

Assessing Methane in Shallow Groundwater for the Berea Sandstone and Rogersville Shale Play Area, Eastern Kentucky*

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Abstract

Rapid implementation of horizontal drilling and hydraulic fracturing technology in producing oil and gas from tight rock formations across the country has increased public concerns about possible impacts on the environment, especially on shallow drinking water aquifers. In eastern Kentucky, horizontal drilling and fracturing activities in the Upper Devonian Berea Sandstone have increased in recent years. While production activities in the Berea Sandstone are at a relatively small scale, public attention has been drawn to the Rogersville Shale, a deeper, thicker, and more areally extensive organic-rich shale projected to become a major shale play in eastern Kentucky. Information about existing groundwater quality, especially dissolved methane, in aquifers overlying the Berea and Rogersville play areas is critical to help address the public's environmental concerns and protect groundwater resources.

The Kentucky Geological Survey, in collaboration with GSI Environmental, collected and analyzed groundwater samples from existing domestic and public water-supply wells located in Greenup, Carter, Boyd, Lawrence, Johnson, and Elliot Counties. The objectives of this project are to obtain an understanding of baseline groundwater chemistry throughout the study area and to use isotope data to evaluate possible sources of methane detected in the groundwater. Fifty-one water wells were sampled and analyzed for major cations and ions, metals, and dissolved gases including methane. Wells with elevated methane concentration were also analyzed for carbon and hydrogen isotopes. Results from this study provide the first assessment of methane concentrations, possible sources of methane, and the relation of methane to water chemistry in the area.

Selected References

Harlow, Jr., G.E., and G.D. LeCain, 1993, Hydraulic Characteristics of, and Ground-Water Flow in, Coal-Bearing Rocks of Southwestern Virginia: U.S. Geological Survey, Water Supply Paper 2388, 36 p., Web Accessed November 24, 2016, http://pubs.usgs.gov/wsp/wsp_2388/pdf/wsp_2388.pdf

Whiticar, M.J., 1999, Carbon and hydrogen isotope systematics of bacterial formation and oxidation of methane: Chemical Geology, v. 161, p. 291–314, Web Accessed November 24, 2016, http://sethnewsome.org/sethnewsome/EE_files/Whiticar%201999.pdf

Wunsch, D.R., 1993, Ground-water geochemistry and its relationship to the flow system at an unmined site in the eastern Kentucky coal field: Thesis Series 5, KY Geol. Survey, Series XI, 128 p.

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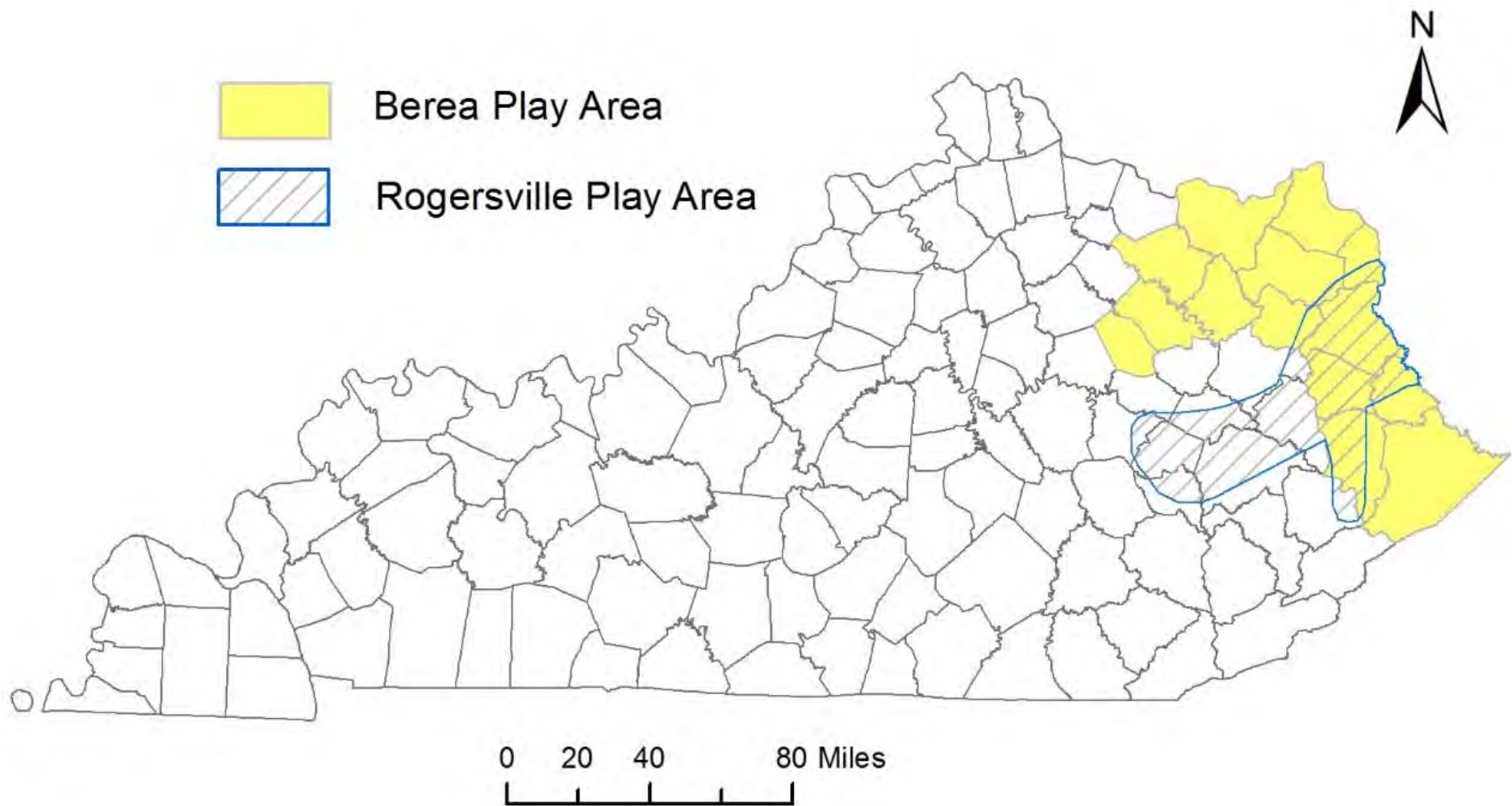
1. Kentucky Geological Survey, University of Kentucky
2. GSI Environmental Inc.



Kentucky
Geological Survey

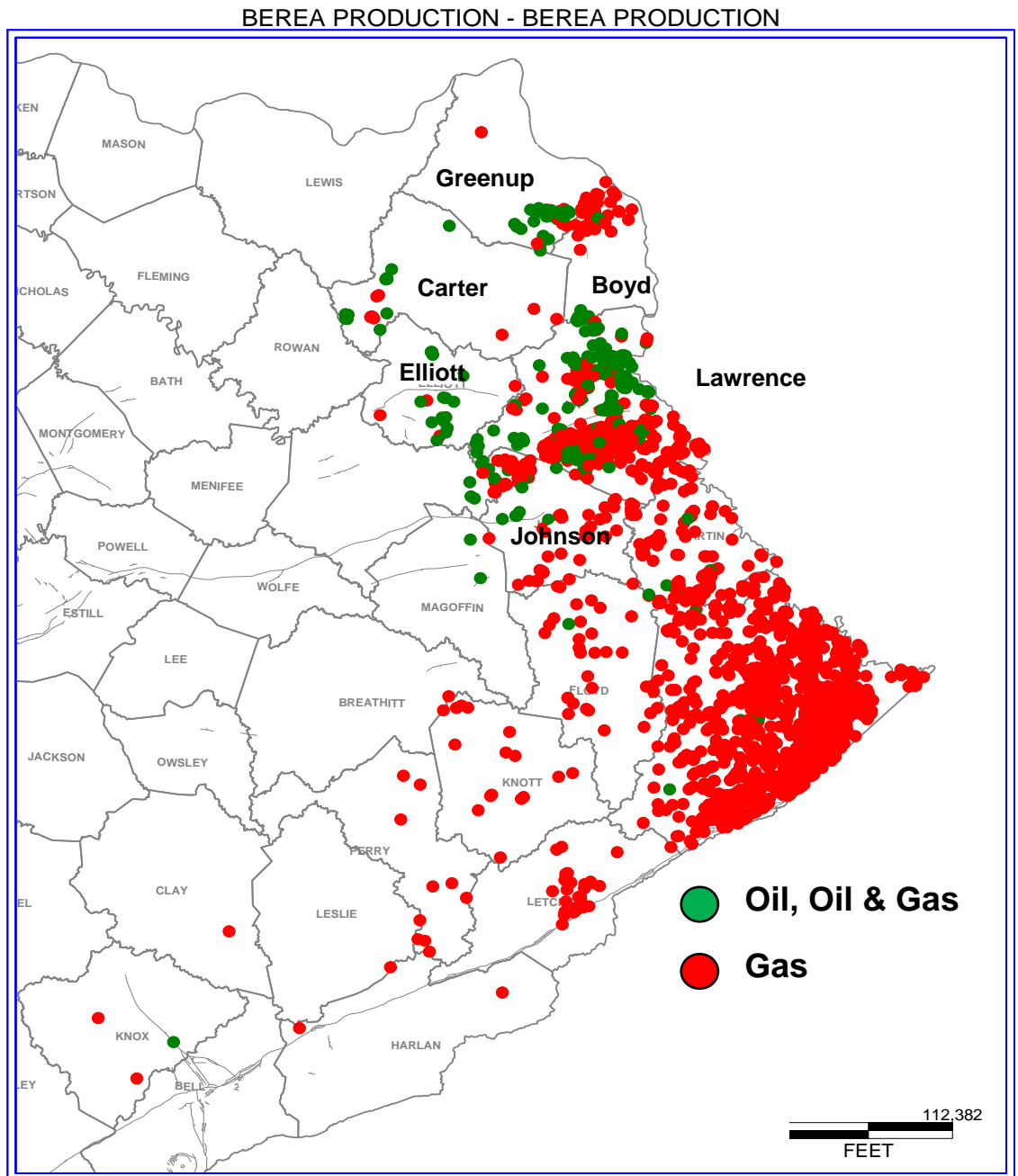
45th Annual Meeting, ES-AAPG
Sept. 25-27, 2016
Lexington, Kentucky





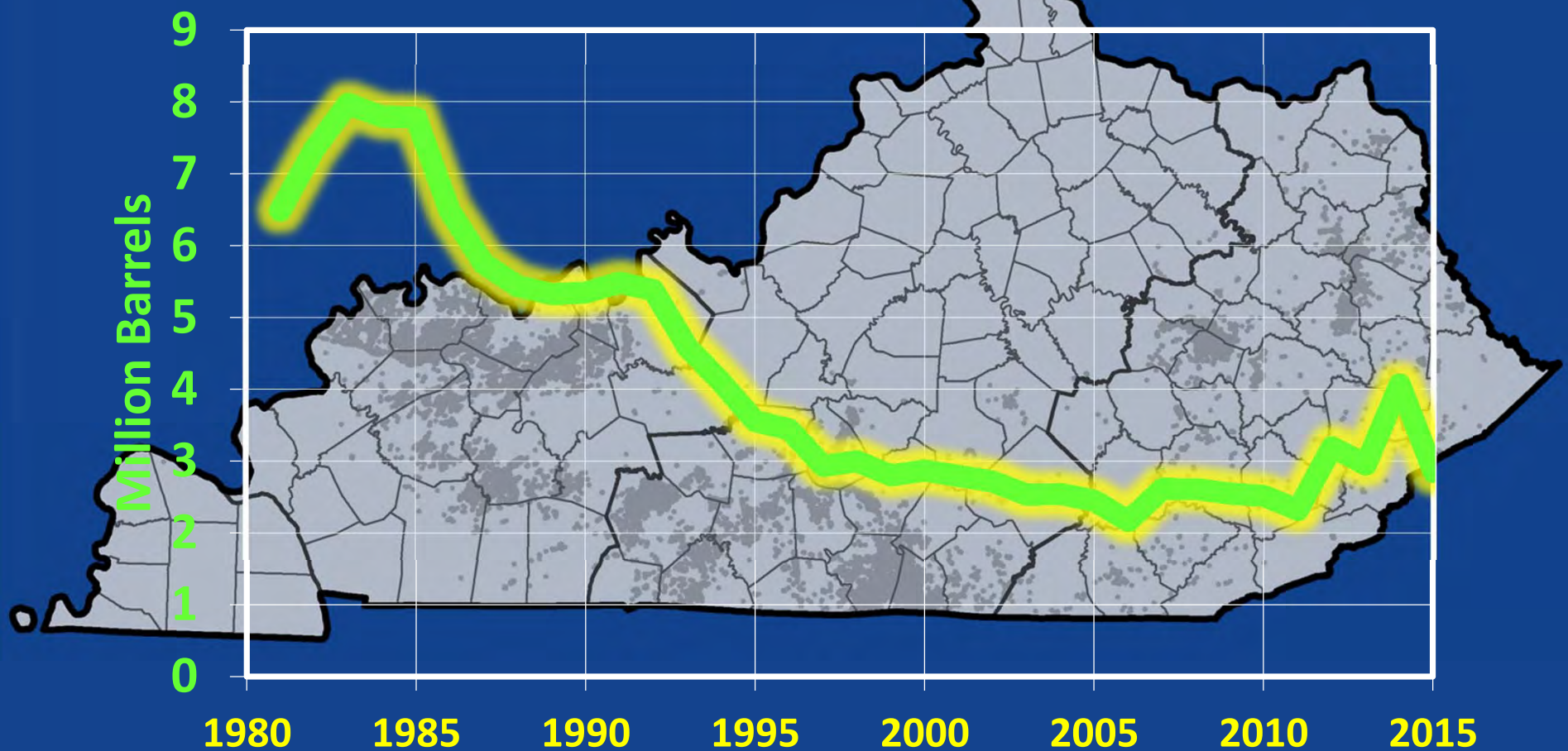
Berea Play

- Historic Devonian Berea Sandstone production mostly gas (red circles)
- Since 2010 active oil play in Elliott, Carter, Greenup, Lawrence, Johnson, and Boyd Counties
- Approximately 70 horizontal oil wells completed (green circles)



Oil Production in Kentucky

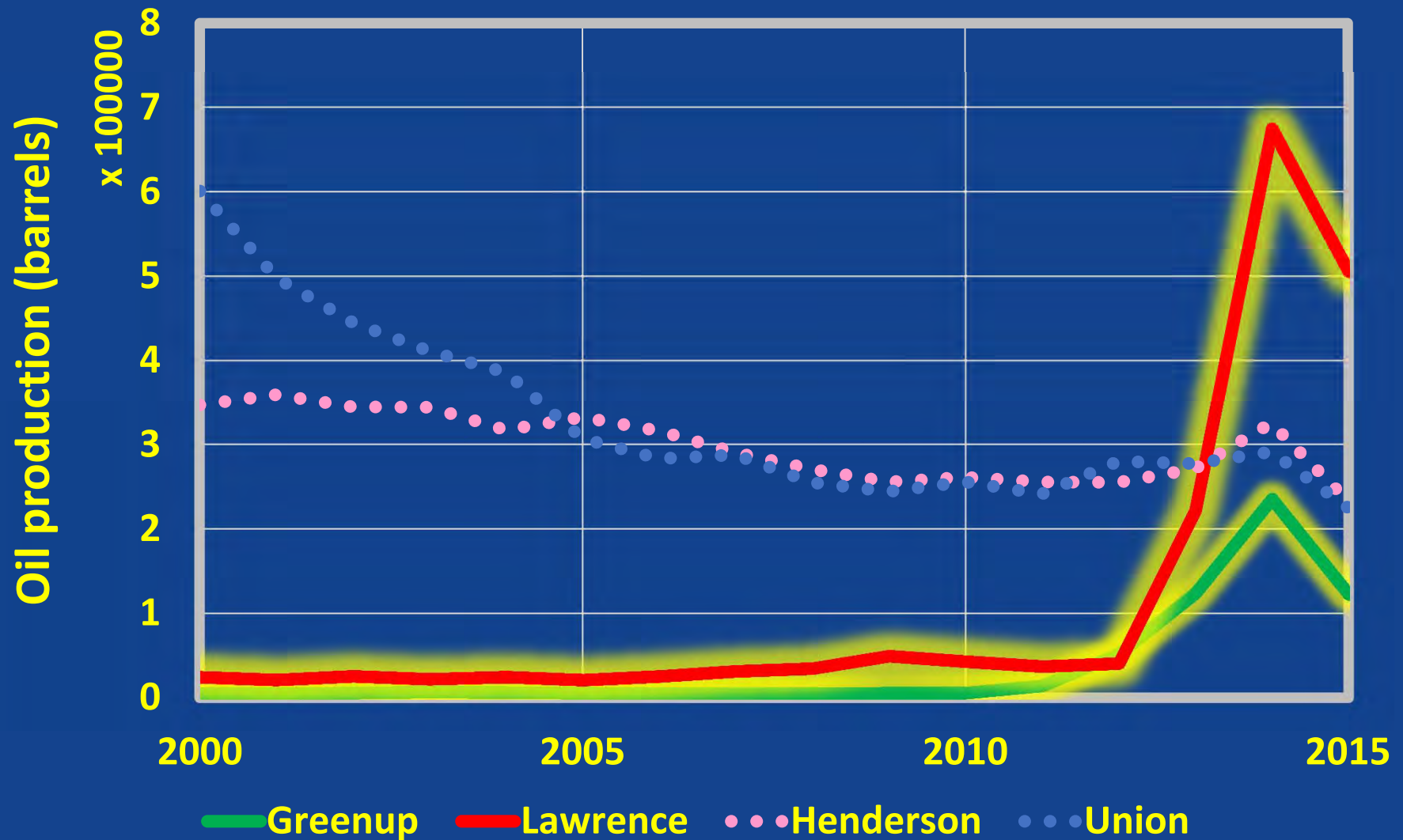
(2014 – 75% increase over 2011)



63 Kentucky counties

Courtesy of B. Nuttall

Significant Increase in Berea Production



Courtesy of B. Nuttall

Eastern Kentucky Mid-Upper Paleozoic Stratigraphy

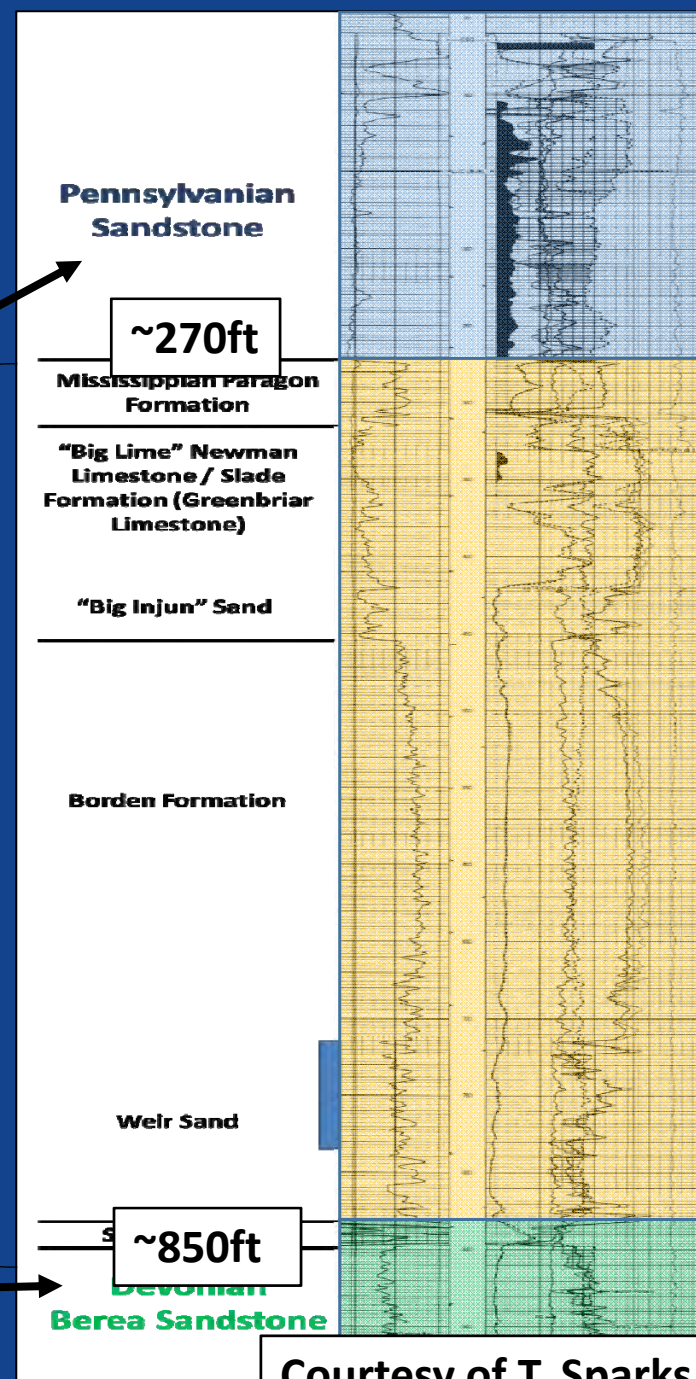
Volume of fluid (10^3 bbls) and sand (10^5 lbs) used in hydraulic fracturing small compared to other unconventional plays

But horizontal drilling and hydraulic fracturing at shallow depth—most less than 2,000 ft)

Groundwater aquifers

Confining intervals (~600 ft thick)

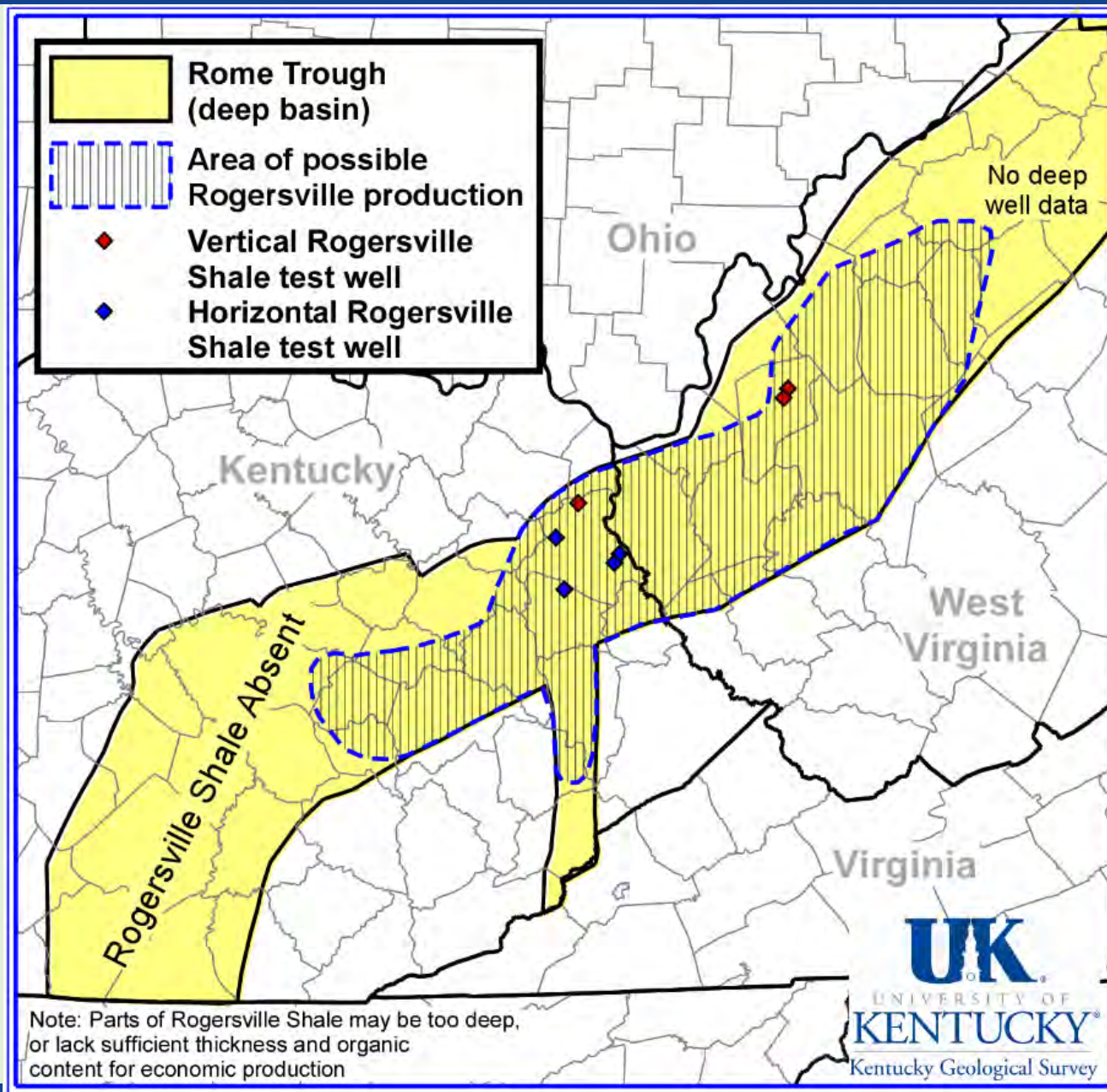
Oil reservoir (~ 150 ft thick)



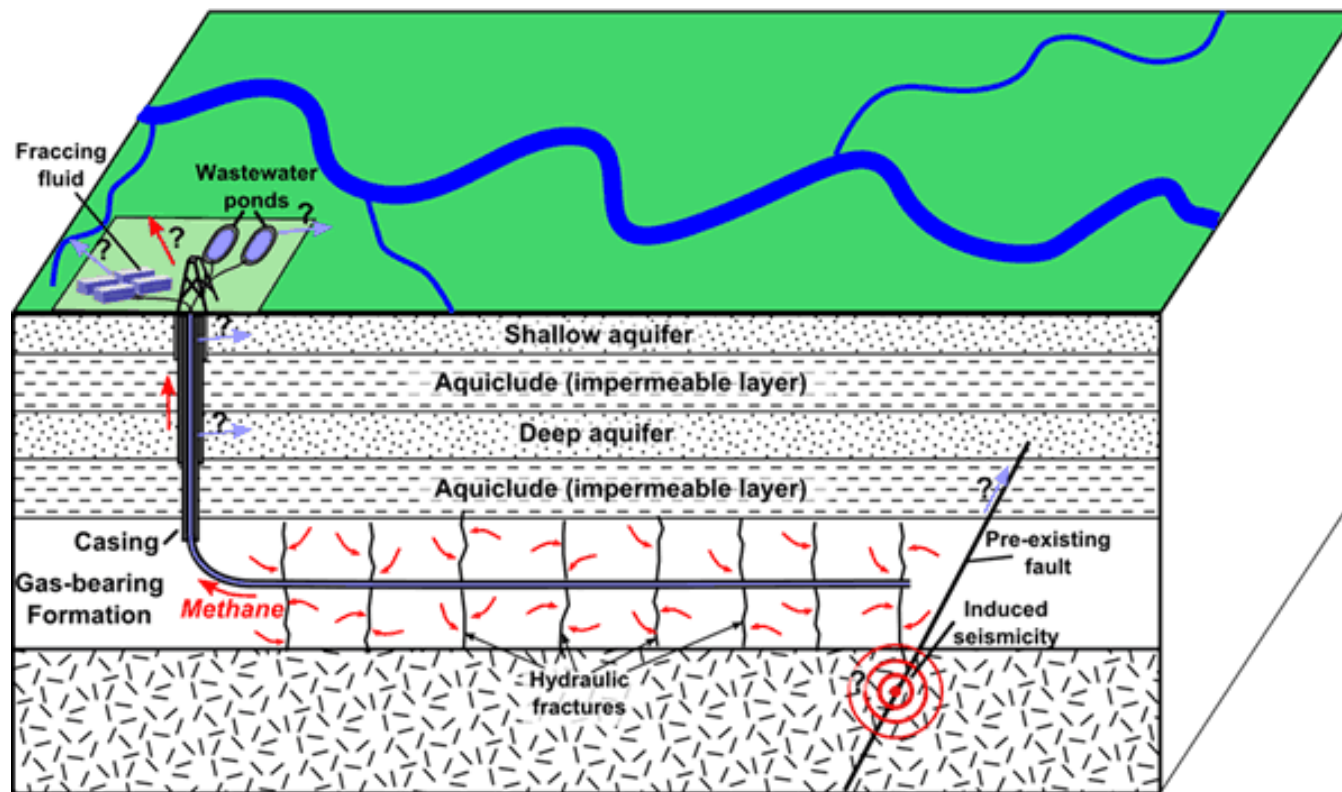
Courtesy of T. Sparks

Rogersville Shale

- 5,000 to 10,000 ft deep
- Up to 1,100 ft thick in Kentucky, but not all is organic rich
- Very early stage of development
- Opportunity to gather baseline groundwater data prior to any large-scale development

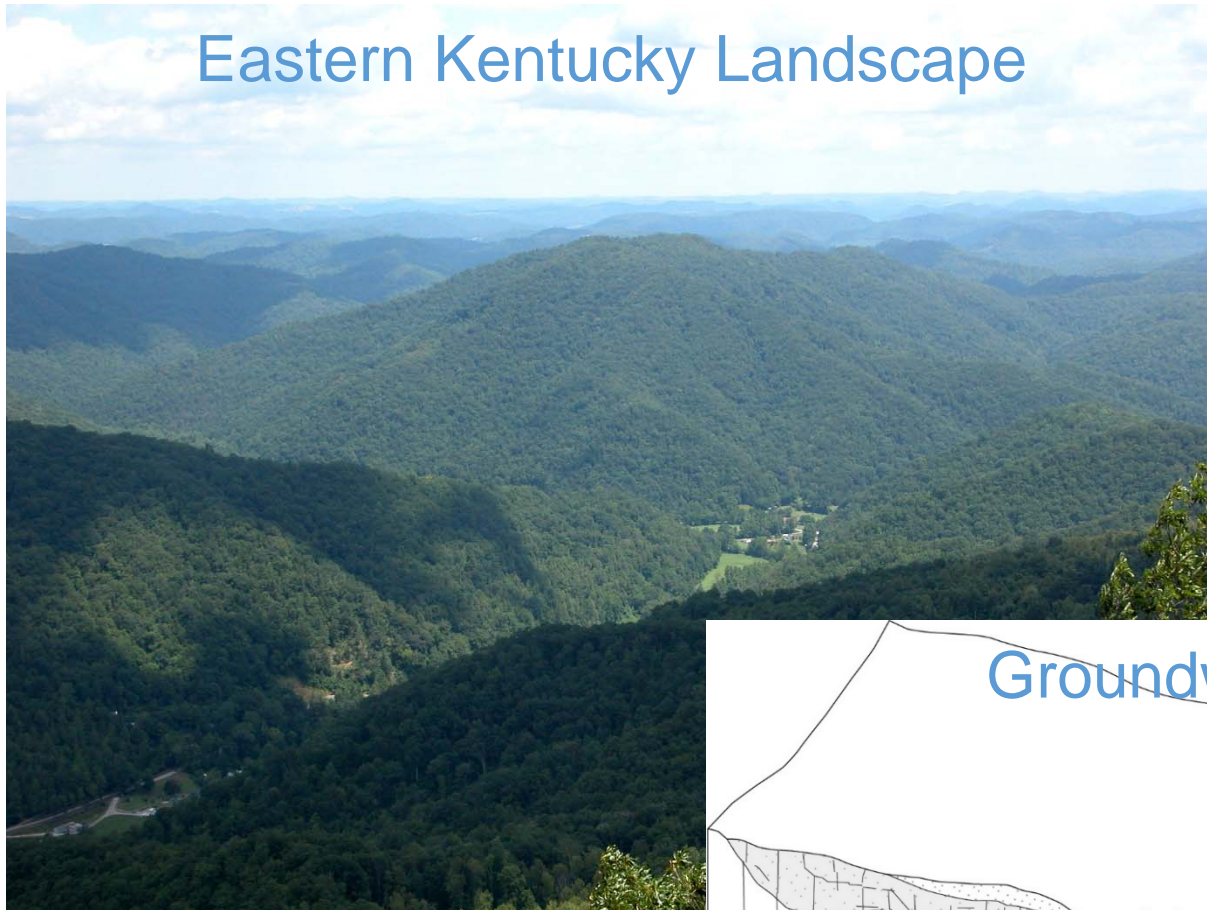


Possible Contamination Pathways of Hydraulic Fracturing to Groundwater Aquifers

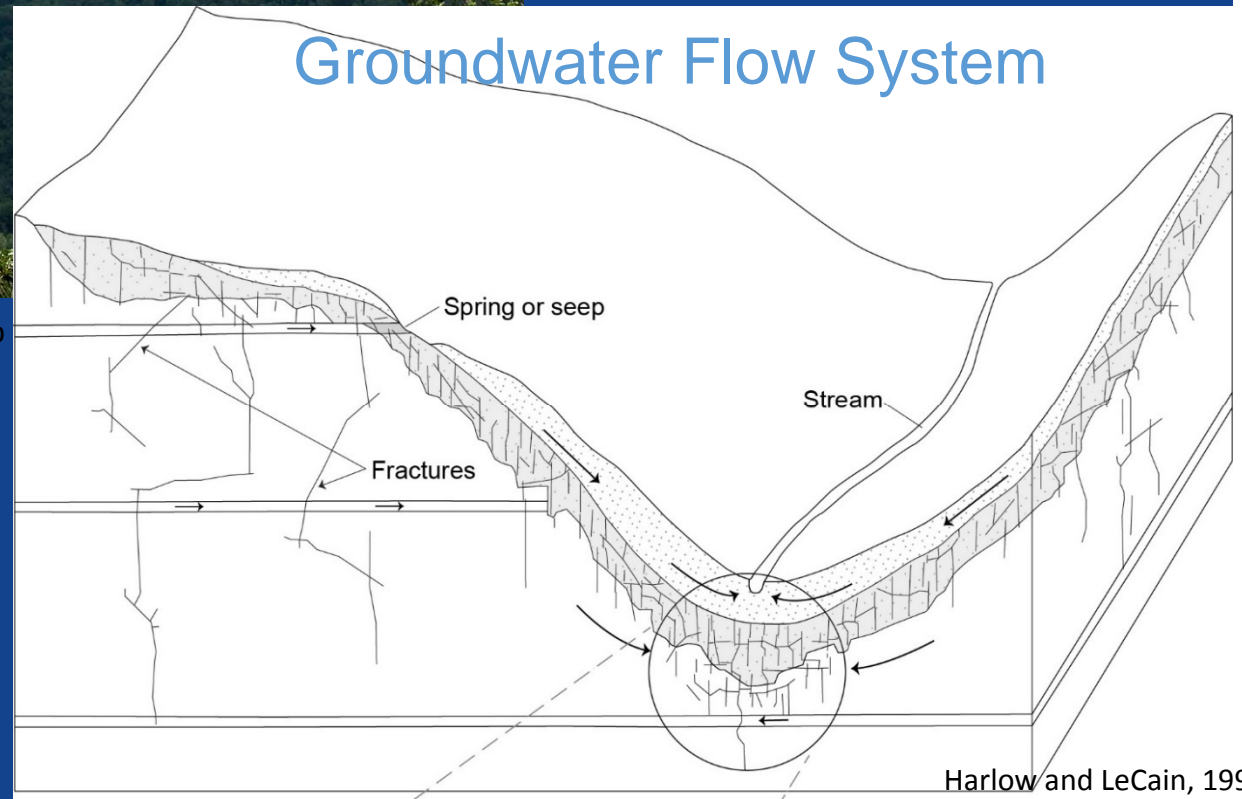


(<http://www.geosociety.org/criticalissues/hydraulicFracturing/waterQuality.asp>)

Eastern Kentucky Landscape

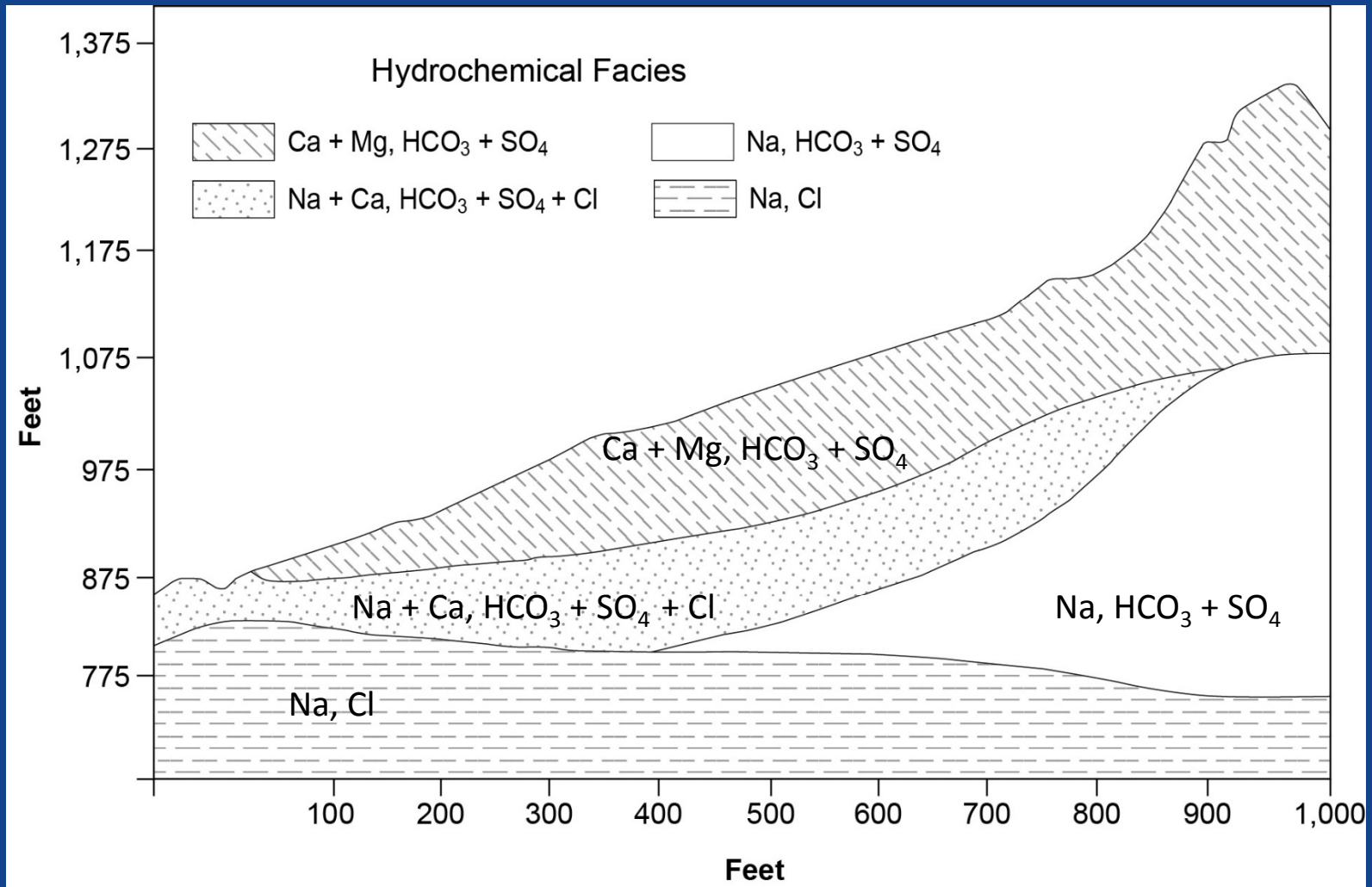


Groundwater Flow System



<http://www2.ca.uky.edu/forestry/maehrbearky.php>

Harlow and LeCain, 1993



(Wunsch, 1993)

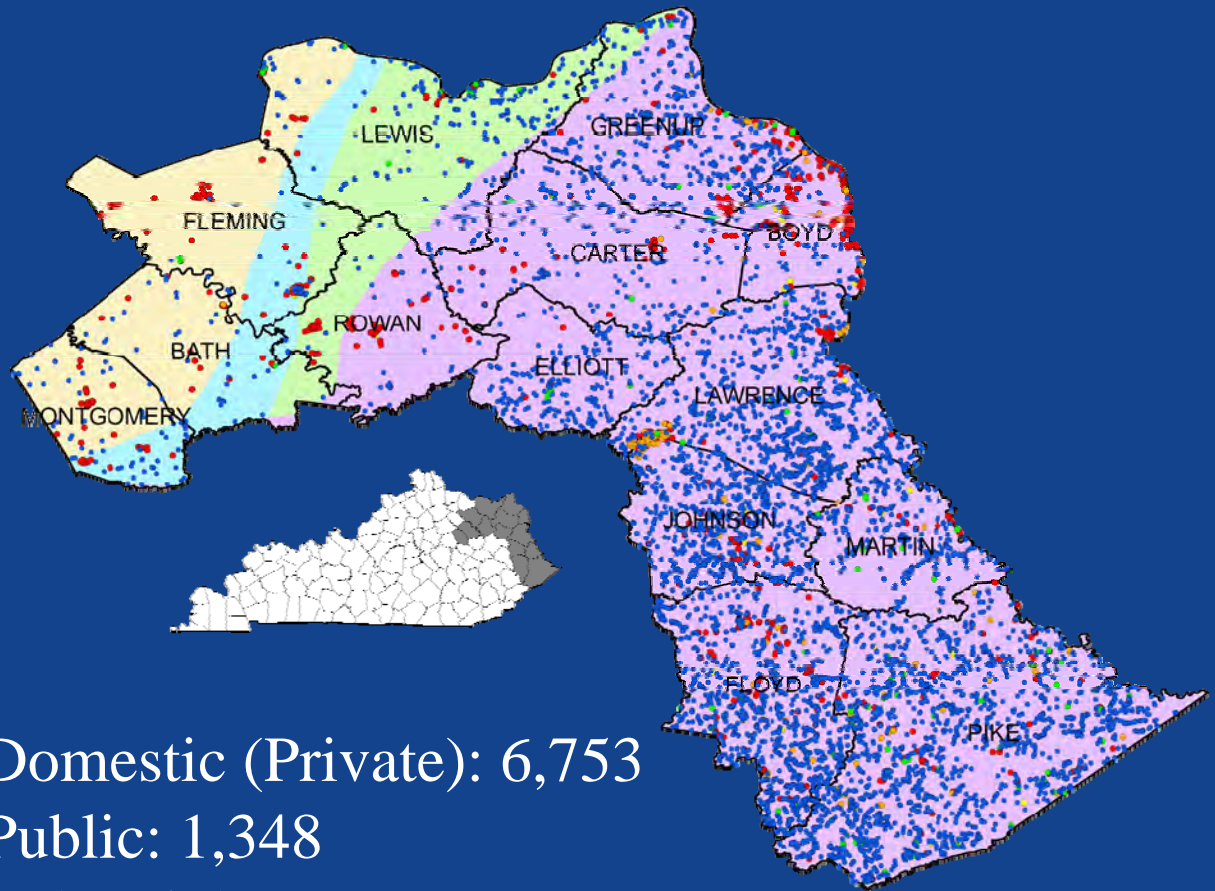
Existing water wells

Type of Well

- Domestic
- Public
- Industrial
- Monitoring
- Irrigation

Physiographic Region

- Eastern Coal Field
- Eastern Pennyroyal
- Knobs
- Outer Blue Grass



Domestic (Private): 6,753

Public: 1,348

Industrial: 55

Monitoring: 3,932

Agriculture (Irrigation or Livestock): 114

TOTAL: 12,202

Possible Methane Contamination of Drinking Water Wells in Kentucky



Posted by [Erin Savage](#) | August 11, 2011 at 3:18 pm

"In all my 20 years of working on water quality problems, I have never seen a drinking water well [catch on fire and burn continuously](#) for days on end," Donna Lisenby said in reaction to [news reports](#) of a well fire in Pike County, Kentucky.



Ted Withrow of KFTC observes the methane contaminated, flaming well. Photo credit: Sue Tallichet

Kentuckians for the Commonwealth Steering Committee member Ted Withrow contacted Appalachian Voices for assistance with heavy metal sampling for 4 Kentucky families whose wells may be contaminated with methane. One well has [flames](#) that shoot more than a foot high out of the top of their well. Families in the area report that the water sometimes runs orange or black, and causes their skin to burn upon contact. Some individuals suspect nearby Excel Number 2 mine to be the source of the contamination. The families reported the water problems to government officials in May, but no action has been taken to help the families.

(<http://appvoices.org/2011/08/11/methane-well-contamination-kentucky/>)

Advanced Analytical Methods

RPSEA 11122-45



- 3-Year project in 2 phases (currently in Phase II)
- \$3.5M from DOE/RPSEA, \$900k in cost share

RESEARCH FOCUS ON THREE KEY ENVIRONMENTAL ISSUES:



Baseline Sampling and Stray Gas Investigation



Advanced Analytics for Air Emissions

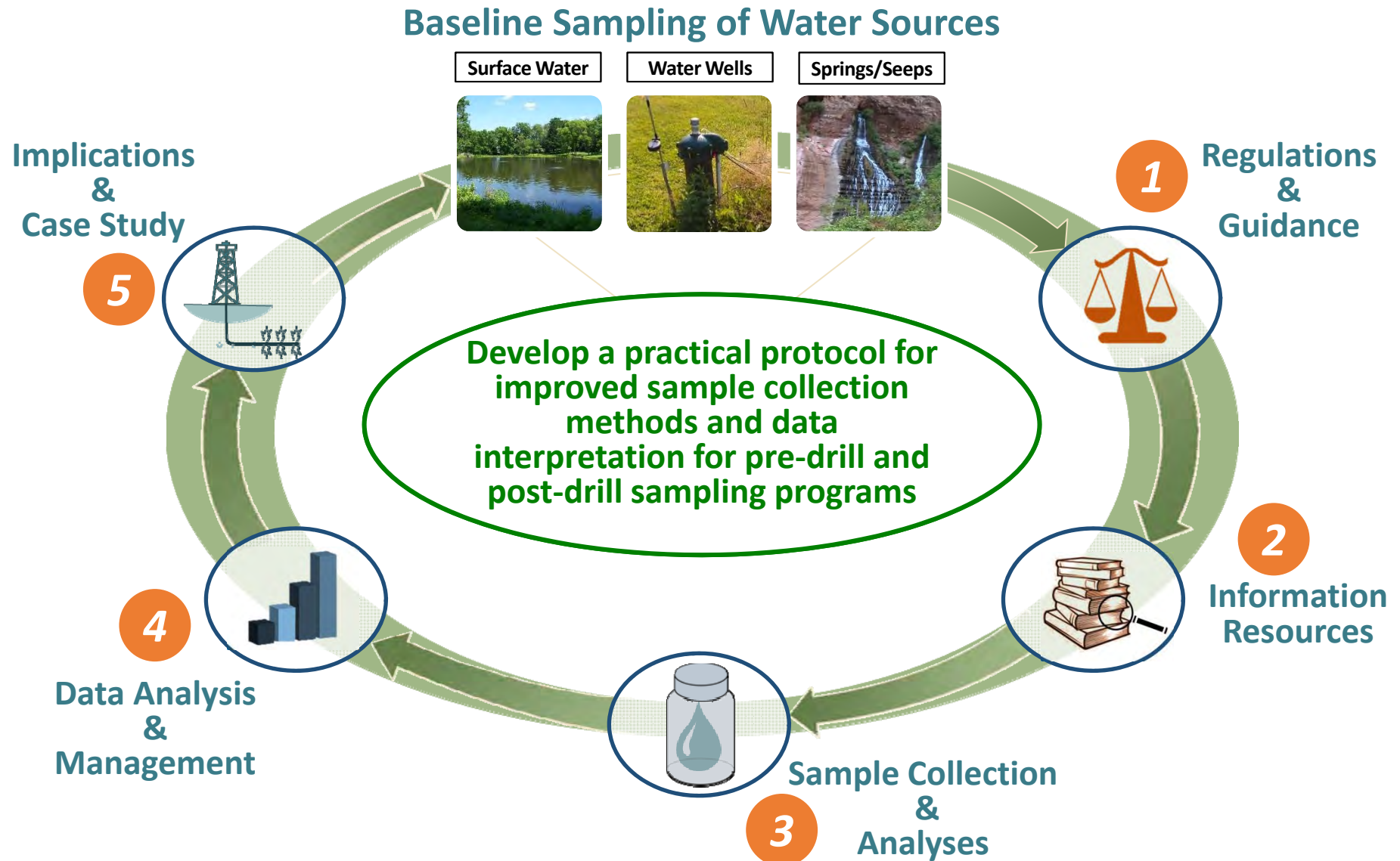


Produced Water Characterization



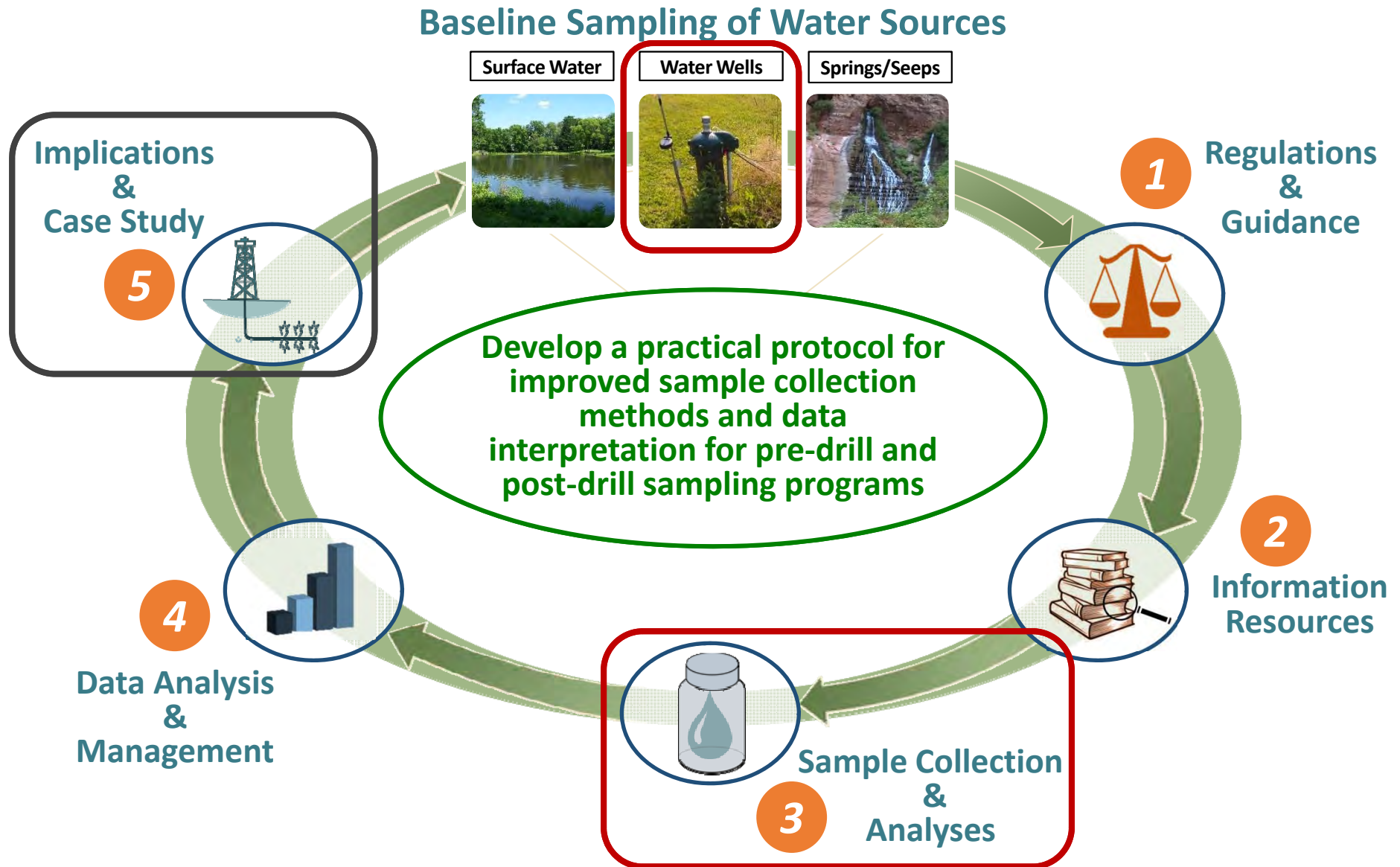
Baseline Sampling Protocol

What's the Goal?



Baseline Sampling Protocol

What's the Goal?



Scope of Work

- 1 Select up to 50 water wells in the study area, including Greenup, Carter, Boyd, Lawrence, and Johnson Counties.
- 2 Follow the Baseline Sampling Protocol to collect water samples, which are analyzed for :
 - Dissolved gases
 - Major cations, anions, and metals
 - Carbon and hydrogen Isotopes (samples with $\text{CH}_4 > 1 \text{ mg/L}$)
 - BTEX/TPH
- 3 Analyze the resulting dataset for:
 - Spatial variability in dissolved gases
 - Relationship between water quality parameters and methane occurrence
 - Origins of methane

The Field Team

Bart Davidson



Steve Webb



Richard Smath



Locating Water Wells

With help from UK Agricultural Cooperative Extension Office, contact well owners to get permission to sample



<https://extension.ca.uky.edu/county>

Field Sample

Collect well information



Purge



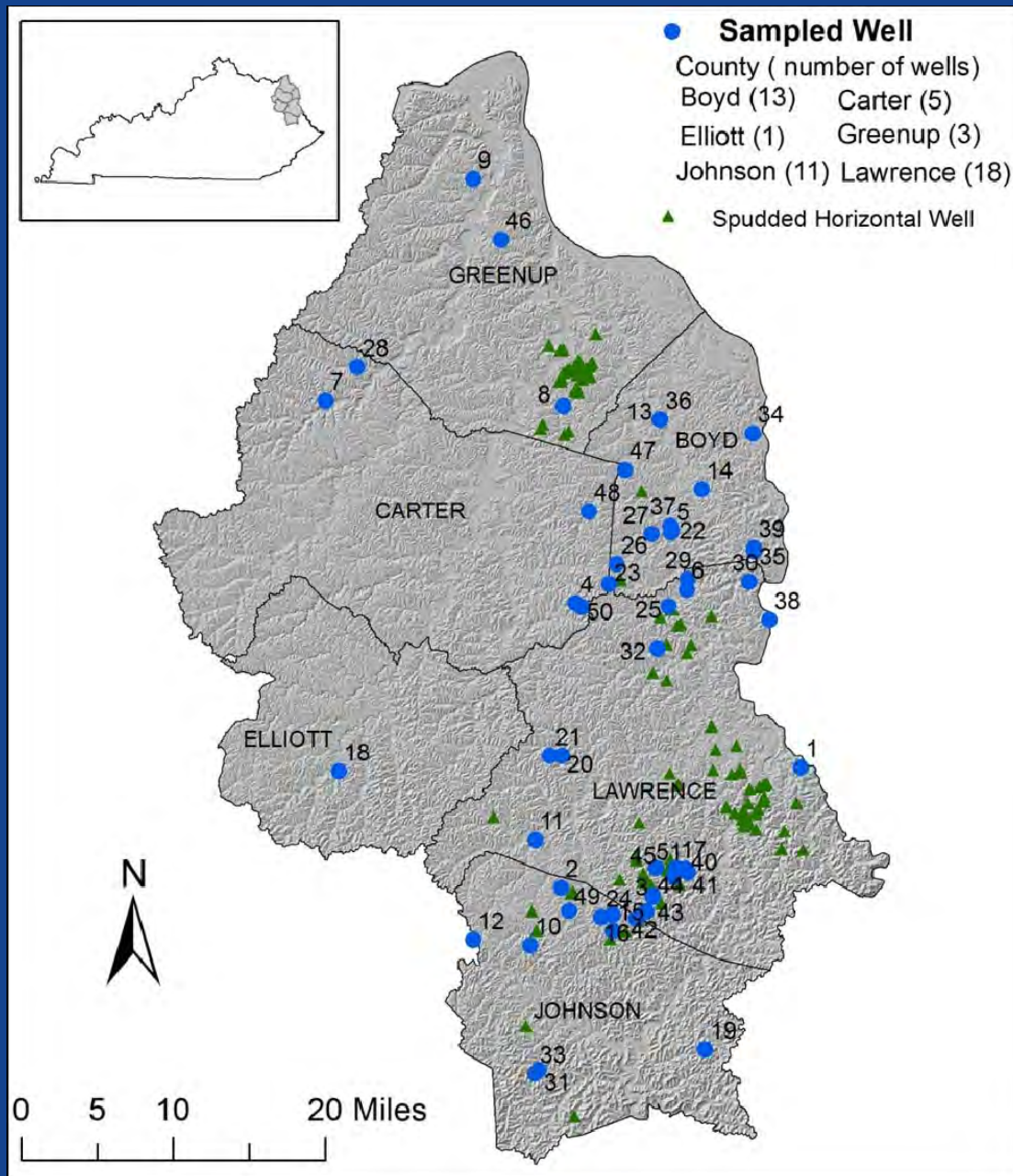
51 wells sampled in March-April, 2016

Collect water samples



Deliver water samples





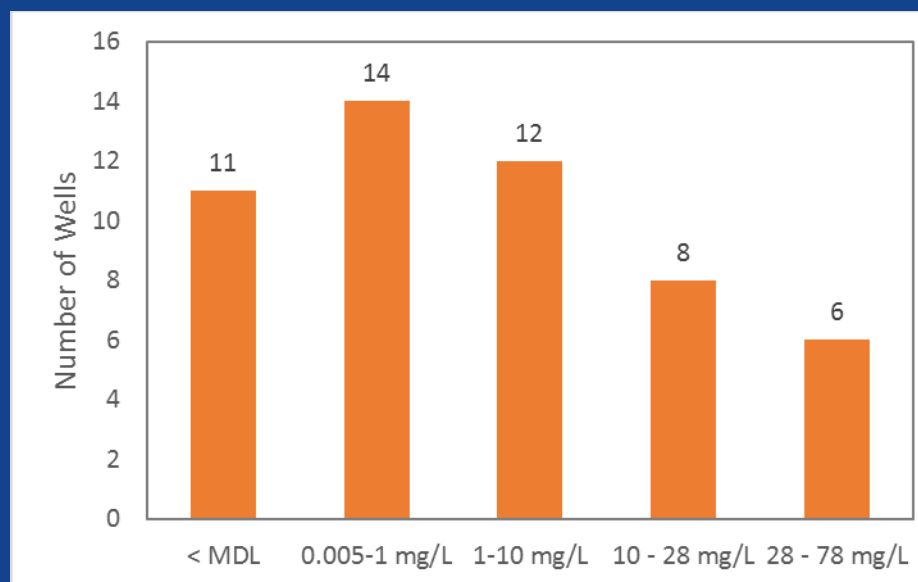
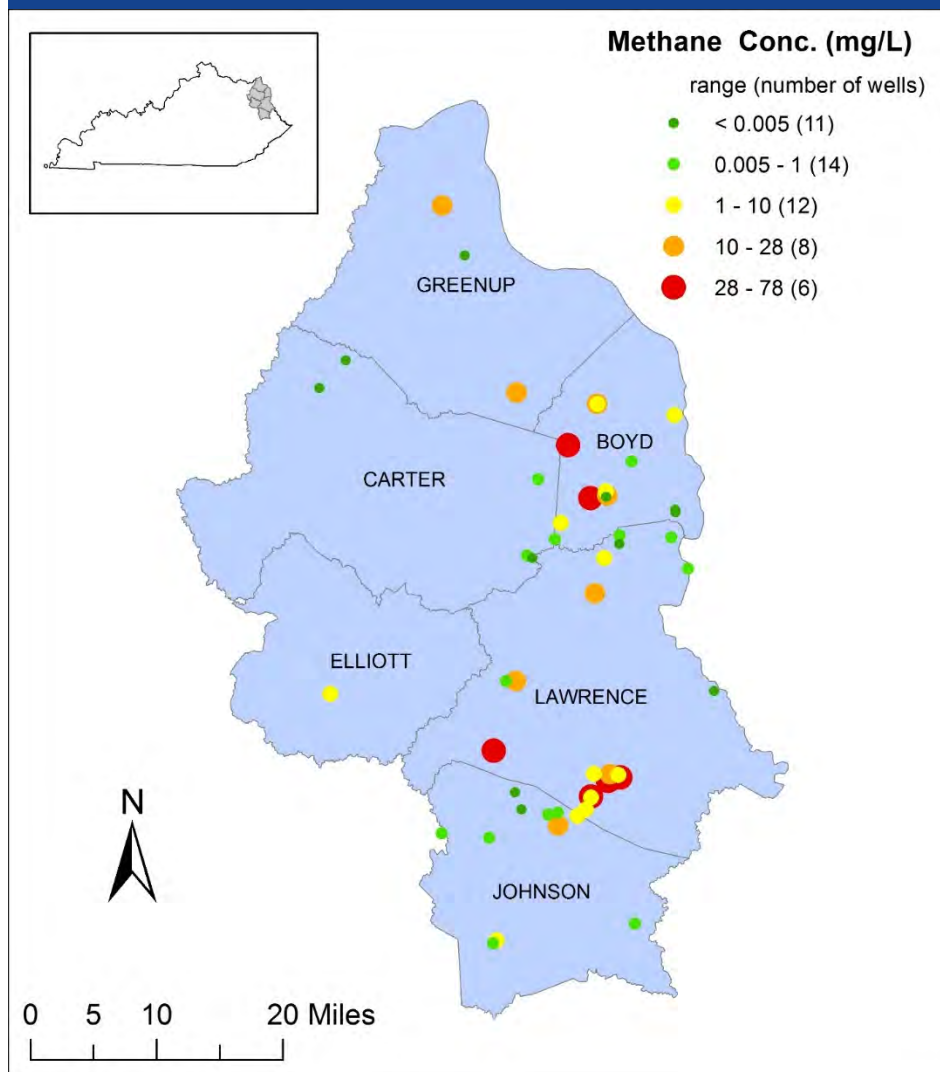
Sample Sites

Surface elevations
range from 550 - 1000 ft

Well depths range from
15 - 485 ft

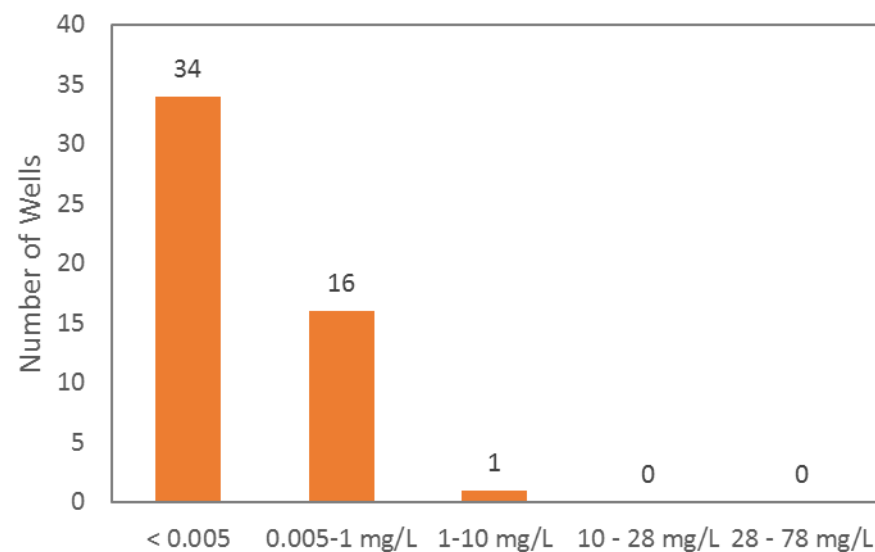
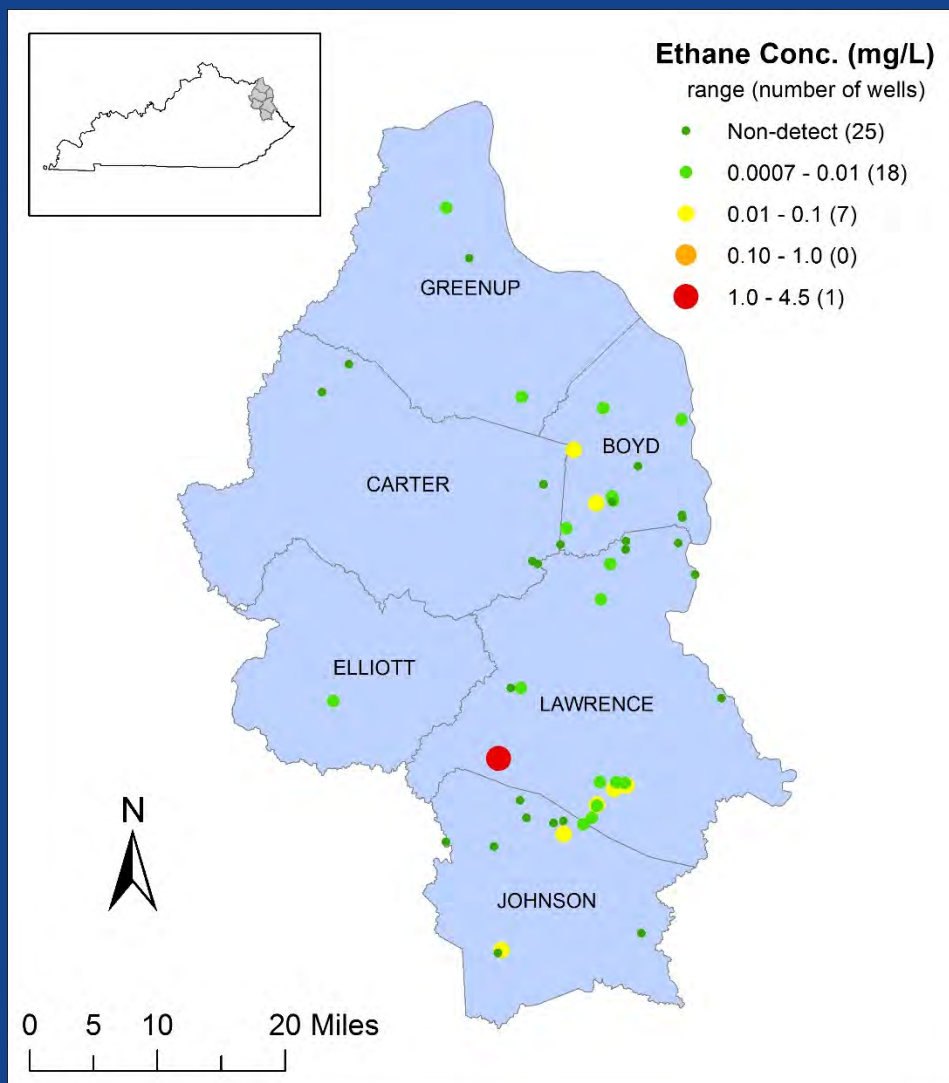
Depths to water range
from 3 - 200 ft

Dissolved Methane Statistics



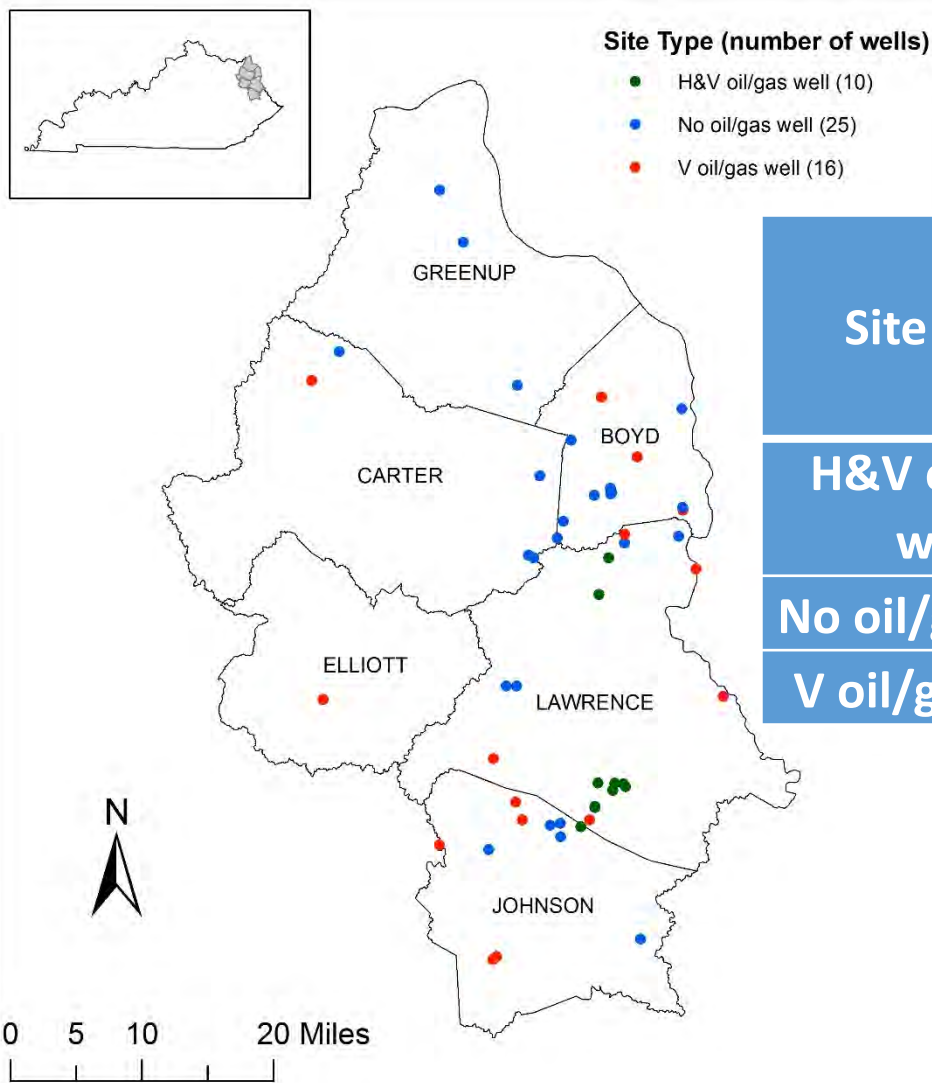
- **78%** of wells have detectable methane (MDL: 5 μ g/L).
- **51%** wells > 1 mg/L
- **27%** wells >10 mg/L
- **12%** wells >28 mg/L

Dissolved Ethane Statistics



- 33% >5 $\mu\text{g/L}$
- 1 wells > 1 mg/L

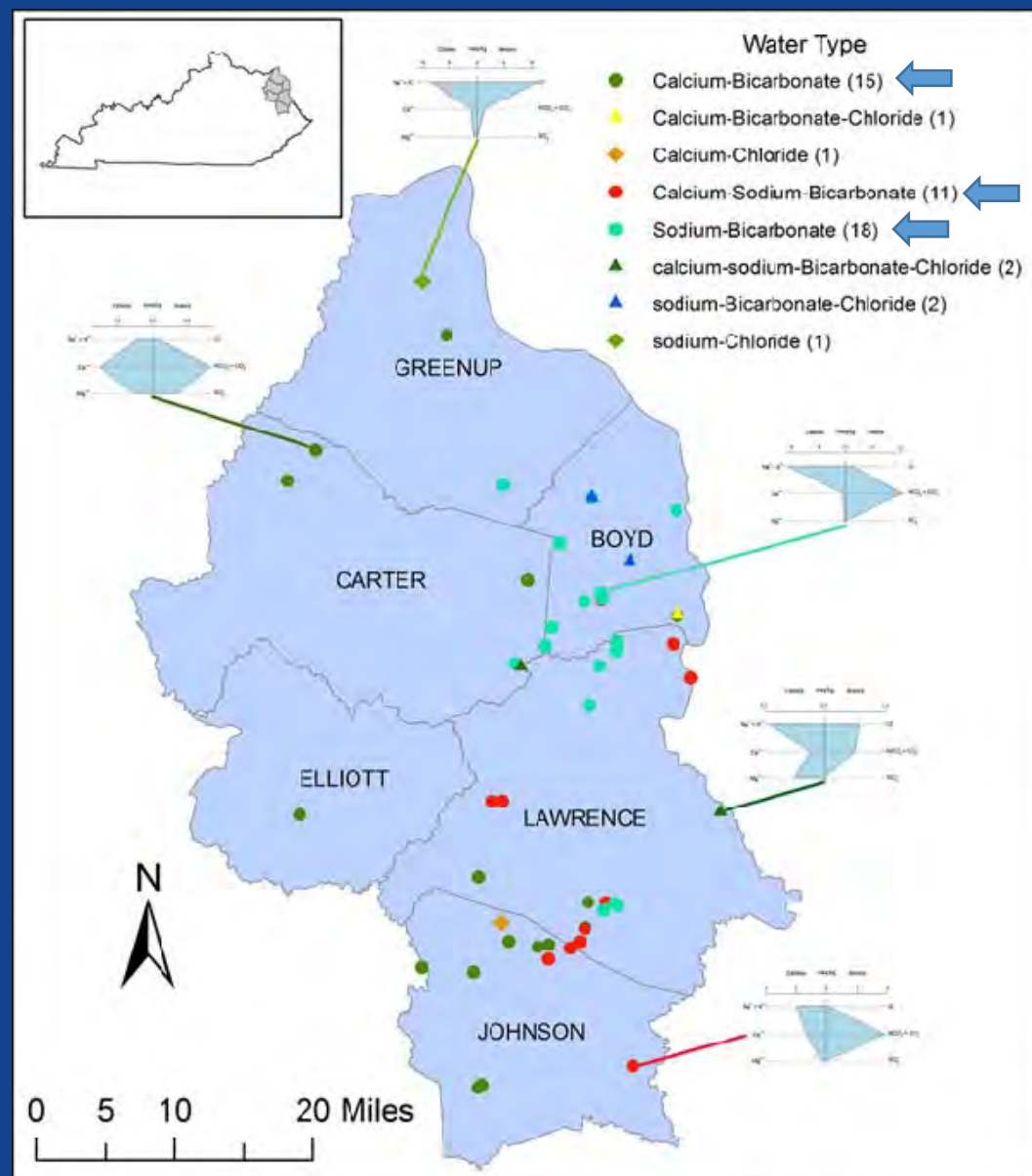
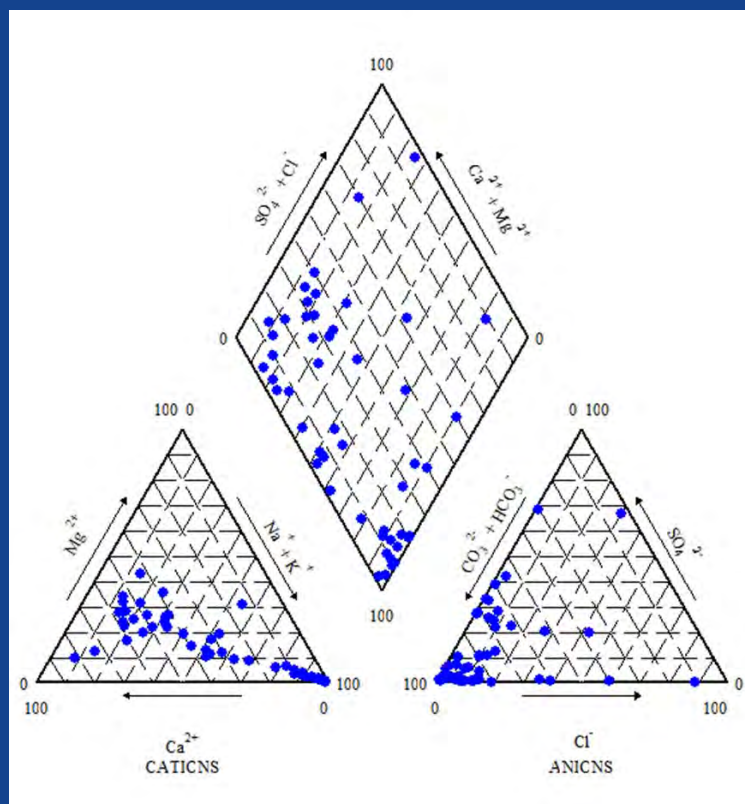
Distances to oil/gas wells



Site type	Count	Wells with CH ₄ > 1 mg/L	Percent
H&V oil/gas well	10	10	100%
No oil/gas well	25	10	40%
V oil/gas well	16	6	38%

Distance Criterion: 3280 ft

Methane vs. Water Types

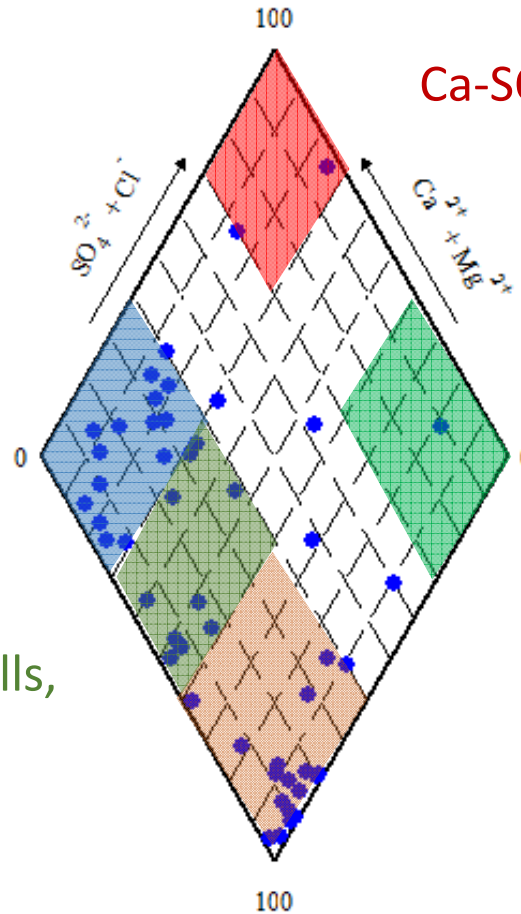


Methane vs. Water Types

Total 51 wells sampled

Ca-HCO₃ Waters – 15 wells, 4
with CH₄ > 1 mg/L

Ca-Na-HCO₃ Waters – 11 wells,
6 with CH₄ > 1 mg/L



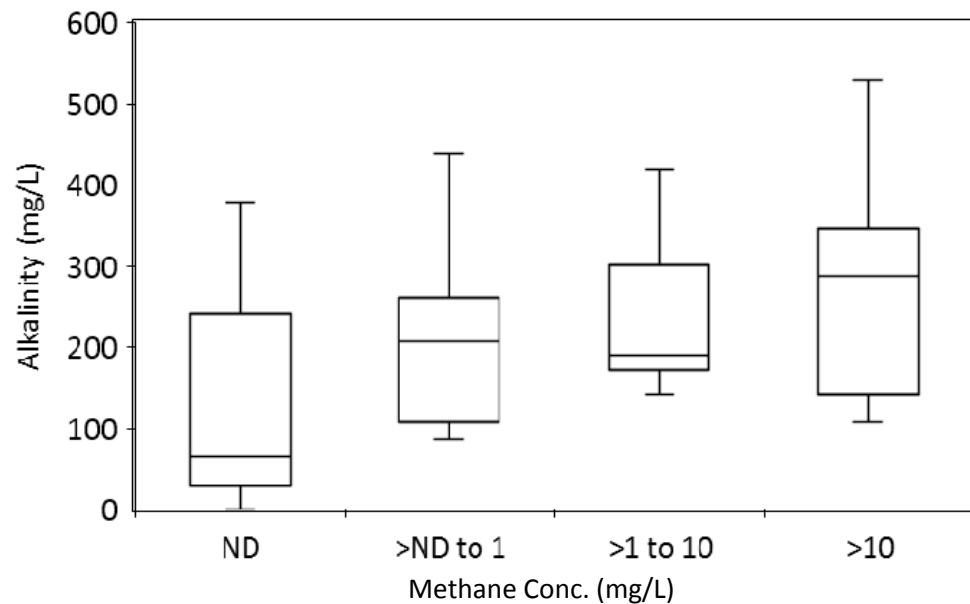
Ca-SO₄ Waters – 1 wells, 0 with
CH₄ > 1 mg/L

Na-Cl Waters – 1 wells, 1 with
CH₄ > 1 mg/L

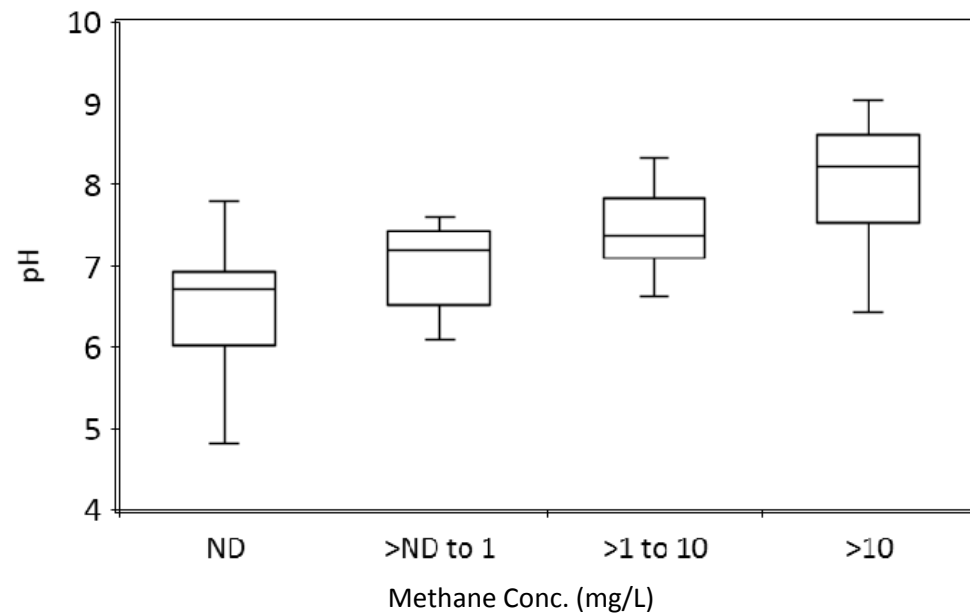
Other types: 5 wells, 1 with
CH₄ > 1 mg/L

Na-HCO₃ Waters – 18
wells, 14 with CH₄ > 1
mg/L

Methane vs. Water Chemistry Parameters

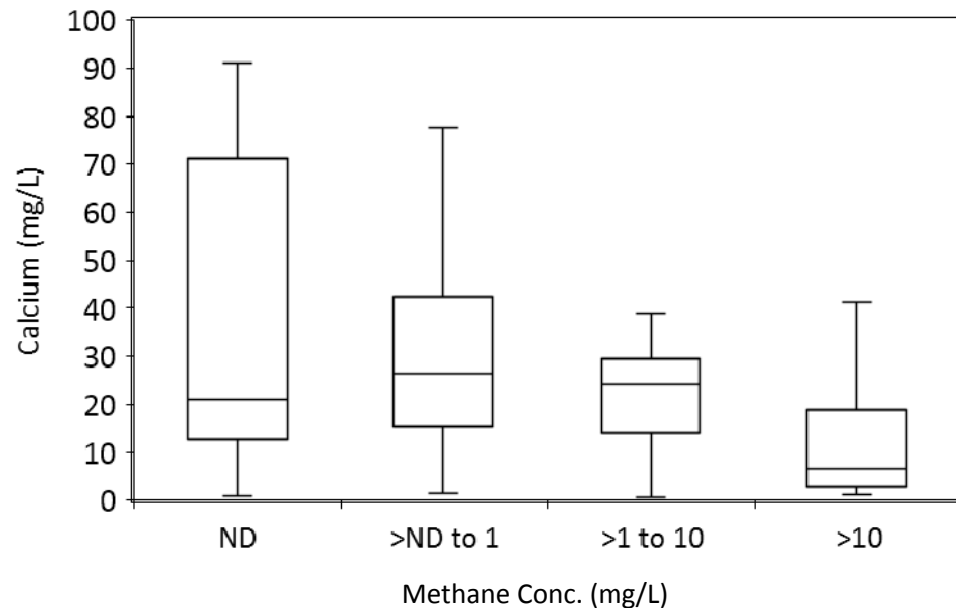


Spearman's R_{uo} : 0.26
Correlation strength : weak
 p -value: 0.1 (insignificant)

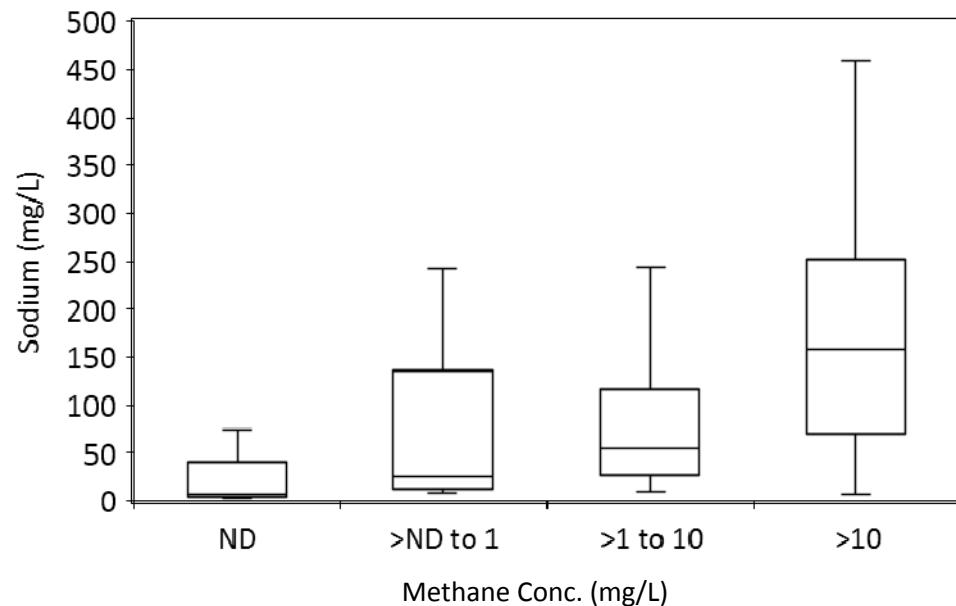


Spearman's R_{uo} : 0.58
Correlation strength: moderate
 p -value: $9e-5$ (significant)

Methane vs. Water Chemistry Parameters

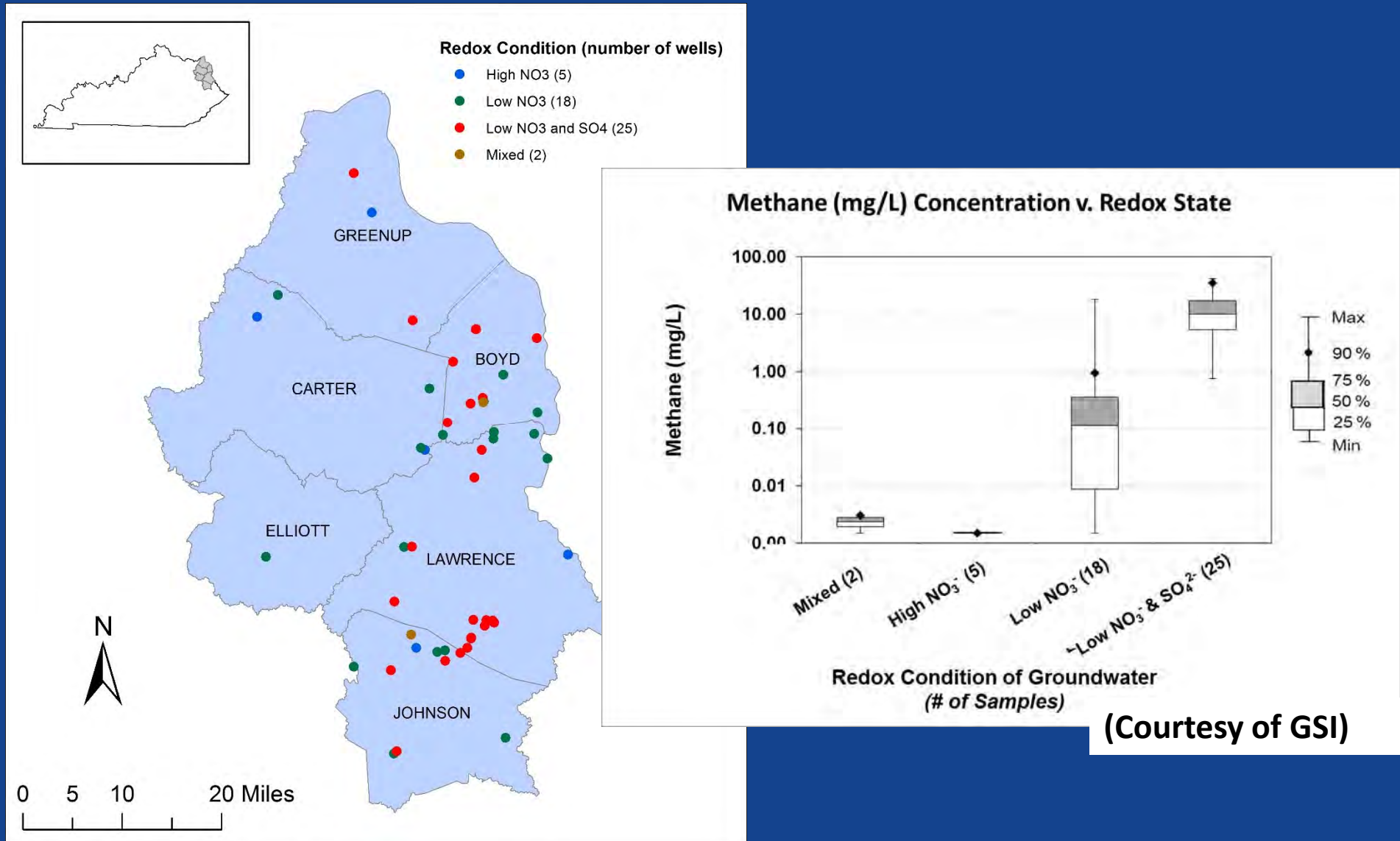


Spearman's R_{uo} : -0.29
Correlation strength : moderate
 p -value: $1e-2$ (significant)

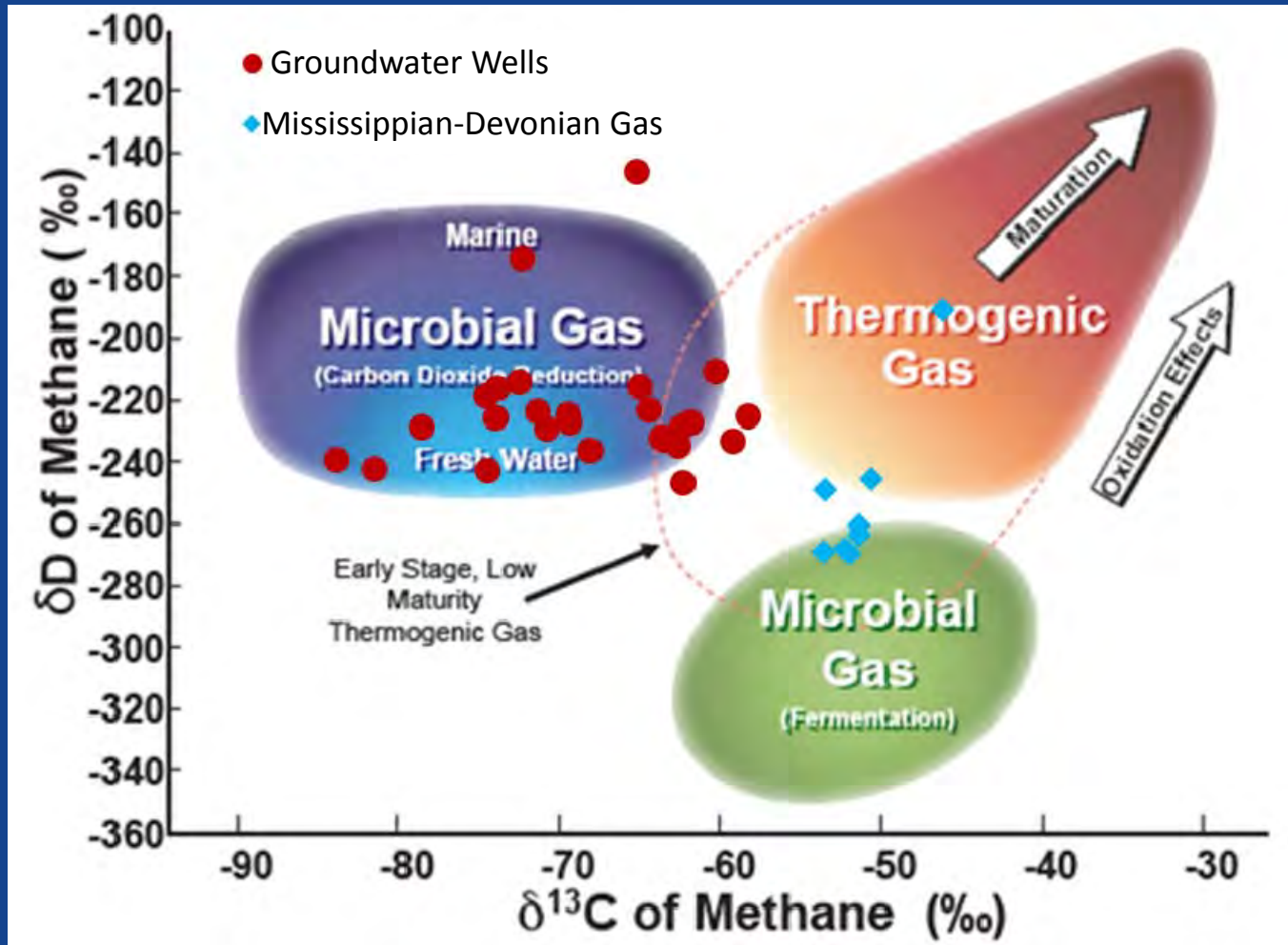


Spearman's R_{uo} : 0.49
Correlation strength: moderate
 p -value: $1e-3$ (significant)

Methane vs. Redox Condition



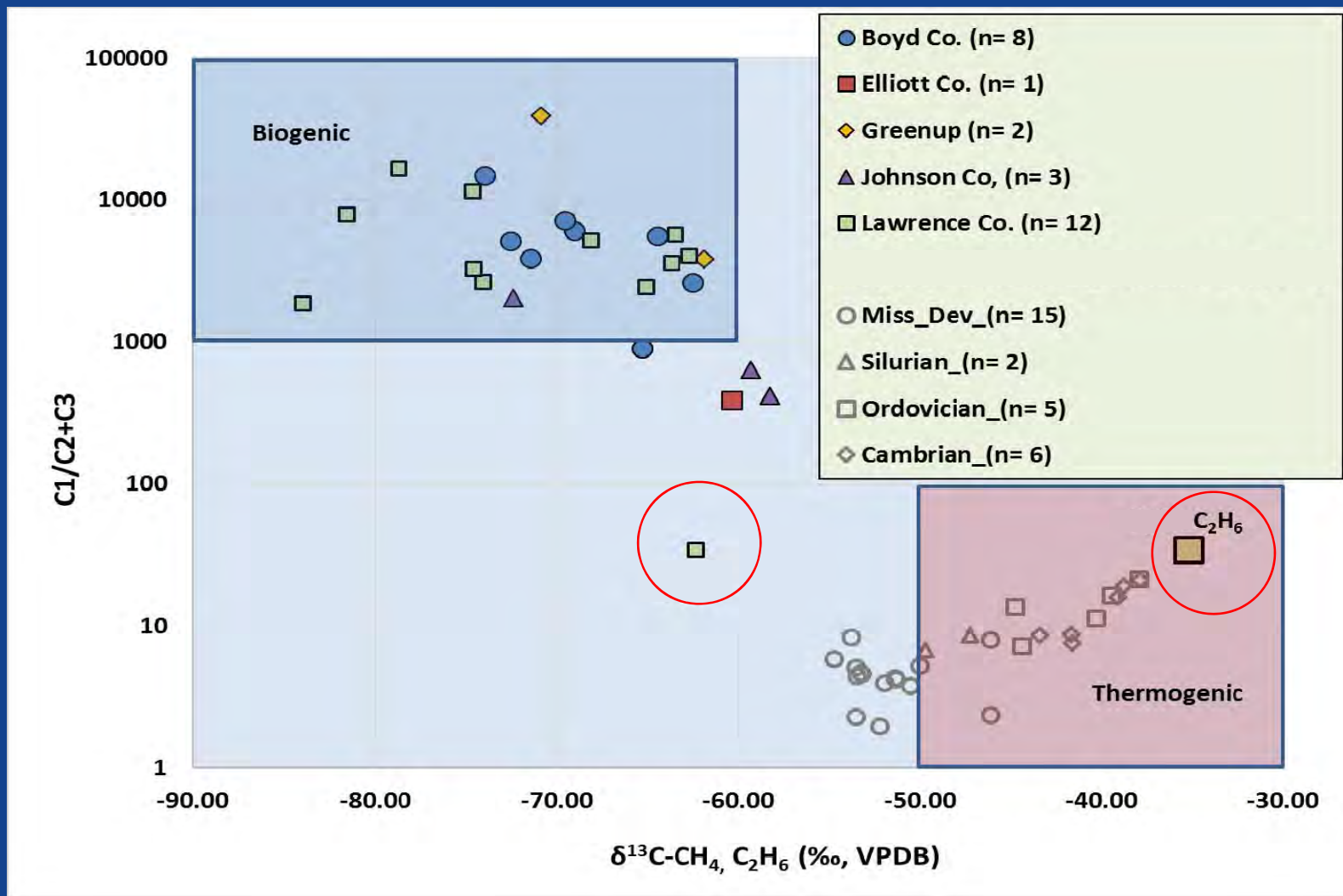
Methane Isotopes



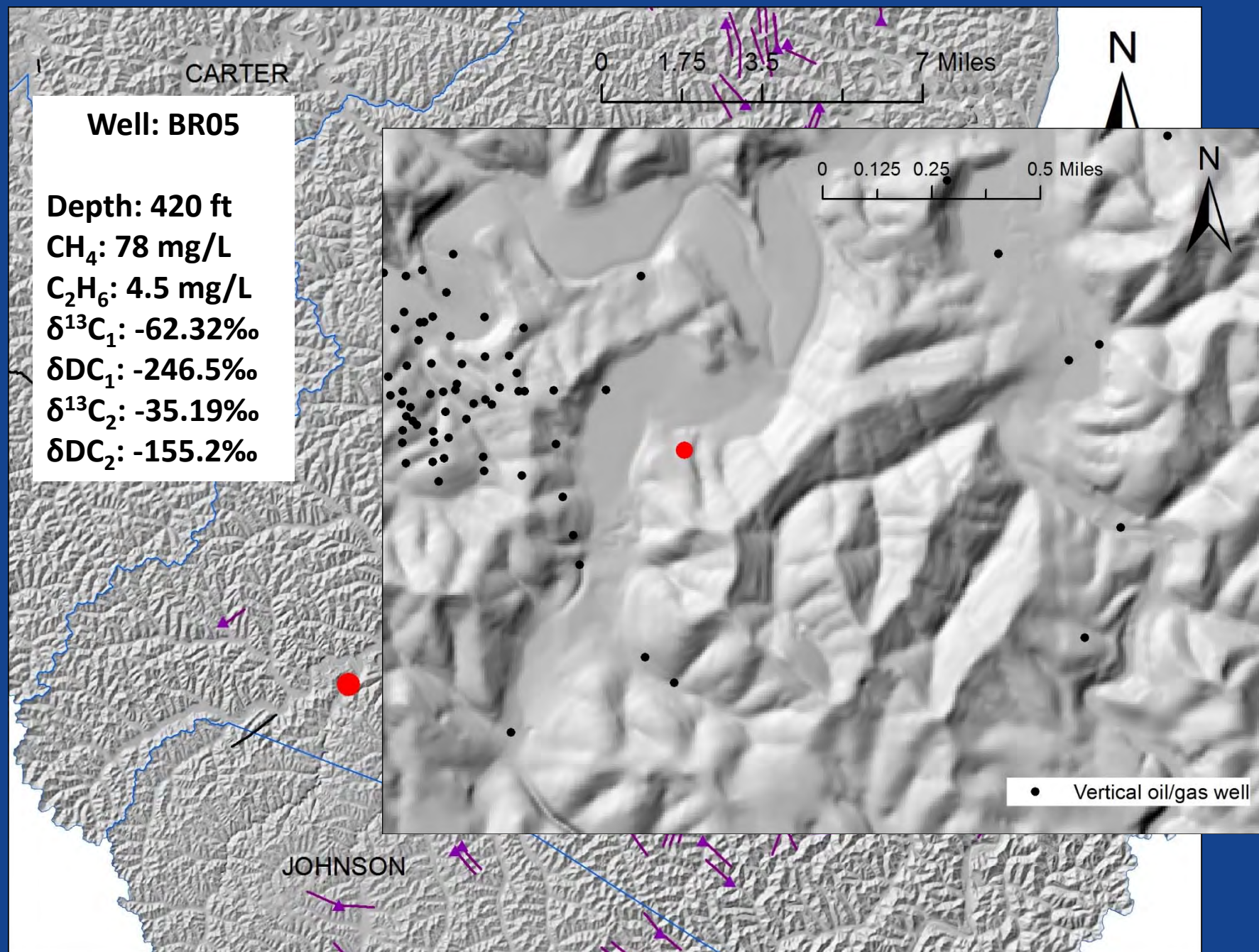
(Image source: Isotech)

The image is based on whiticar (1999)

Gas Wetness



Gas wetness ($C_1/(C_2 + C_3)$) versus $\delta^{13}C\text{-CH}_4$. Dissolved gases in groundwater are shown with filled symbols, whereas gases from eastern Kentucky oil and gas reservoirs are shown with unfilled symbols.



Conclusions

- Methane is a relatively common occurrence in shallow groundwater in Berea and Rogersville play areas of eastern Kentucky
- methane in groundwater is primarily generated from microbial sources
- methane is associated with hydro-geochemical conditions. Elevated methane concentrations were found more common in sodium-rich water and reducing redox conditions.

Acknowledgements

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University of Kentucky:

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Bart Davidson

Richard Smath

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Chuck Taylor

Glynn Beck

GSI:

Steve Richardson

Jenna Kromann

Lisa Molofsky



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Thanks

Questions?

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