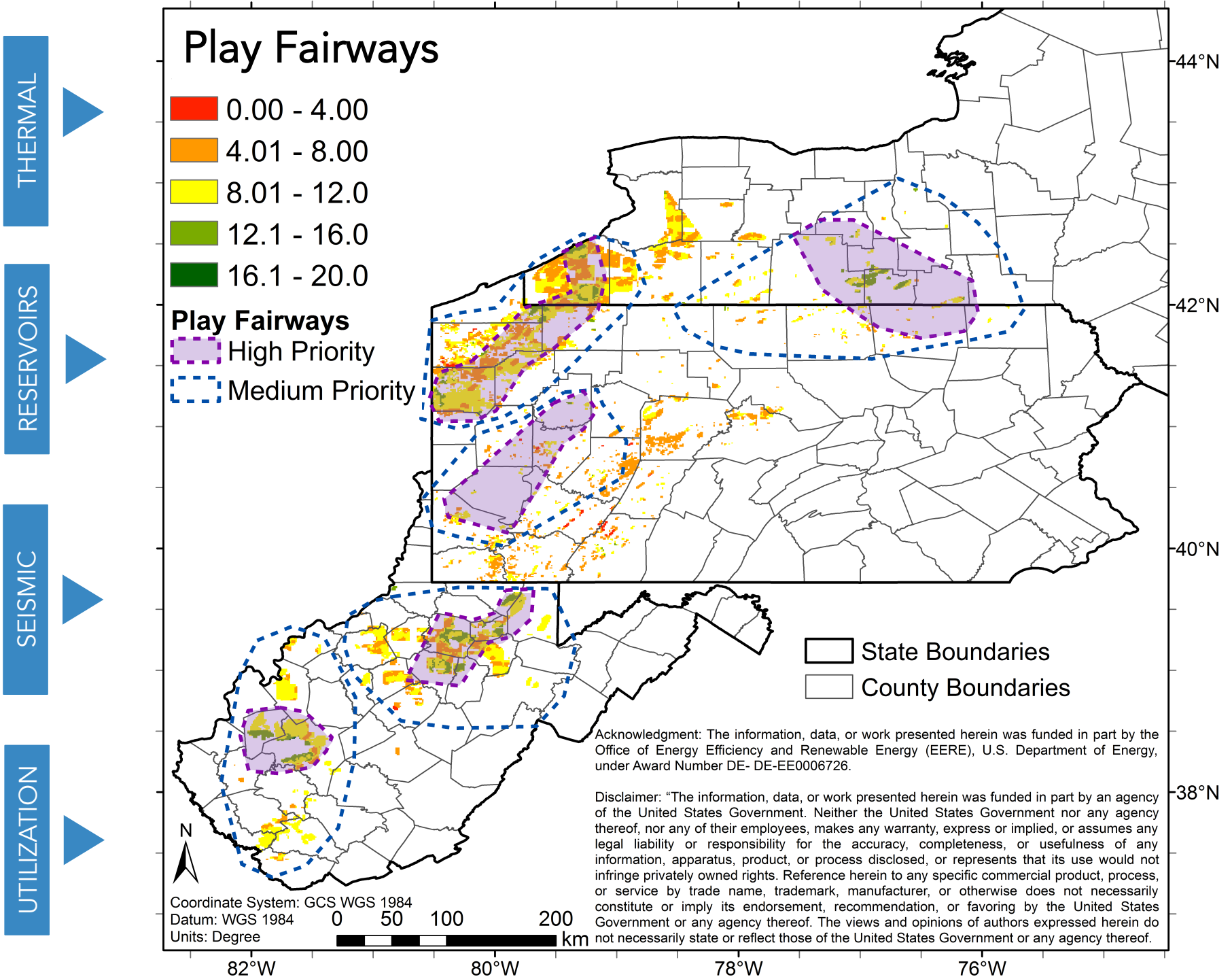

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Reservoirs Task

Methods and Results

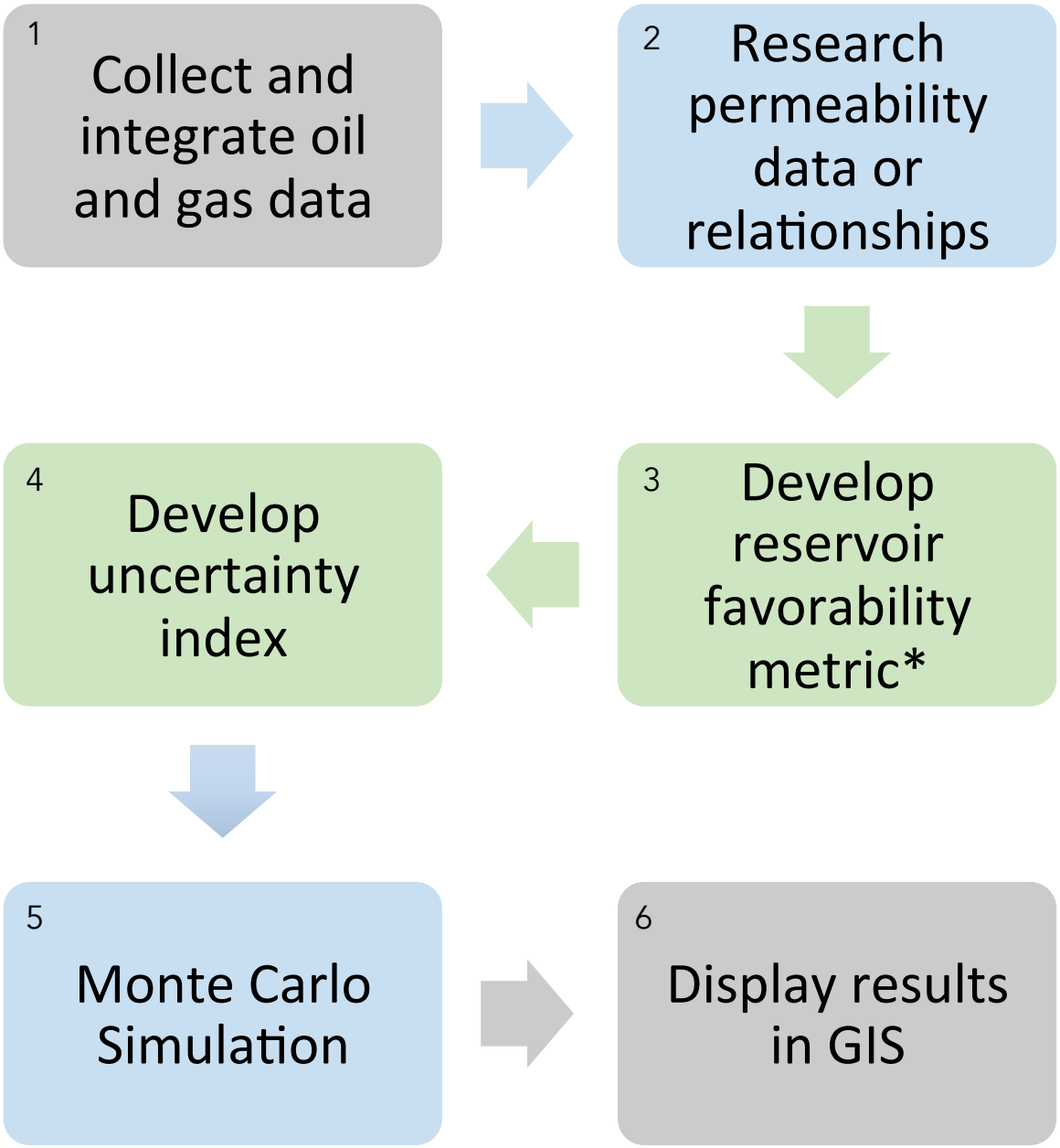
Reservoir Analysis Goals

1. Map out all reservoirs in study area that have produced hydrocarbons

2. Quantify reservoir favorability using available *reservoir* data

3. Quantify uncertainty for all reservoirs

Methods



*Available data:

- Porosity
- Permeability
- Thickness
- Depth

Flow Rate → Reservoir favorability?

Well Productivity Index:
Dupuit Eq., Porous Media

$$\frac{Q}{\Delta P} = \frac{2\pi kH}{\mu \ln\left(\frac{D}{r_w}\right)}$$

Q = flow rate
ΔP = pressure drop
k = permeability
H = reservoir thickness
μ = water viscosity
D = distance between wells
r_w = radius of wellbore

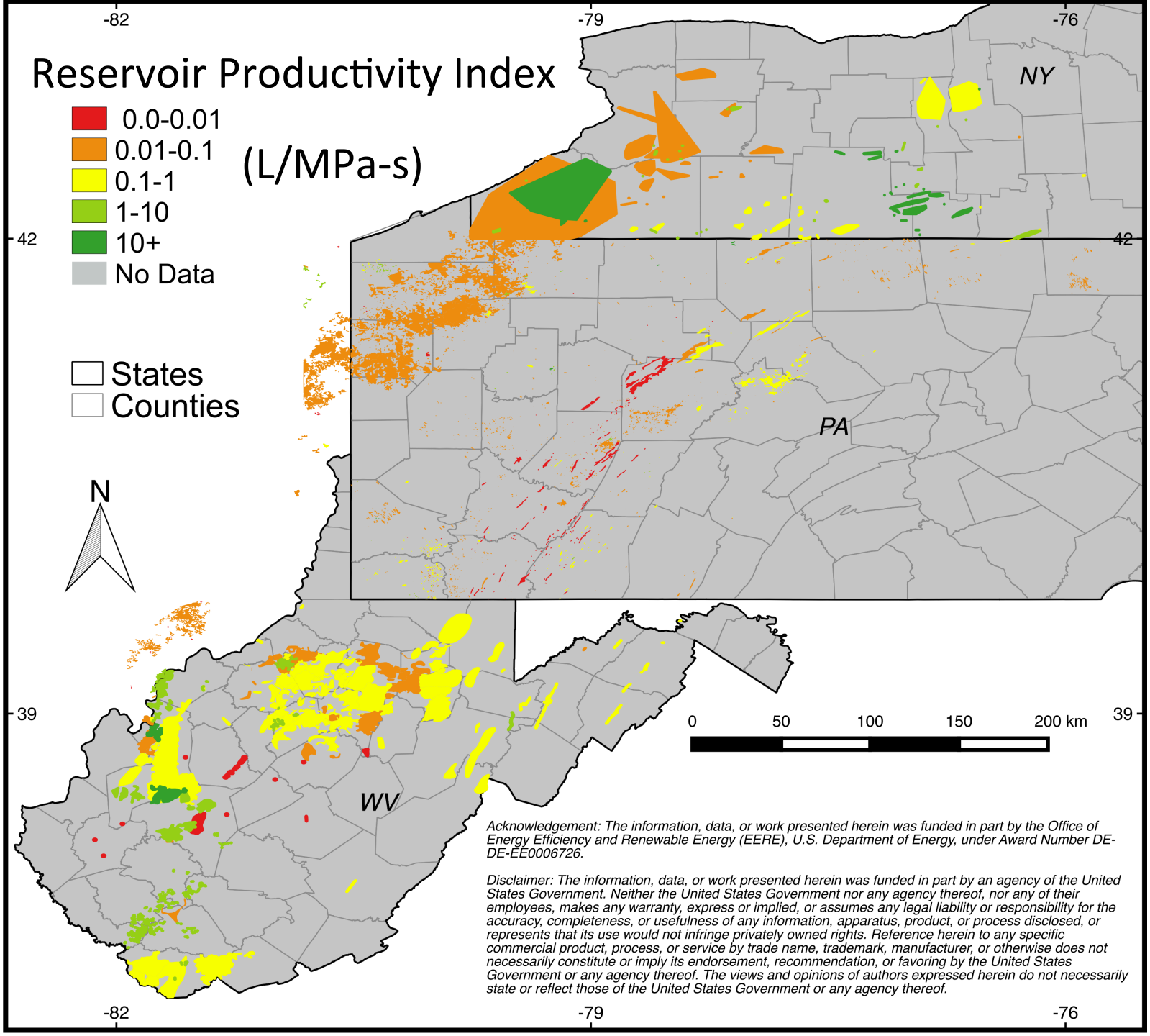
Reservoir Productivity Index:
Modified, Porous Media

$$\frac{Q}{\Delta P} = \frac{2\pi kH f_a}{\mu}$$

units: L/MPa-s

f_a = area factor
μ = *f*(depth)

Gringarten, 1978



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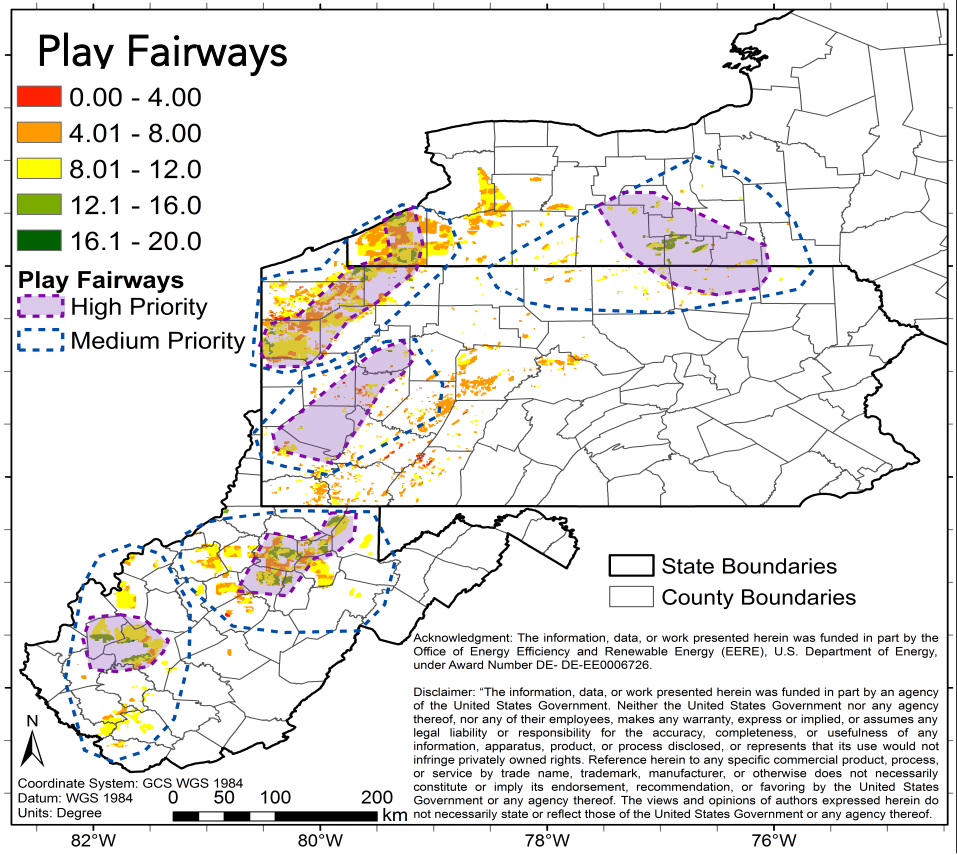
Lessons Learned—Reservoirs

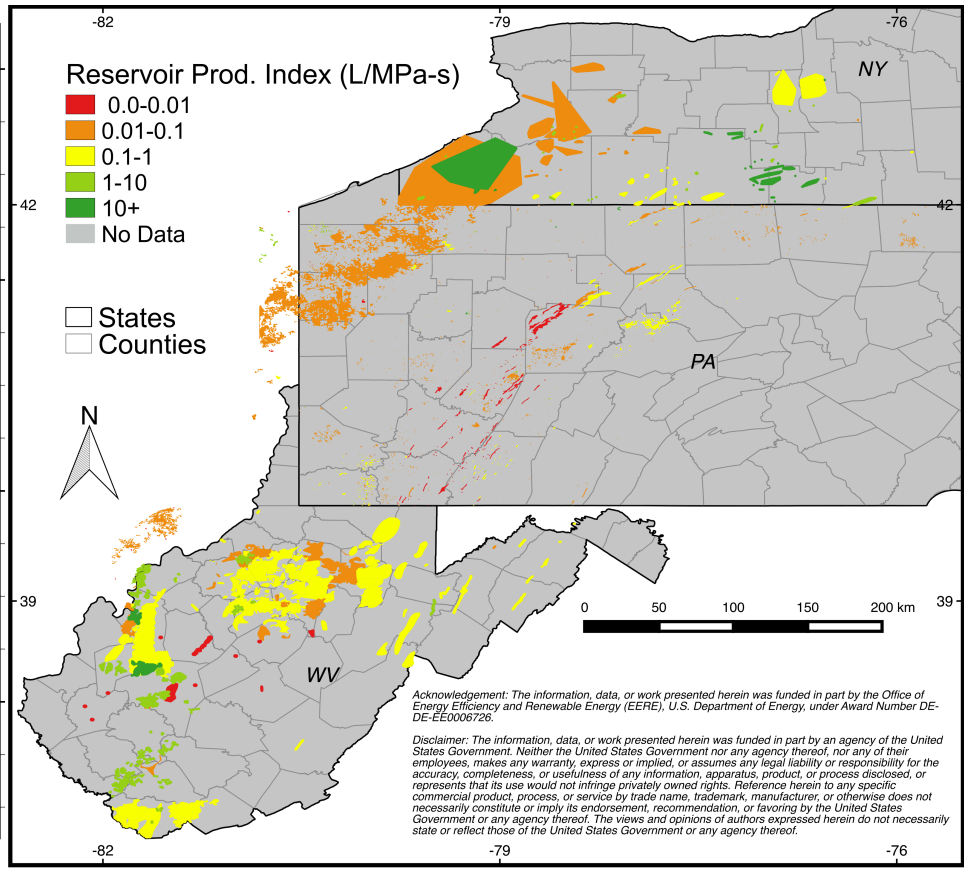
- ✓ Favorability metric not ideal
- ✓ On average low Reservoir Productivity
  - ❖ Permeability and thickness are major factors
- ✓ Low spatial coverage
  - ❖ Hydrocarbon database is limiting
  - ❖ 3D distribution is a challenge
- ✓ Permeability data quantity and quality are barriers
  - ❖ No way to quantify heterogeneity in reservoirs
- ✓ State boundaries present an issue

Future Considerations

- ✓ Inclusion of “dry” wells and geologic extrapolation
  - ❖ Find the “unknown” reservoirs
- ✓ Reservoir Productivity estimates likely to change with better permeability predictions
  - ❖ Acquiring flow data
  - ❖ Inter-well permeability approximations
  - ❖ Different equation for fractured reservoirs

Conclusions





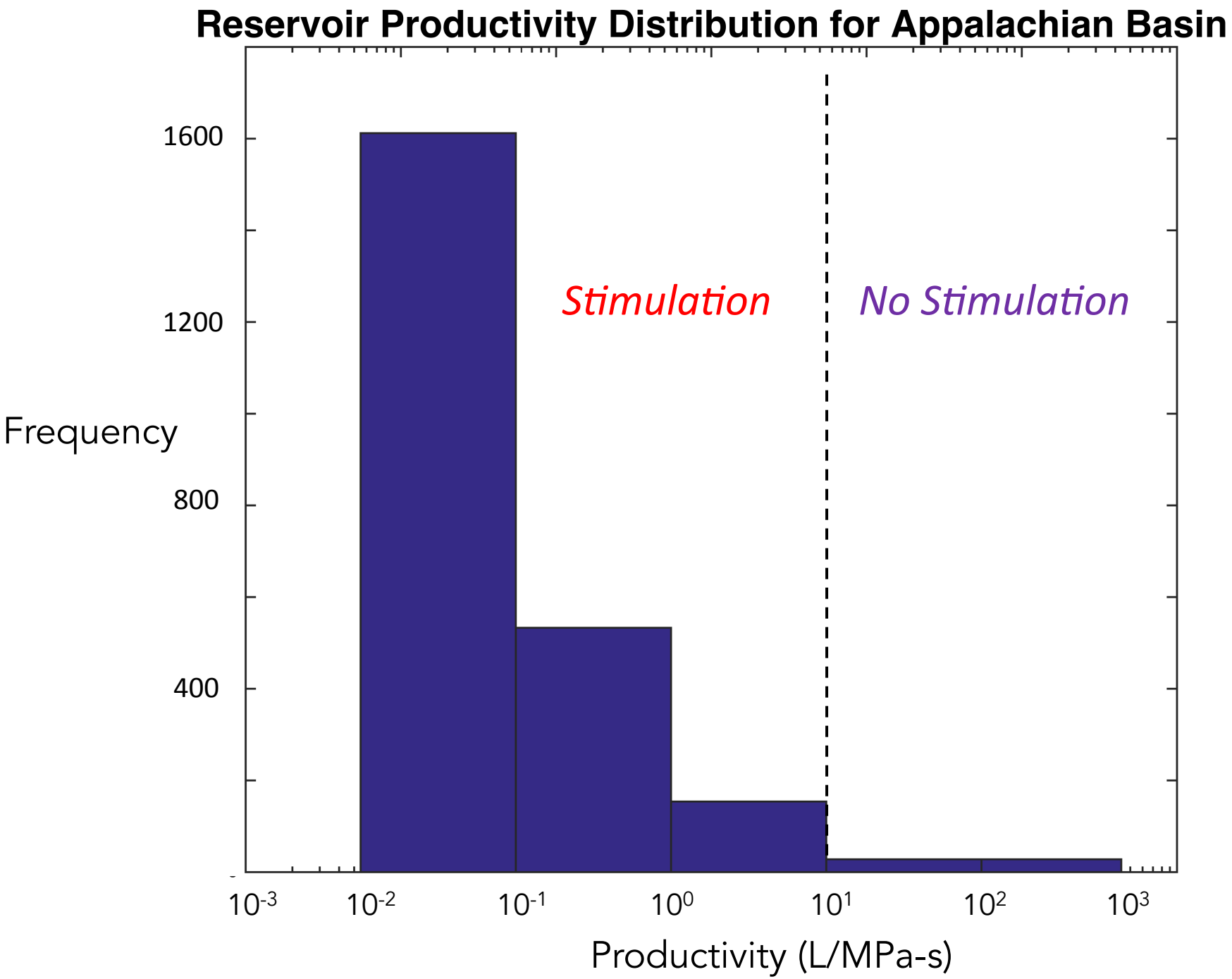
✓ Play Fairway Analysis is a useful tool

✓ Basin-scale reservoir analysis has challenges but does good job

Thank you! Questions?

Extra Slide

- Best Formations/Plays:
  - Trenton-Black River Dolomite (NY, PA)
  - Lockport Dolomite (PA)
  - Oriskany Sandstone (PA, WV, NY)
  - Newburg Sandstone (WV)
  - Onondaga Pinnacle Reefs (NY)
  - Devonian Unconformity Play (PA)


Reservoir Productivity Distribution for Appalachian Basin
Frequency
1600
1200
800
400
Stimulation
No Stimulation
10-3
10-2
10-1
100
101
102
103
Productivity (L/MPa-s)

Sensitivity Analysis for Reservoir Productivity Index