Welcome to 6th Annual Shale Network Workshop

Please sit near the front of the room! It is a big room…

Morning speakers: please upload your talks by the last break before your talk.

Afternoon speakers: please upload talks directly in the computers in the afternoon rooms (not here)

Thank you for funding from National Science Foundation, Oak Ridge Assoc. Universities, CUAHSI, Penn State Institutes of Energy and Environment, Penn State Earth and Environmental Systems Institute; Marcellus Center for Outreach and Research, Univ of Pittsburgh. Thank you for organizational help from PA DEP and SUNY Binghamton

Welcome to 6th Annual Shale Network Workshop

Sharing Data about Shale Gas Development: From Drilling to Disposal

Susan L. Brantley,

on behalf of the Shale Network team including Radisav Vidic, Matt Gonzales, Liza Brazil, Tao Wen, X. Niu, Josh Woda, Patryk Soika, Dave Yoxtheimer, Jon Pollak, Kathy Brasier, Anna Wendt, Todd Sowers, Jennifer Williams, Julie Vastine, Candy Wilderman, Debbie Lambert, others

With a lot of help from PA DEP, including Seth Pelepko and Stew Beattie

Penn State, University of Pittsburgh, Dickinson College, Consortium of Universities for the Advancement of Hydrologic Sciences Inc., SUNY Binghamton, ORAU

Welcome

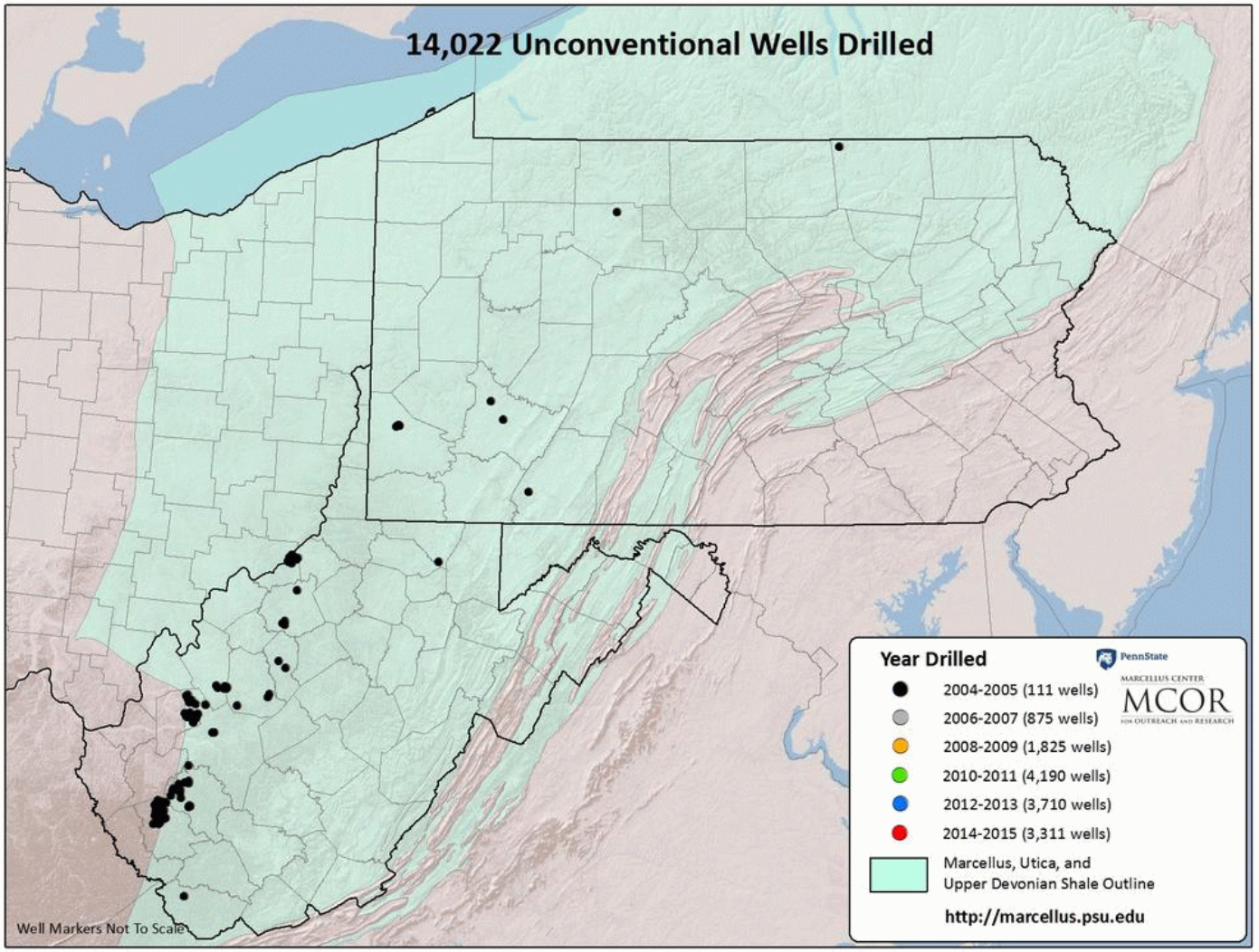
- Introductions (Watershed groups and volunteers, Academics, Gas Industry, Environmental Industry, Government Entities, Other)
- Introduction to Shale Network

Remember: please leave time for questions

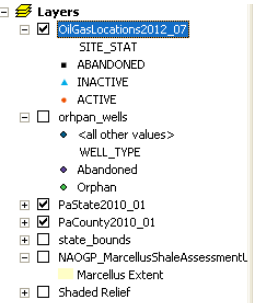
- Today we host nonscientists and scientists: remember that we want to try to speak jargon-free and to maintain open communication so everyone can understand and feel comfortable in the conversation
- We encourage respectful, friendly, and hard questions…acoustics are good, you can speak questions with or without a microphone (we will have them available for each row)
- Think about what you want to suggest for next year…

Drilled shale-gas wells 2004 – 2015

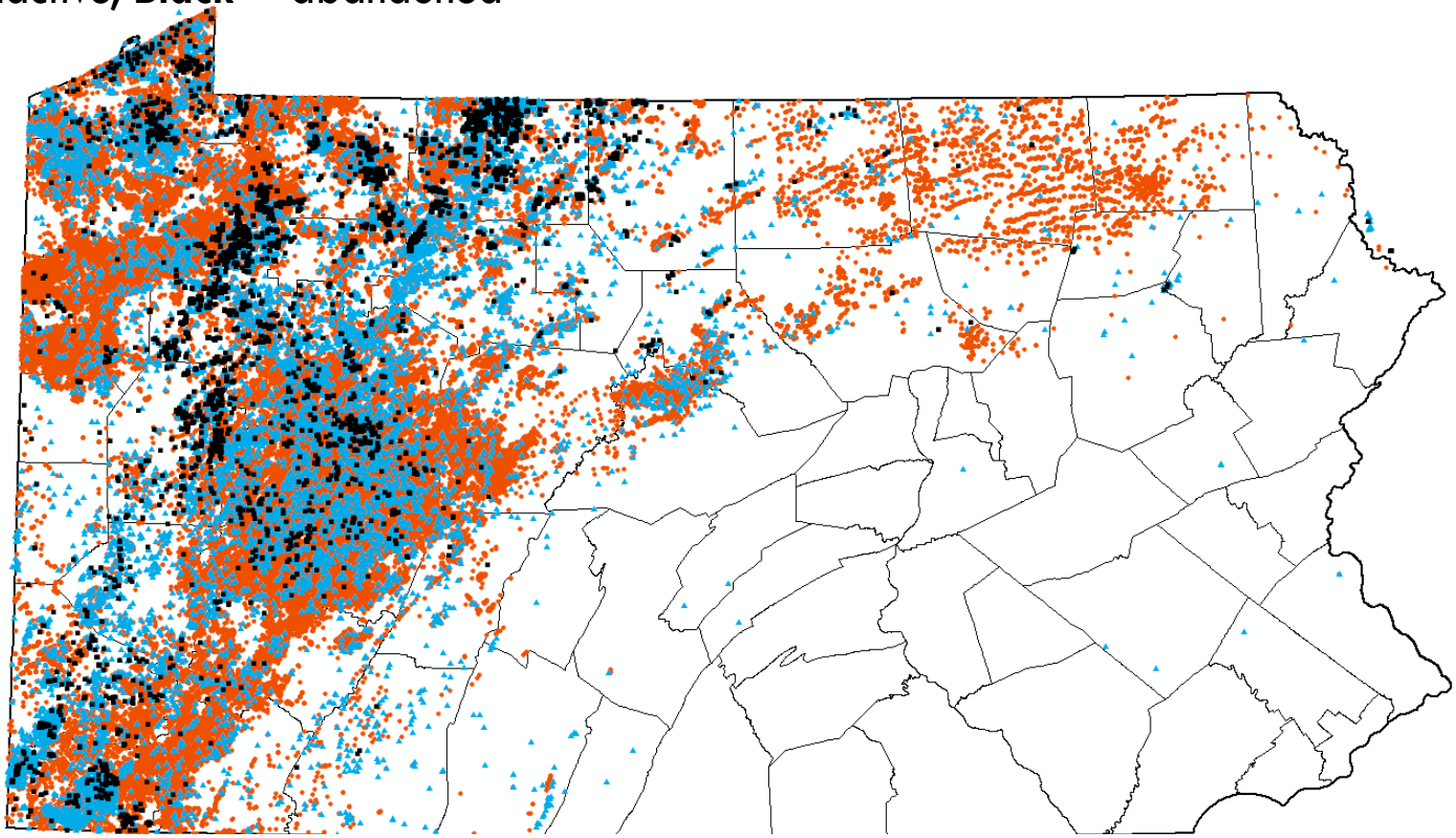
WV, OH, PA



Oil and gas wells in PA (data from PA DEP upload 2012)

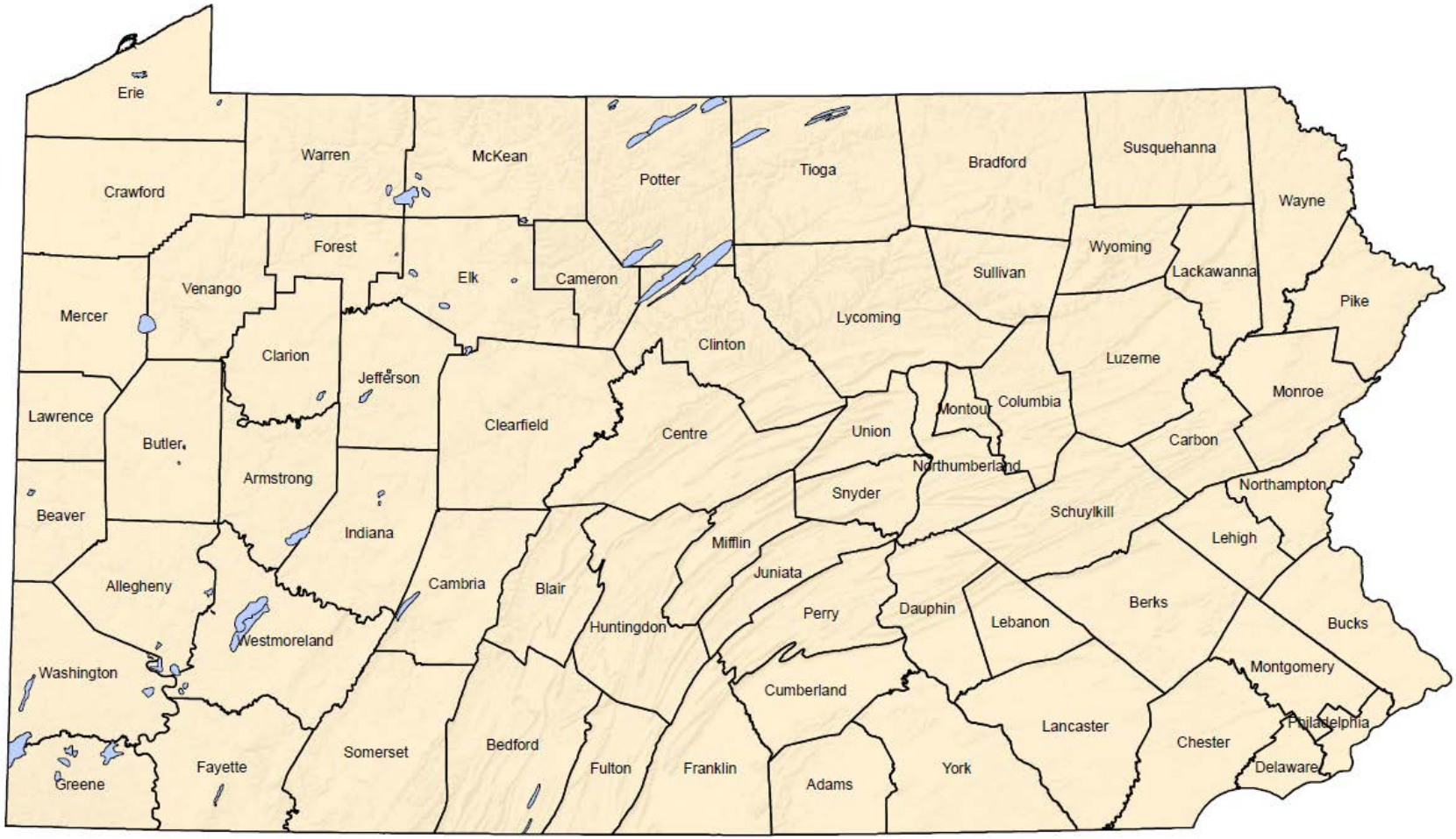


Pennsylvania DEP estimates that 350,000 oil and gas wells have been drilled in PA. The location of maybe 100,000 of them are unknown. Red = active, **Blue** = inactive, **Black** = abandoned



Interstate Oil and Gas Compact Commission (IOGCC) estimates that hydrofracking is used to stimulate 90% of domestic oil and gas wells (unconventional shales use higher volume). Technique used since 1940s

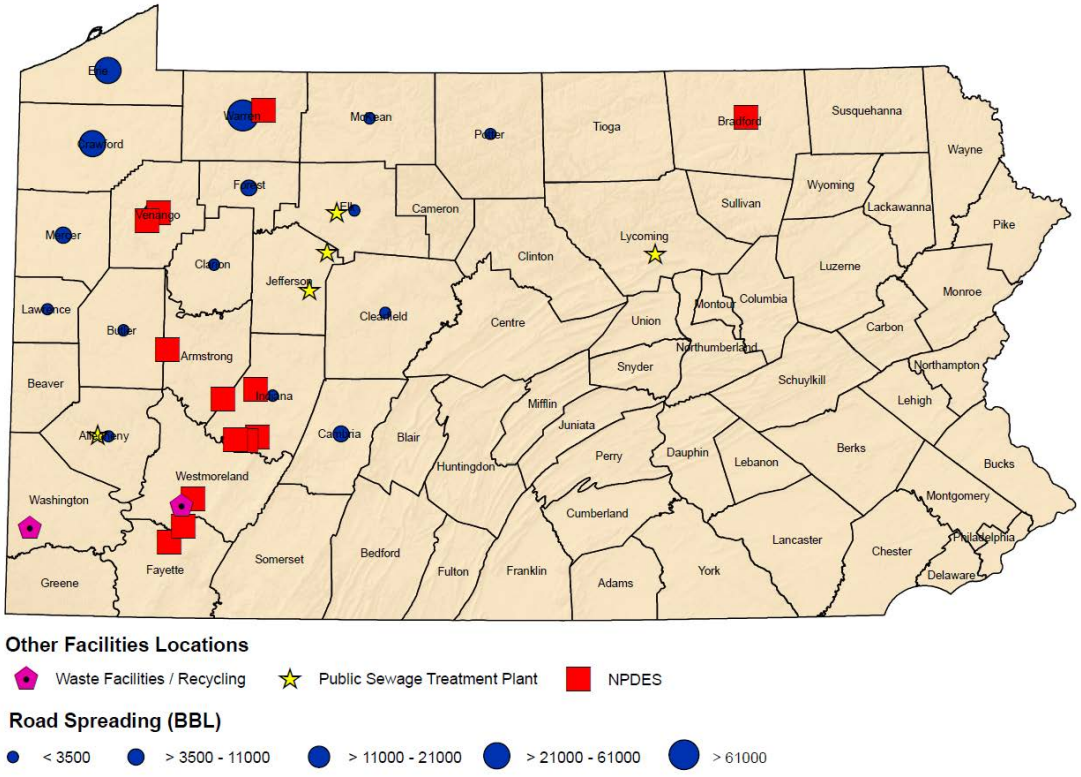
Gas storage field boundaries with active wells as of 5/17/2017



DCNR (2012), provided by S. Beattie, DEP

Management Options

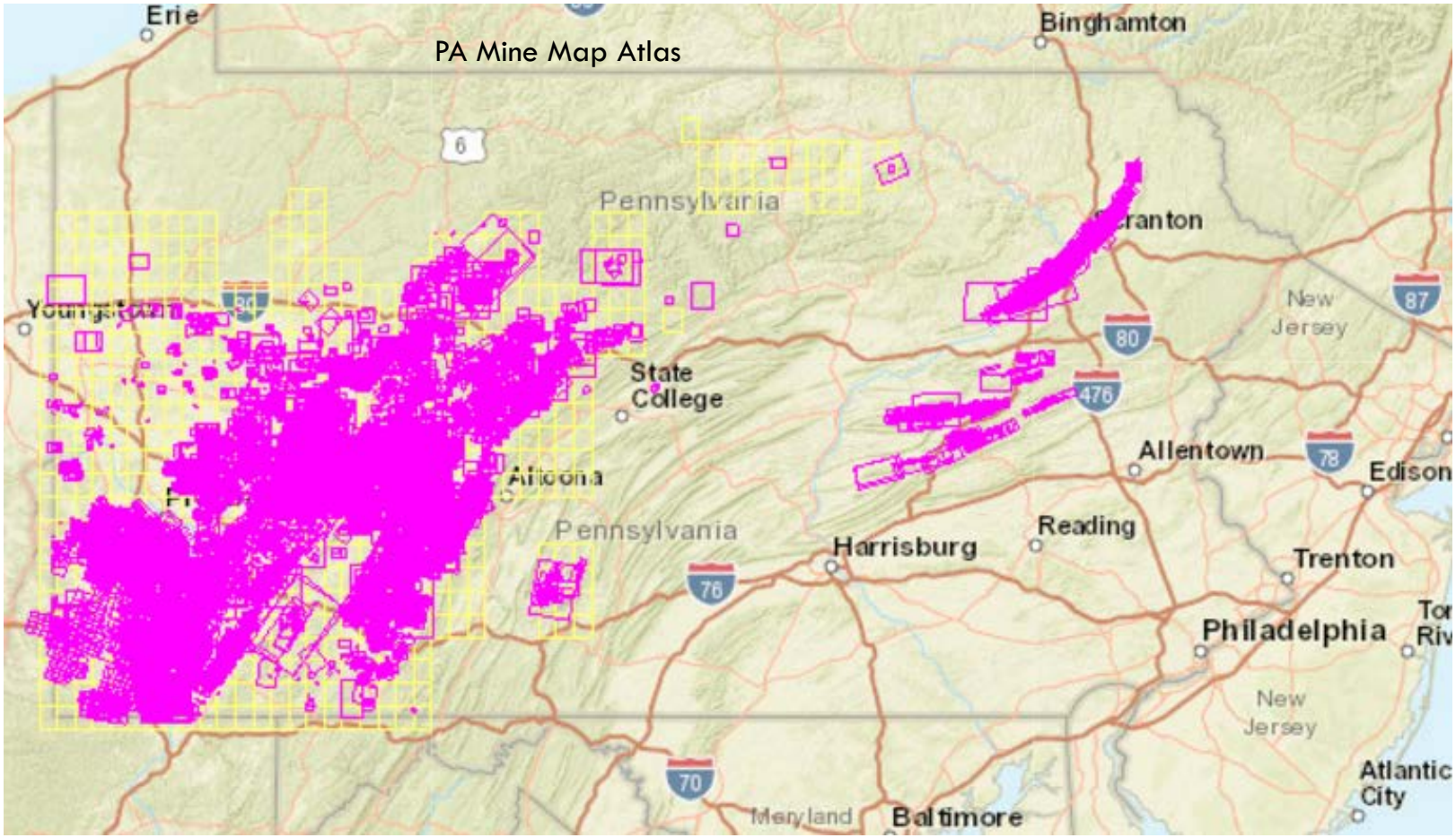
Conventional Treatment Facility Inv



PA DEP, slide from S. Pelepko

Coal Mines

- At least 100,000 abandoned coal mines in Pennsylvania (Patrick Jaquay- Pa DEP)



Shale Network Hypothesis

An online, shared compilation of water quality and quantity data collected by citizen scientists, government agencies, industry, nonprofit corporations and university personnel in areas of shale gas production will pull people together and provide the understanding needed to make good decisions.

PENNSTATE 1855

UNIVERSITY OF PITTSBURGH VERITAS 1787 VIRTUS

ALLARM Alliance for Aquatic Resource Monitoring est. 1986

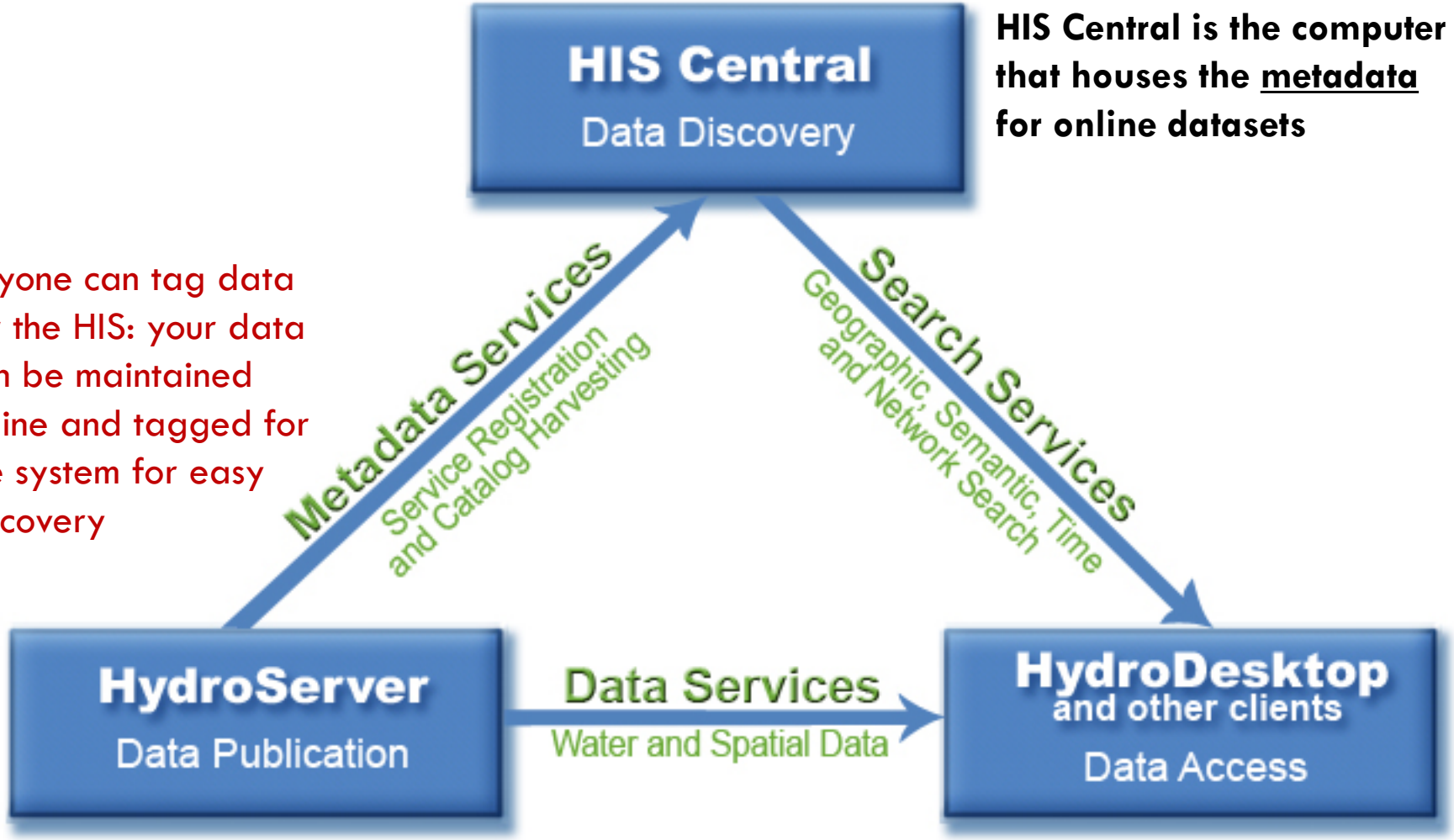
Educate. Engage. Empower.

DICKINSON COLLEGE

CUAHSI HIS

Sharing hydrologic data

What is the Hydrologic Information System?



HIS Central is the computer that houses the <u>metadata</u> for online datasets

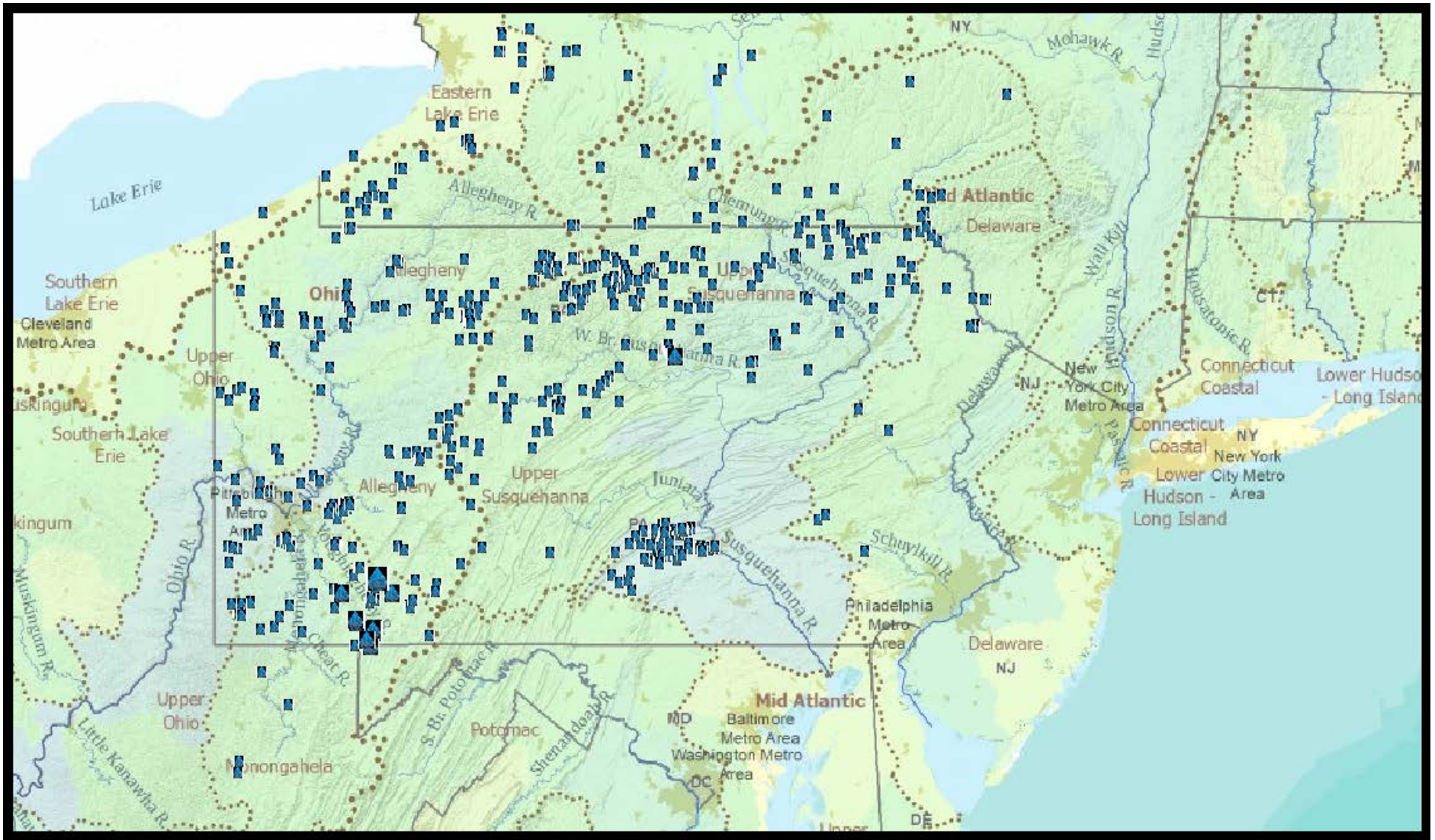
Anyone can tag data for the HIS: your data can be maintained online and tagged for the system for easy discovery

Hydroservers are computers around world that post <u>online data</u>

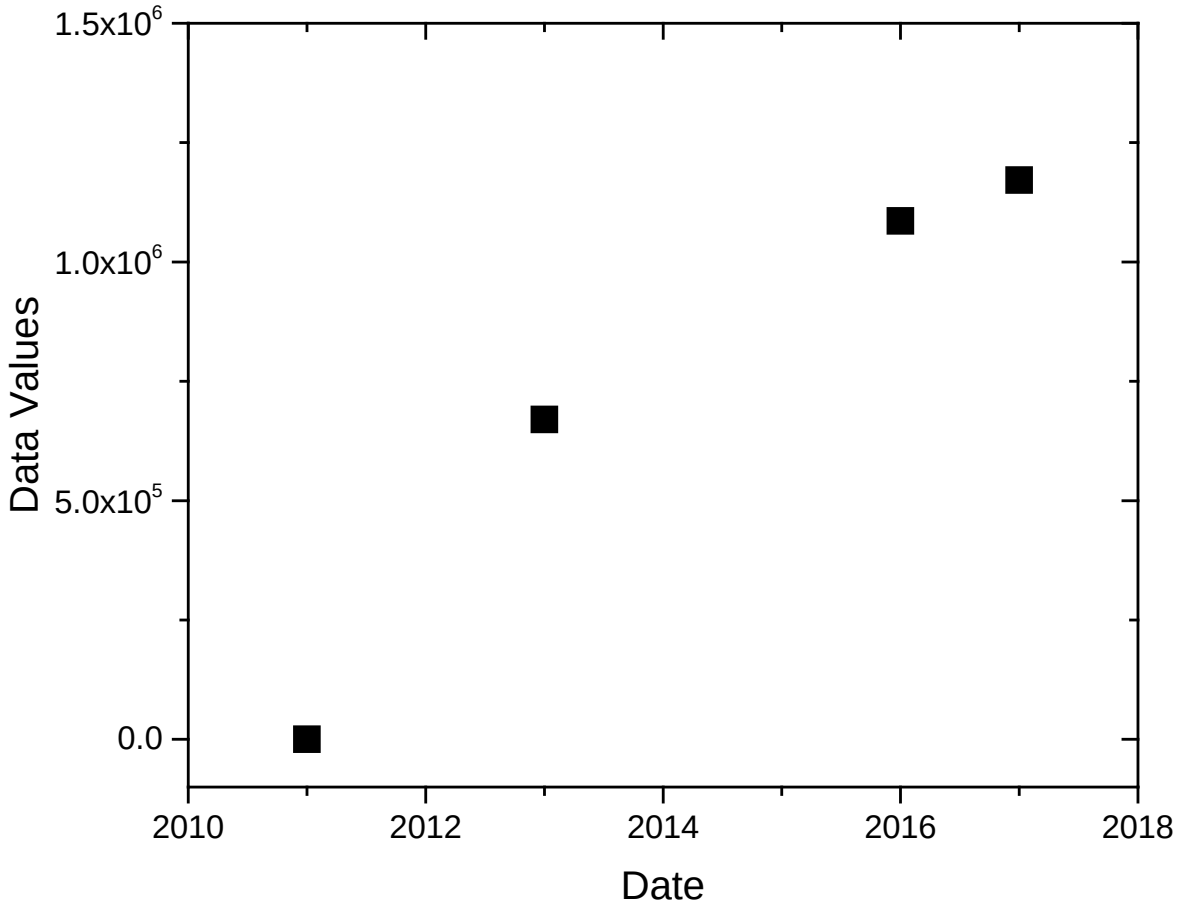
CUAHSI
universities allied for water research

HydroDesktop or HydroClient is a tool that allows you to find water data and work with it on your computer

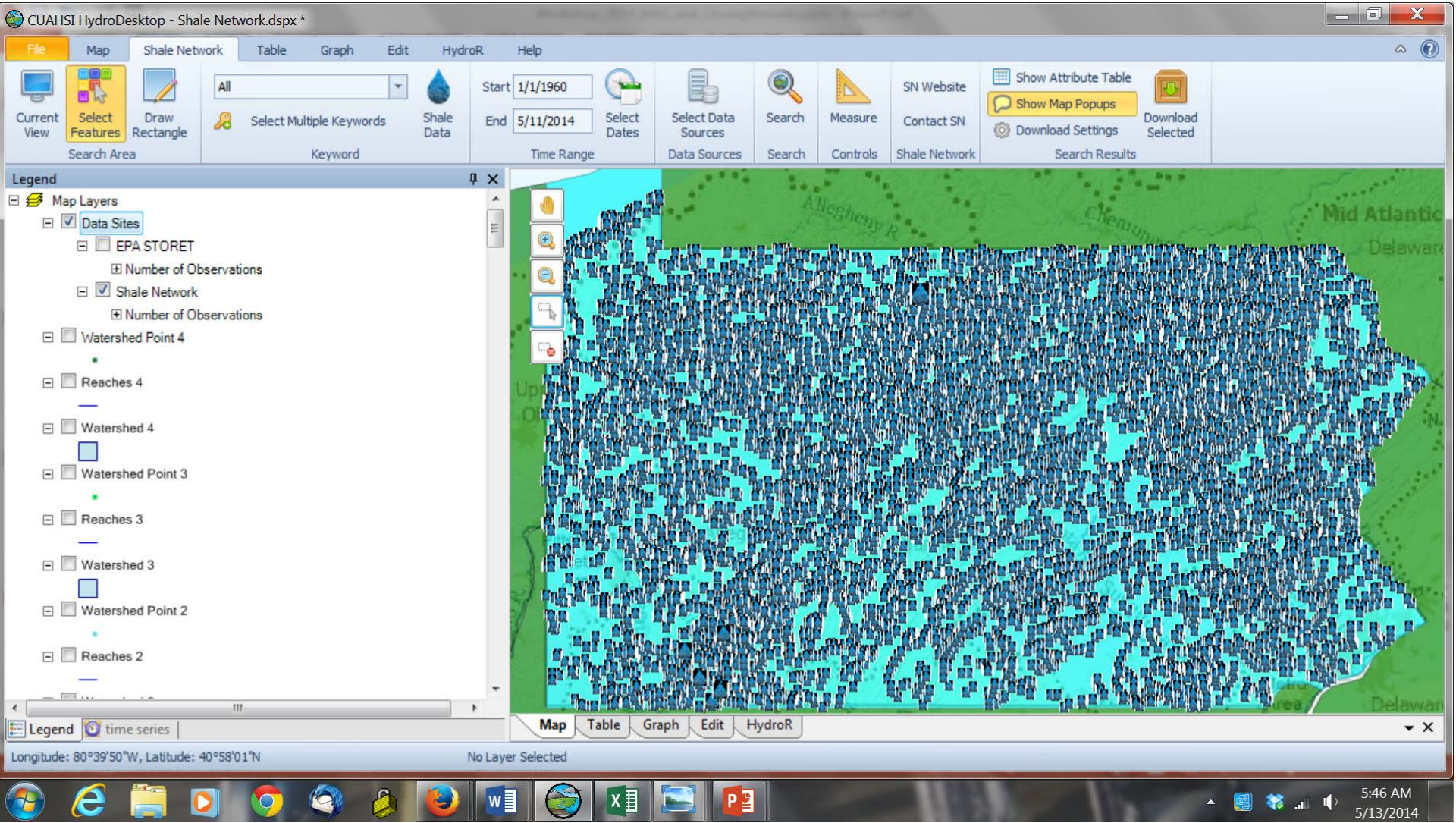
All data uploaded by Shale Network (started 10/11) as of December 2012: ~500 sites (www.shalenetwork.org)



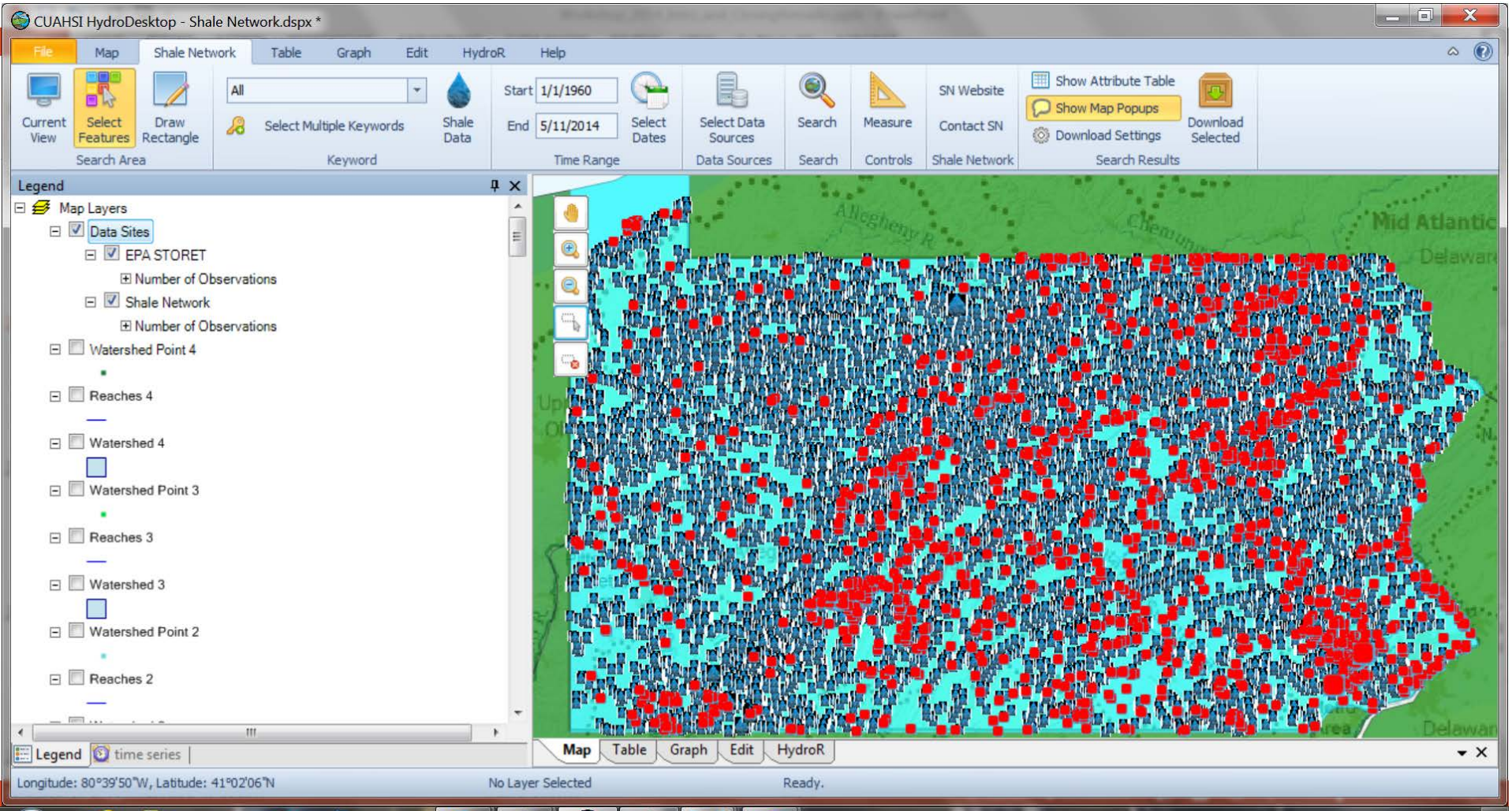
Growth of Shale Network Database



Why we use HIS: Data in ShaleNetwork can be found along with EPA, USGS and other tagged data



All locations with Shale Network (blue) and EPA (red) data as of May 2014



What data types are in the database?

Data Types

- Water quantity: discharge rates or stage height, etc
- Sensor data (water quantity, water quality)
- Chemical analyses on grab samples
- Samples collected on sporadic or regular basis

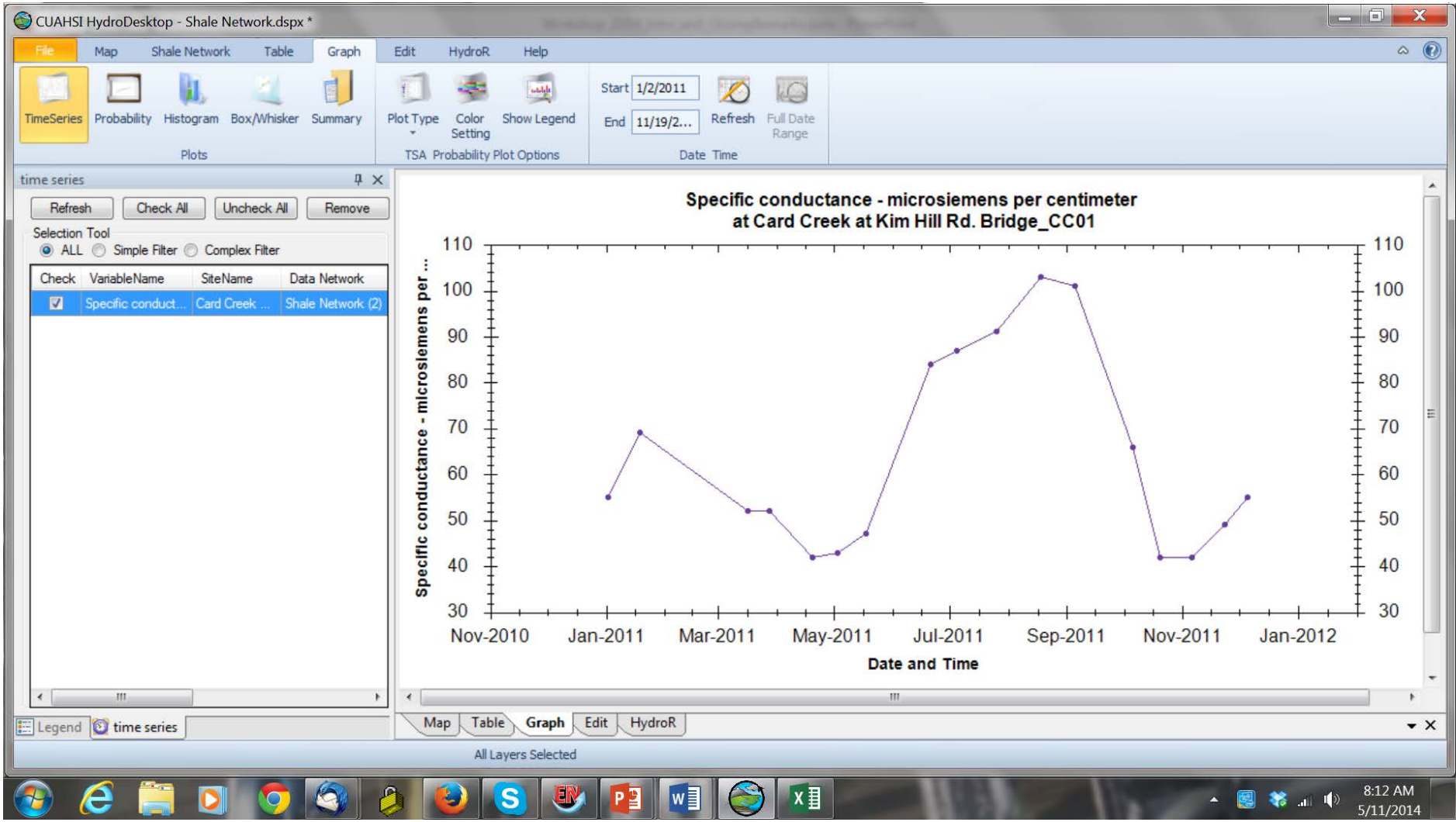
Water Types

- Surface water
- Ground water
- Flowback water
- Production water

Who are the data providers?

- Universities (unpublished data): 6
- Government entities: 8
- Volunteer groups: 41
- Oil/gas industry organizations: 9
- Private entities: 2

Volunteer data: collected for Card Creek in Potter County by Cork Sauve of GC Trout Unlimited



What about data quality?

- Shale Network includes data from any group using established data protocols -- from industry sources, government sources, university sources, nonprofits, citizen scientists
- SN philosophy is that even published peer-reviewed or gov't data has problems, so as much as possible we want to put data online with appropriate metadata for researchers to assess…THE BEST WAY TO ASSURE DATA QUALITY IS TO PUT IT ONLINE FOR SCRUTINY
- The metadata includes some information about data quality
- If problems are found in data we can remove data

The components of our project

Activity

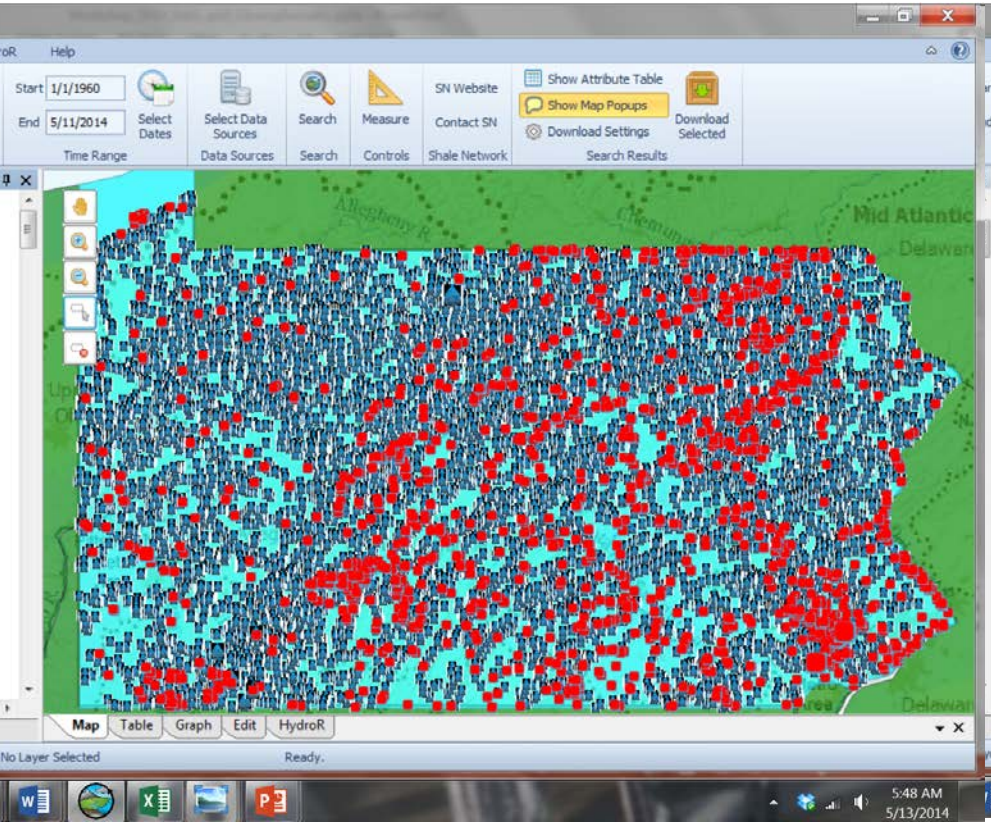
- Finding, organizing, formatting and publishing data online
- Educating graduate students in the topic
- Working with volunteers
- Interpreting data
- Running workshops that promote conversation among all stakeholders

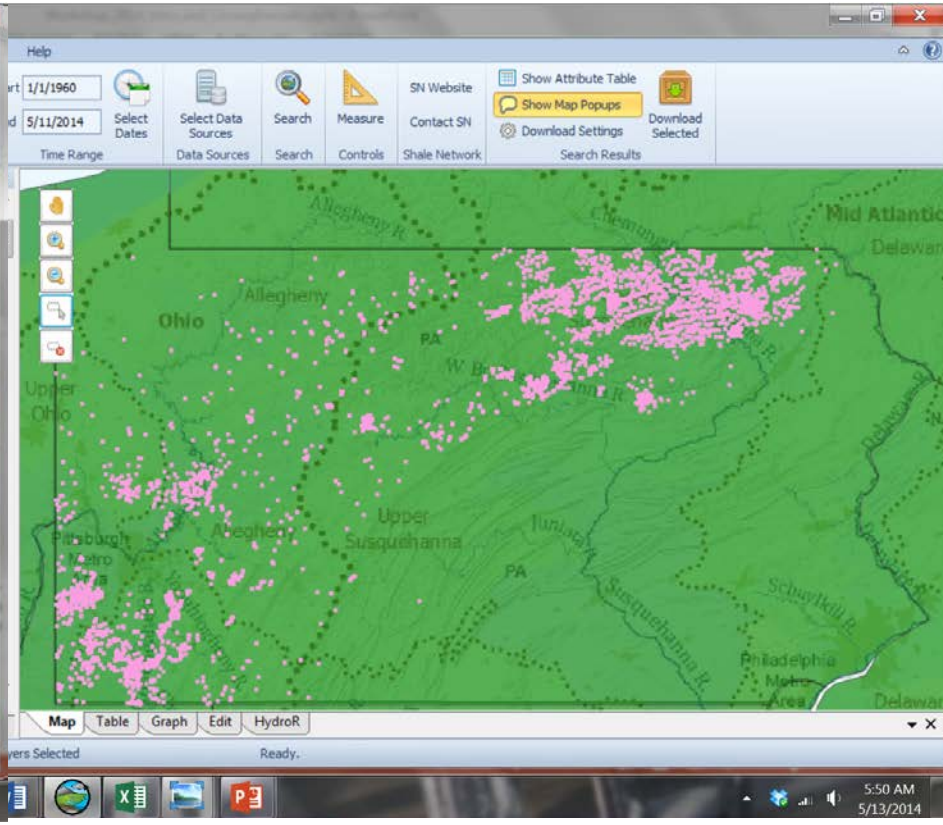
Funding

- NSF Shale Network (2011-2016)
- General Electric Gift to Penn State (2014-2016)
- NSF INSPIRE (2016-2019)
- Funds or advice from Penn State, Univ of Pittsburgh, Dickinson College, PA DEP, Bucknell Univ., SUNY Binghamton, ORAU

What have we learned from publicly available data?

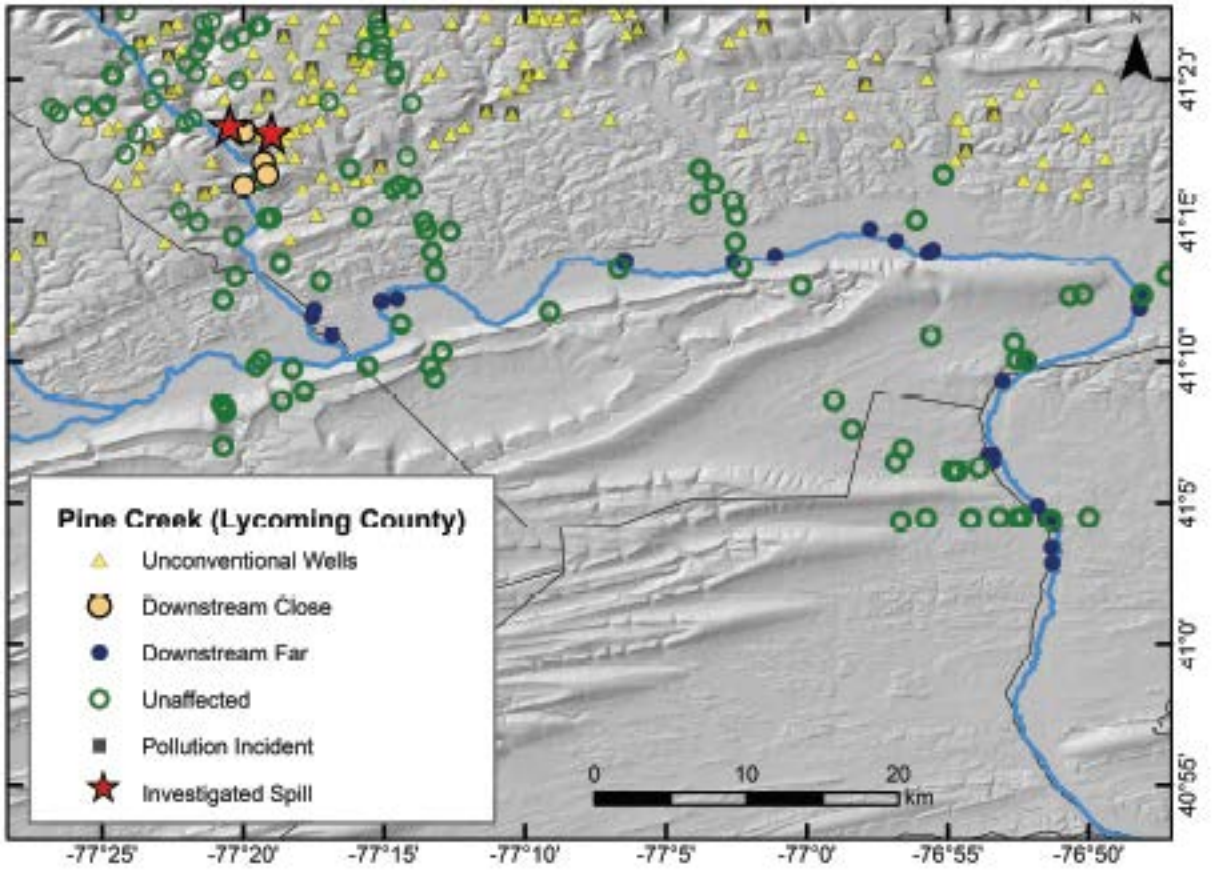
Even with > 1 million data values in the database, conclusions about impacts are limited because of lack of monitoring stations located at appropriate sites with the appropriate analytes measured at the appropriate times over appropriate durations.





Example: three spills into Pine Creek

Wendt et al., in prep.

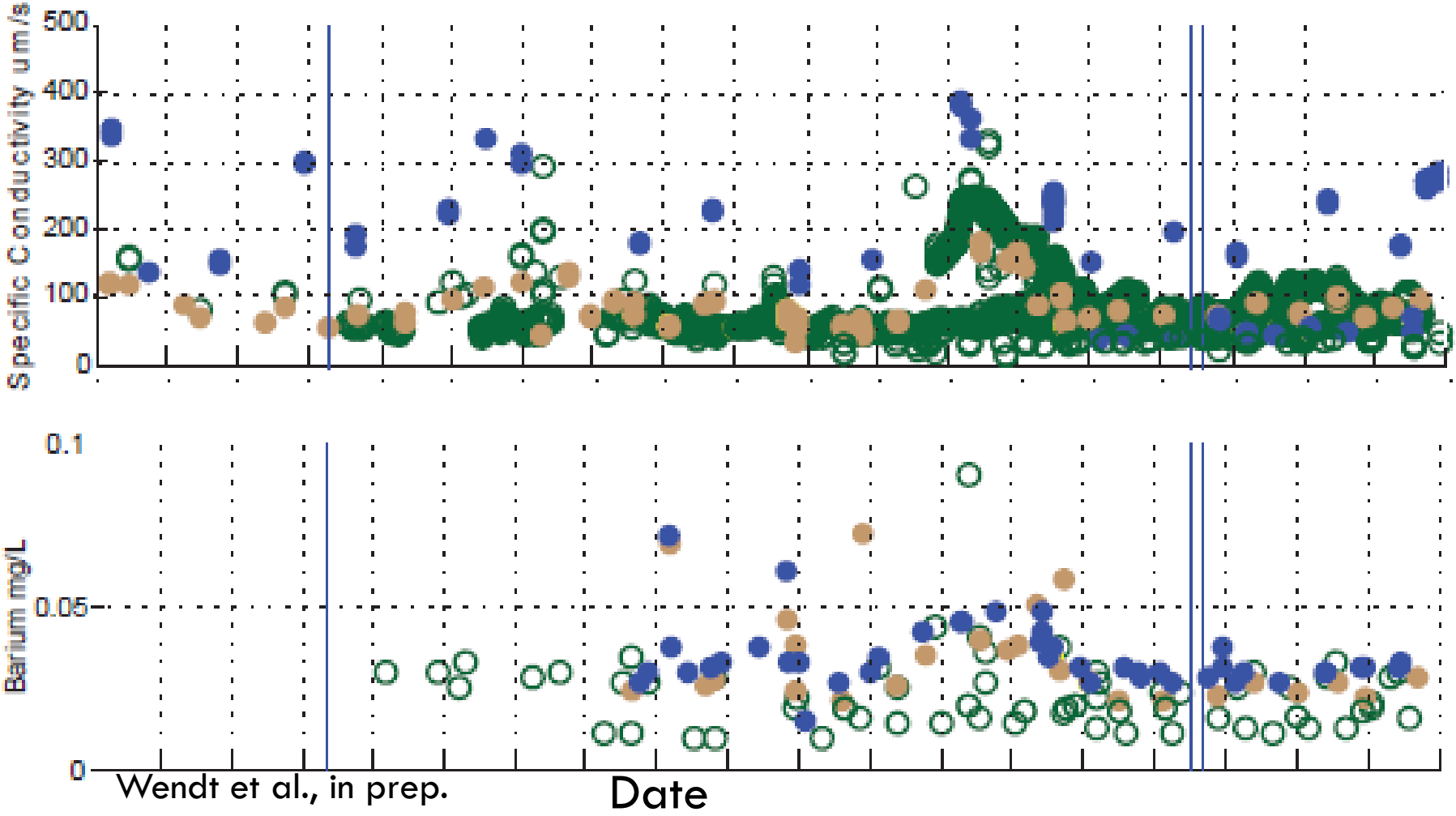


Airfoam 3/13/2010; Brine and diesel 1/6/2012 and 1/15/2012

Pine Creek spill: No evidence in data

Tan = downstream close to the spill
Blue = downstream far
Open green = Nearby tributary

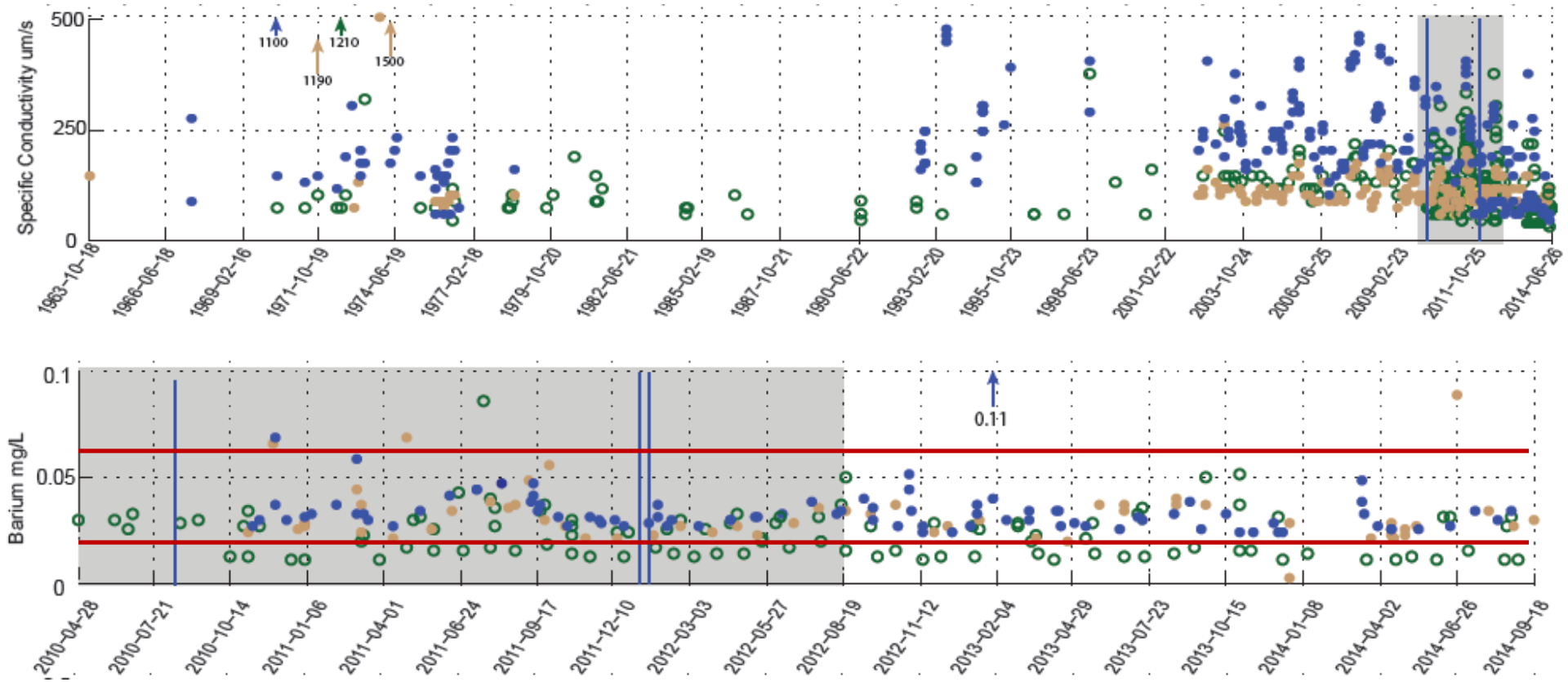
A spill of Airfoam occurred on March 13 and March 14, 2010 (released at 180 gal/min), a spill of 8200 gallons of brine occurred on 1/6/2012 and a spill of 89 gal of diesel occurred on 1/15/2012.



Longer time interval: no evidence

Tan = downstream close to the spill
Blue = downstream far
Open green = Nearby tributary

Wendt et al., in prep.



By investigating spills in PA, what can we learn about monitoring?

- Only ~2 out of the big 45 spills can be observed in publicly available data
- Unlikely to catch an event because of the low spatial density and temporal frequency of sampling, and the cost of monitoring
- Measurements nonetheless yield information about background values for streams – what we want to protect

Understanding baseline: Sulfate and Ba from early to mid 1900s to 2014

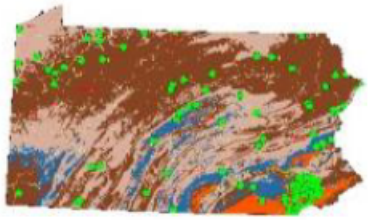
Data Sources

Publically available historical water quality data:

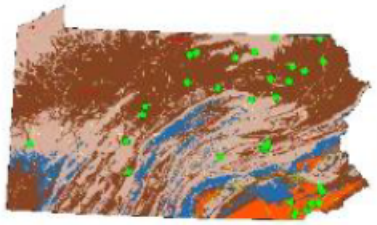
[SO4]:
1904 ~ 2014

[Ba]:
1963 ~ 2014

Pristine Rivers

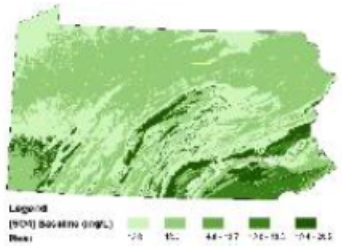


[SO4] : A total of 87 "pristine" streams

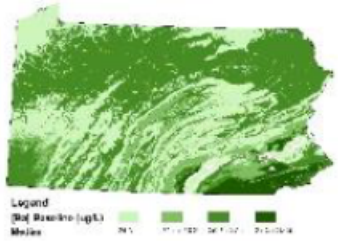


[Ba] : A total of 37 "pristine" streams

Baseline Values



[SO4] - PA Statewide:
15.8 ± 9.6 mg/L



[Ba] - PA Statewide:
27.7 ± 10.6 µg/L

Niu et al., in review

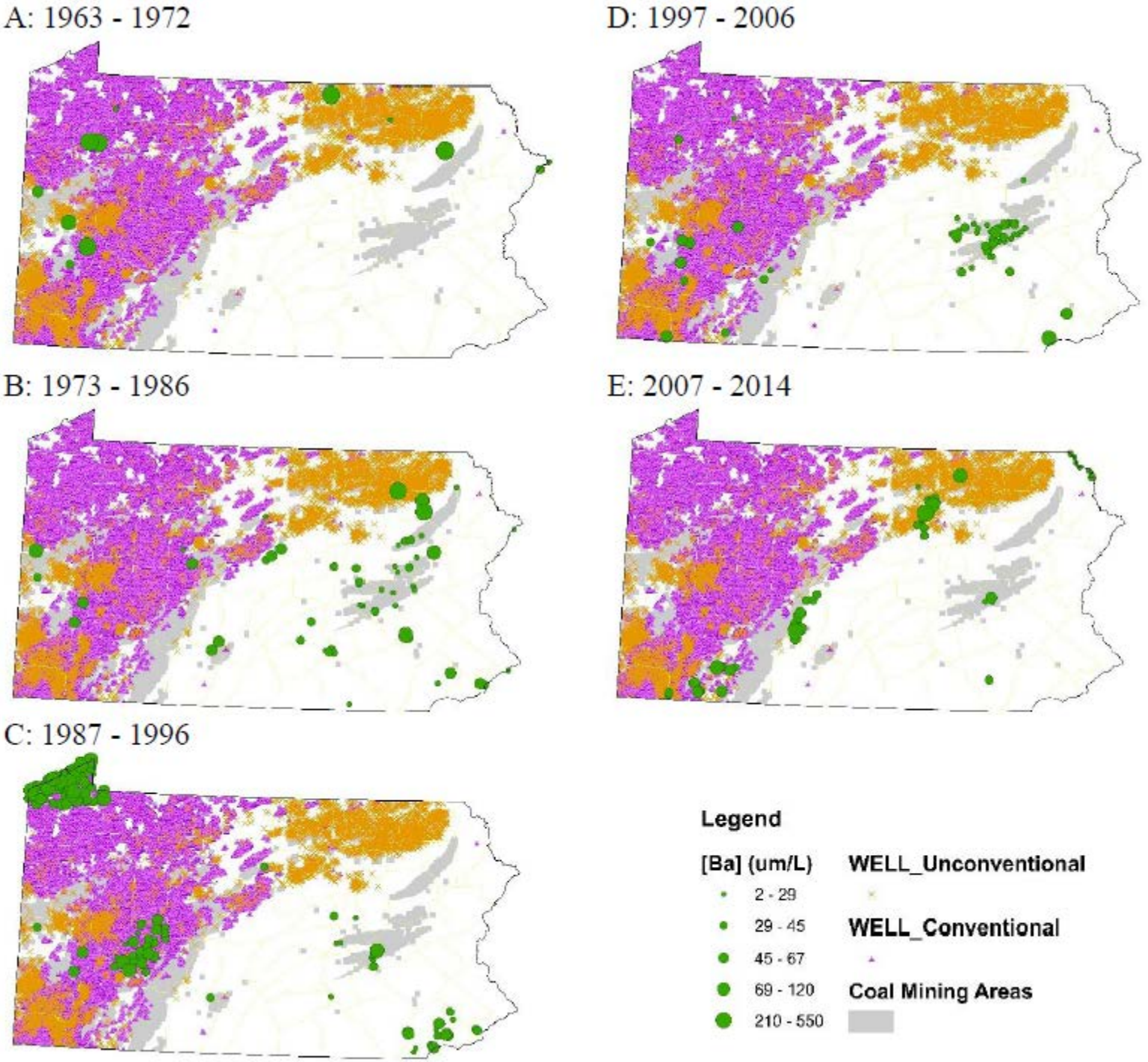

A: 1963 - 1972
D: 1997 - 2006
B: 1973 - 1986
E: 2007 - 2014
C: 1987 - 1996
Legend
[Ba] (um/L)
2 - 29
29 - 45
45 - 67
69 - 120
210 - 550
WELL_Unconventional
WELL_Conventional
Coal Mining Areas

Table 3

Summary of statistics of barium concentrations in PA surface water for areas with/without gas-wells (WELL) and areas with/without coal mining (COAL)

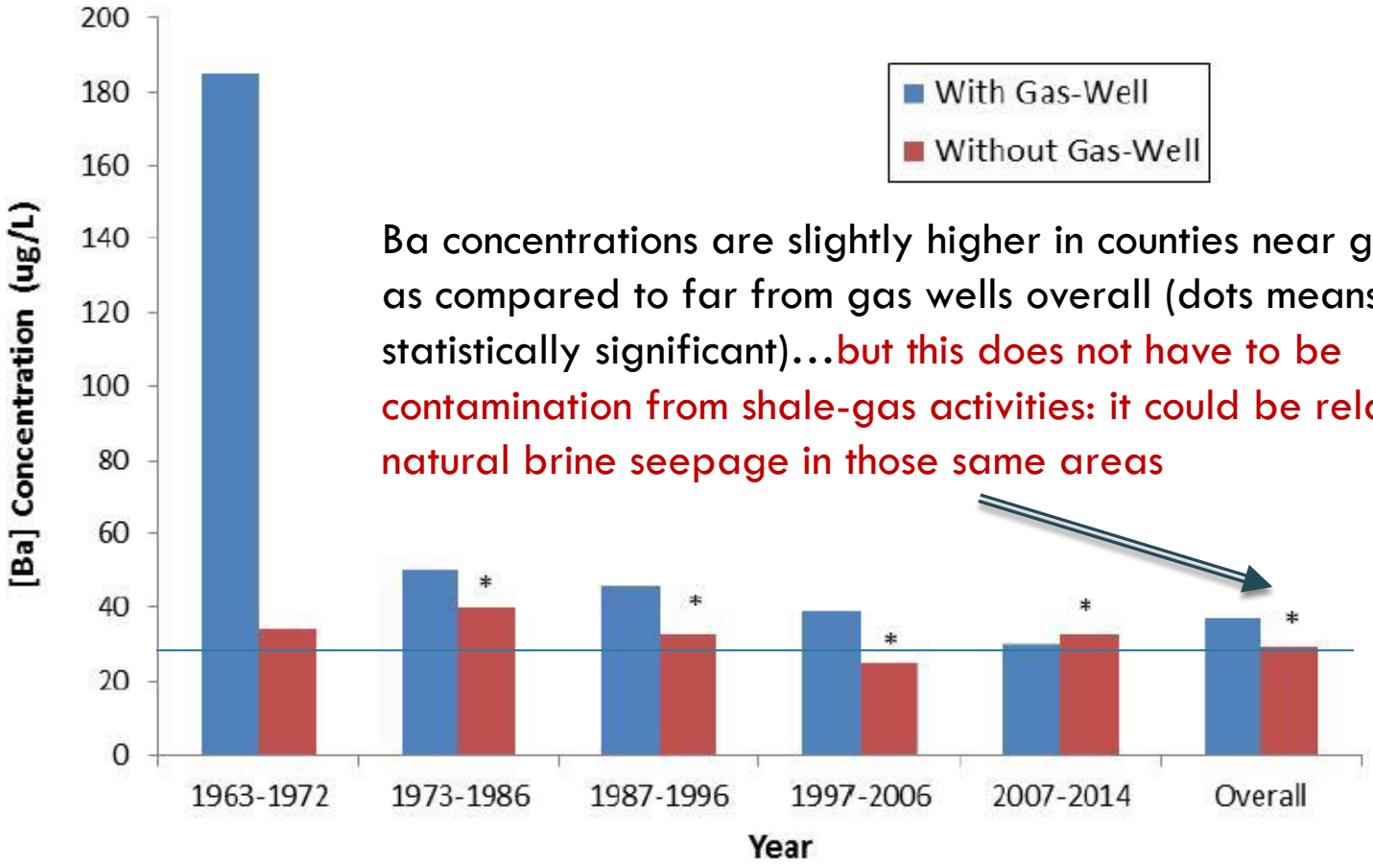
	COAL	NO	YES	NO	YES
	WELL	NO	NO	YES	YES
		A	B	C	D
	Mean (ug/L)	37.6	26.3	33.6	42.1

Very slight increases in [Ba] since 2007 could document impacts from shale gas development, but it could also document prevalence of natural brines.

P-Value						
	NO	NO	A			
	YES	NO	B	0.000 *		
	NO	YES	C	0.007 *	0.000 *	
	YES	YES	D	0.000 *	0.000 *	0.000 *

P-Values were calculated for differences between different combinations of WELL and COAL. For example, the first column of P-Values are for comparison of B vs. A, C vs. A, and D vs. A, respectively.

[Ba] in PA streams in regions with and without gas wells

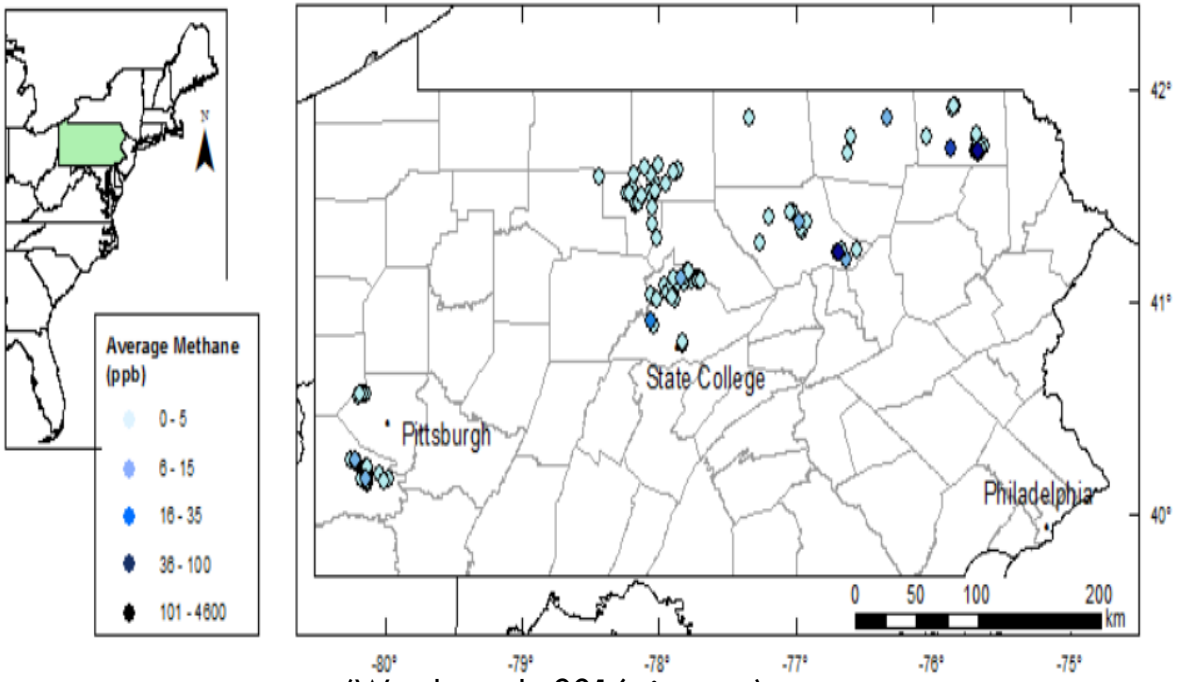


Ba concentrations are slightly higher in counties near gas wells as compared to far from gas wells overall (dots means statistically significant)…but this does not have to be contamination from shale-gas activities: it could be related to natural brine seepage in those same areas

Niu et al., in prep.

Understanding baseline: Methane in streams (2015-2016)

In collaboration with Vic Heilweil and Dennis Risser at USGS, we discovered one stream which appears to be contaminated by leakage from a nearby shale-gas well (Heilweil et al., 2015, EST)



(Wendt et al., 2016, in prep)

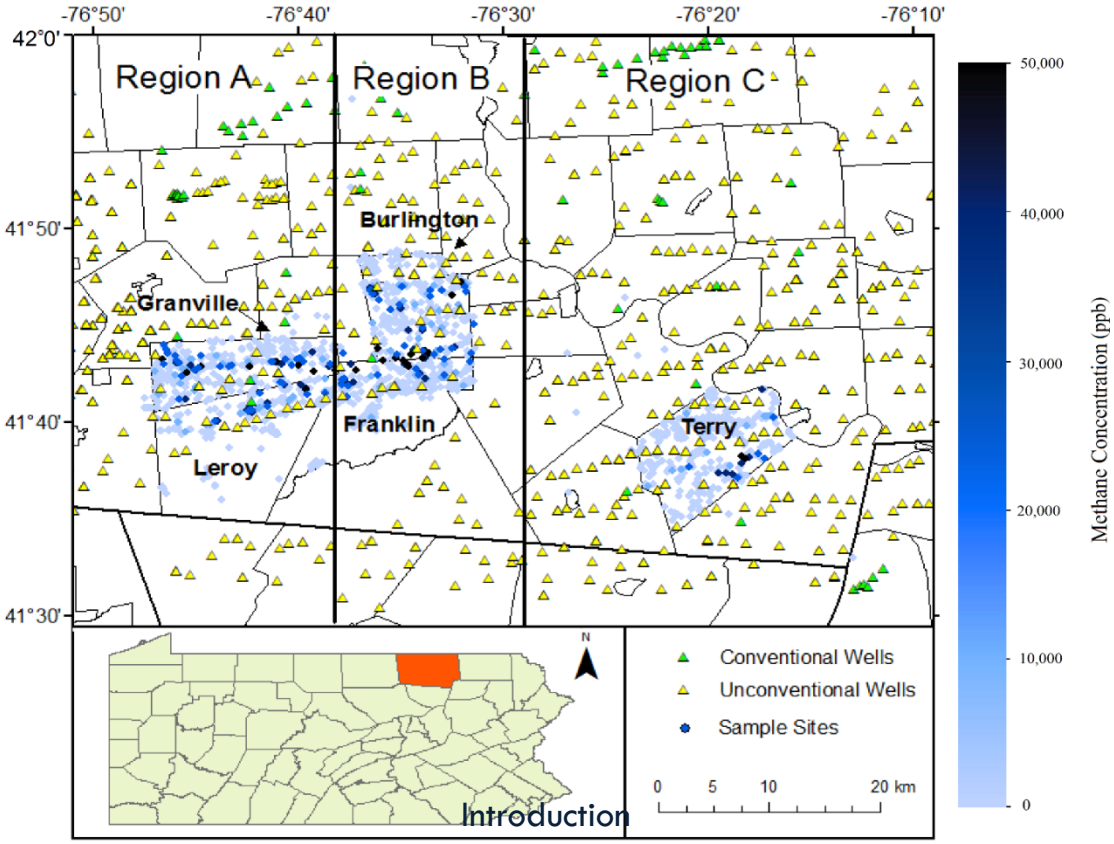
- 263 samples, 155 stream sites
- 40% of samples collected by volunteers
- Median stream CH_4 concentration, $[CH_4]$, is **~1 µg/L**
- The maximum stream $[CH_4]$ without wetland or anthropogenic inputs **= 7 µg/L**

See talks by Josh Woda (Penn State) and Luanne Steffy (SRBC) for impacts

We have also been investigating background in groundwater methane

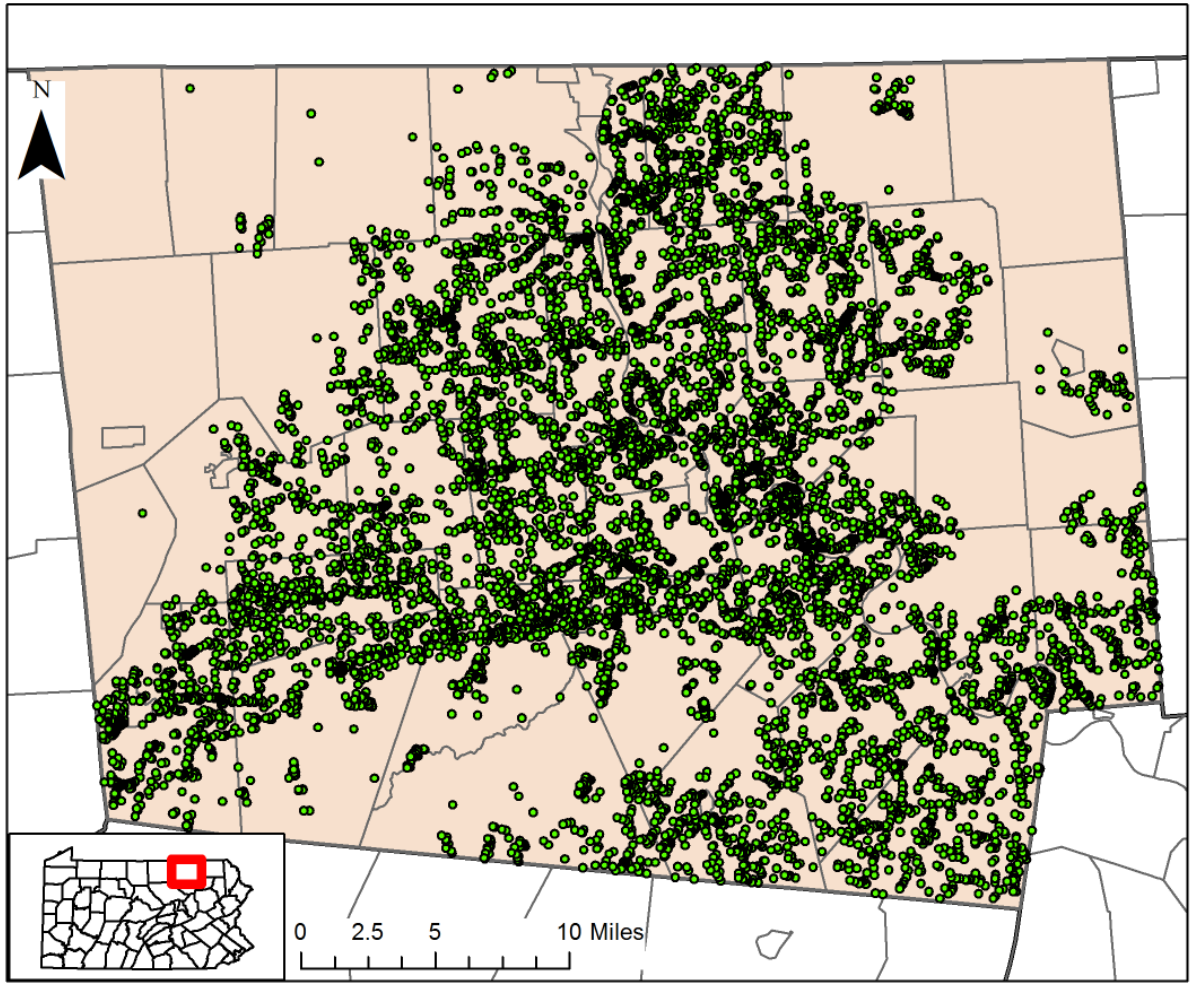
Map of 1690 groundwater samples from 5 townships in Bradford County, PA collected from private water wells by gas companies before they drill, released to PA DEP and shared with Shale Network team, now published online

Each blue dot is a water sample (intensity of color indicates methane concentration). Yellow triangles are shale gas wells



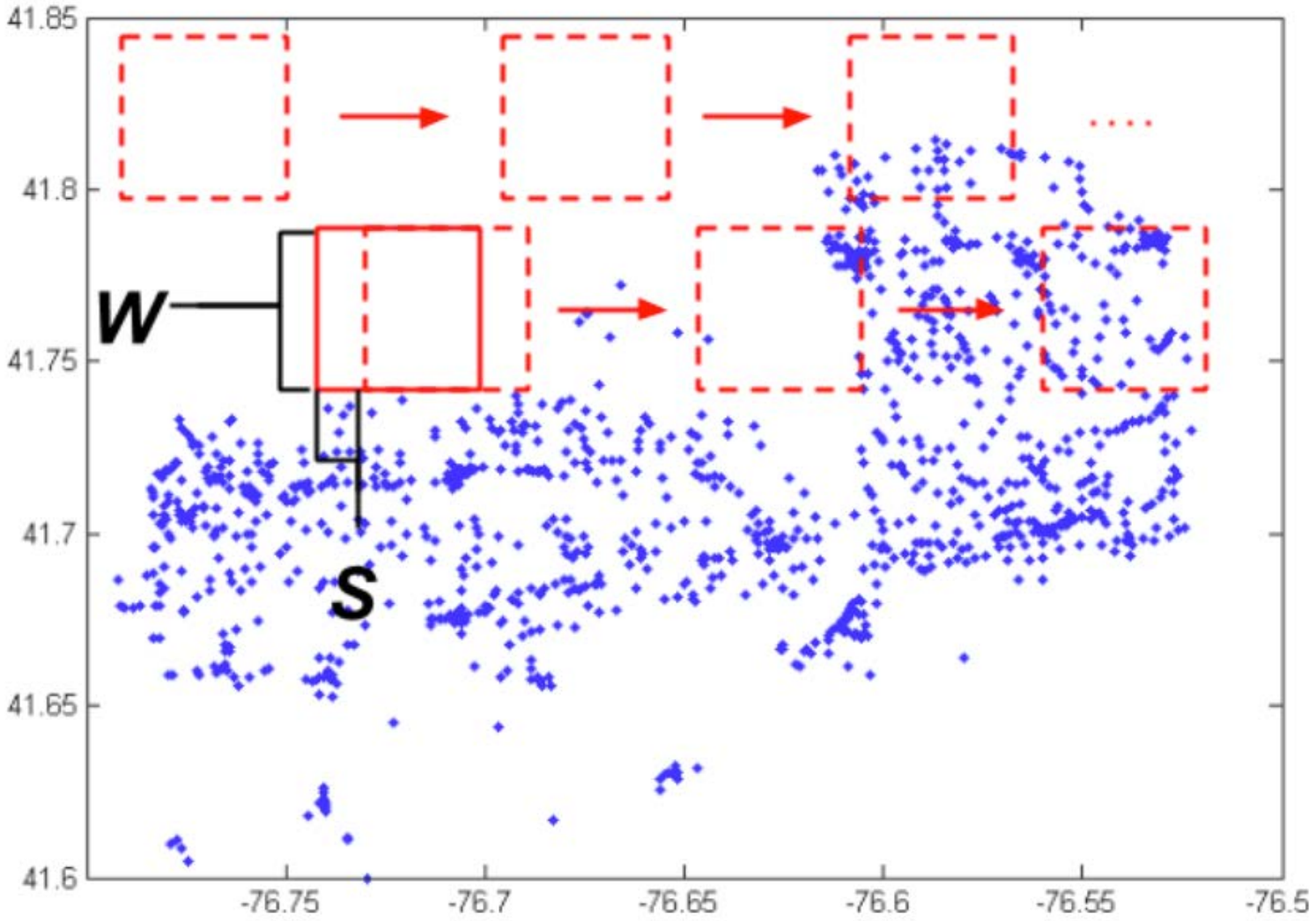
Li *et al.* (2016) Journal of Contaminant Hydrology

Study area – Bradford County



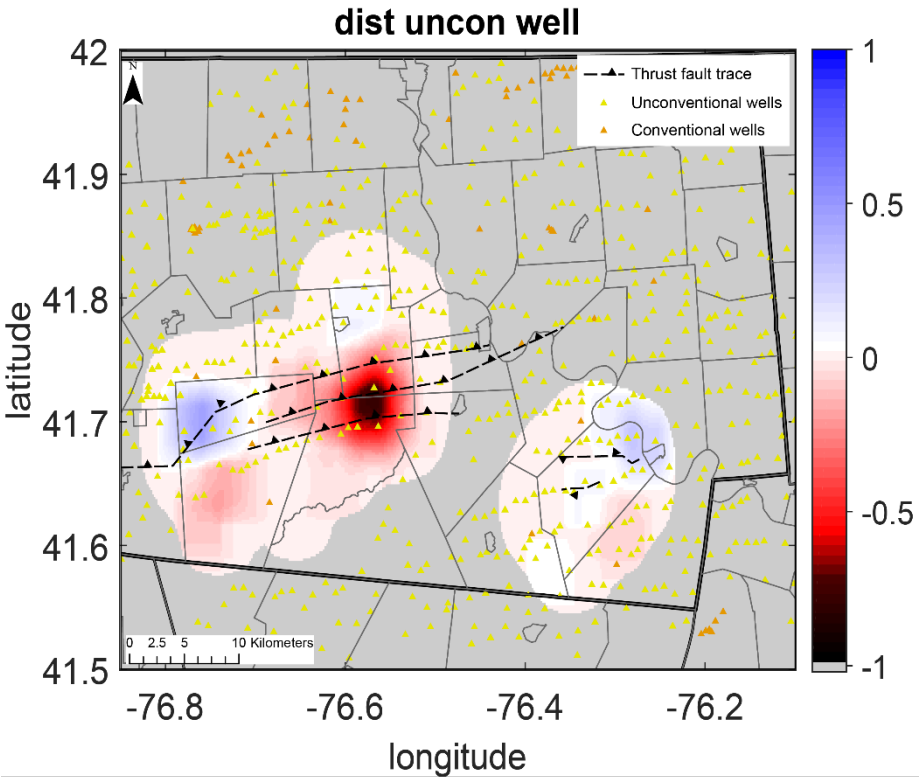
- ~11000 groundwater samples collected by oil&gas companies 2010/12-2014/07.
- Provided to us by PA DEP.
- Bradford was chosen because of know gas leak issues.
- Work by Tao Wen, Penn State

Sliding window technique developed by PSU Assistant Prof. Jessie (Zhenhui) Li and students

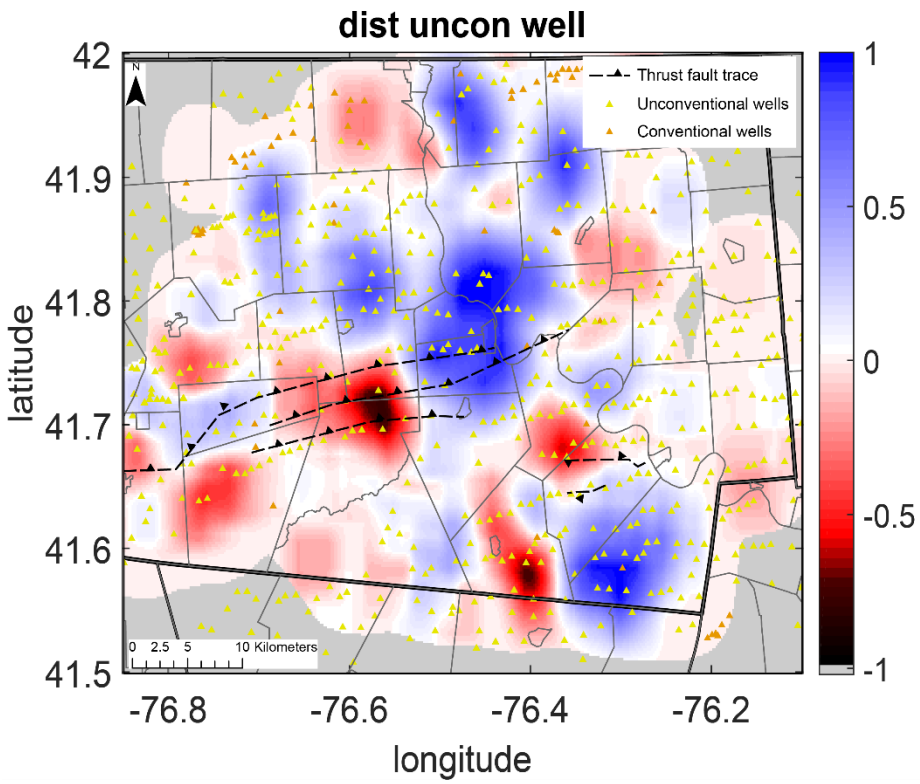


Correlation of [CH_4] with distance to unconventional shale gas well

1690 data points from Li et al. (2016)



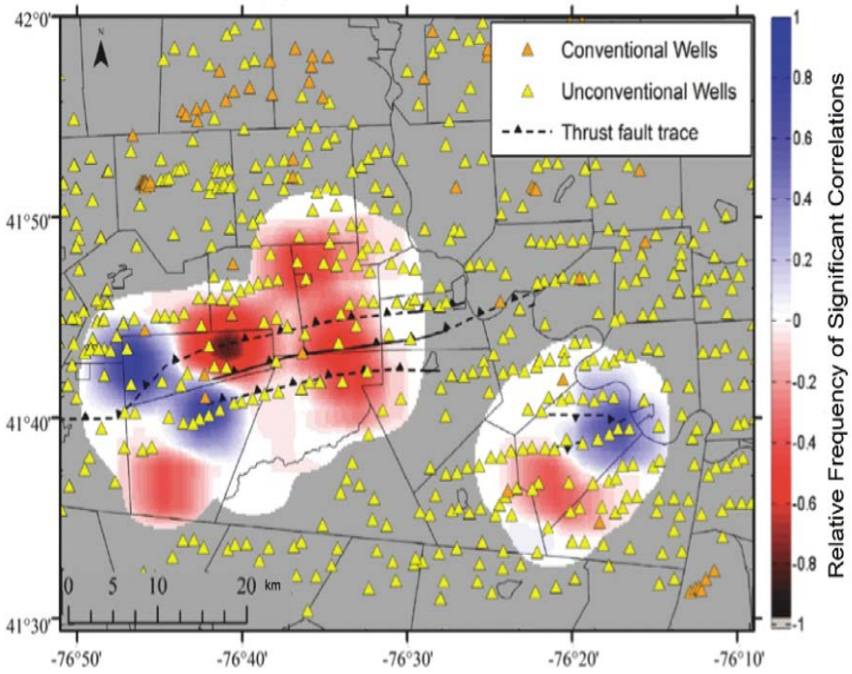
11,000 data points from this study

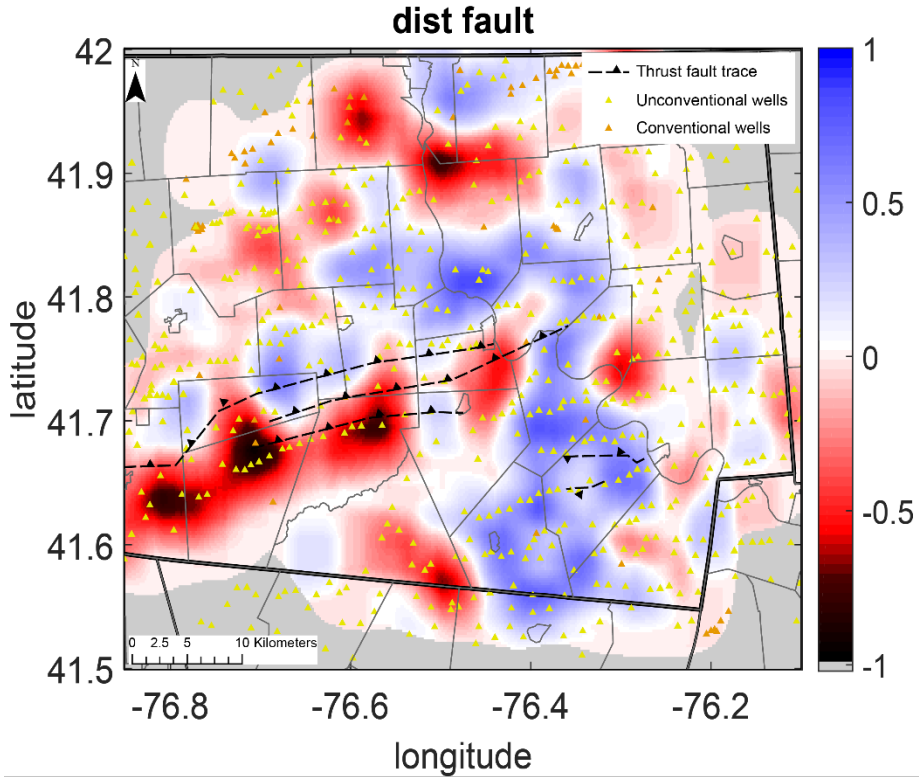


New calculations by Tao Wen, Penn State

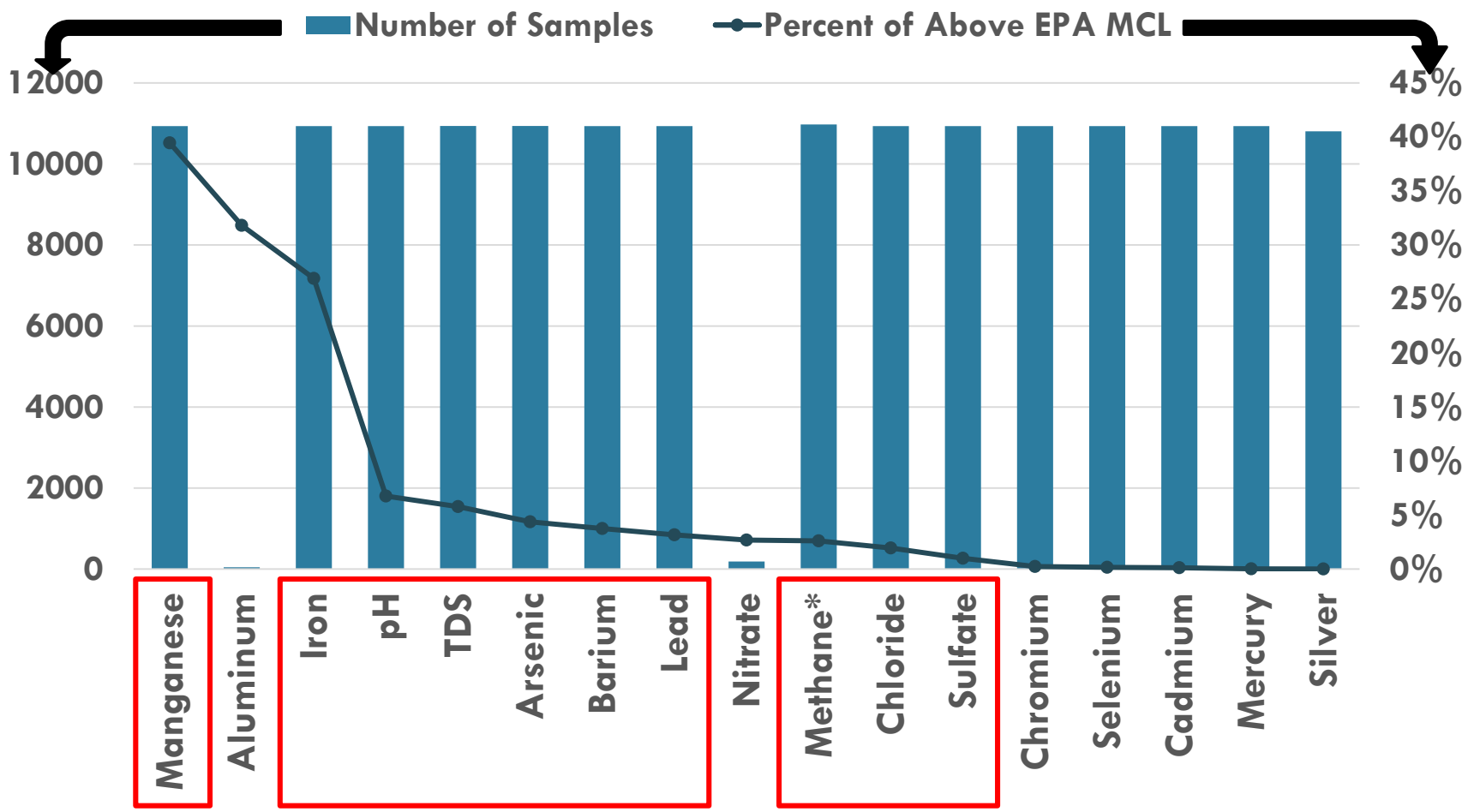
Correlation of [CH_4] with distance to fault

A huge benefit of all the interest in potential impacts on water quality from shale-gas development is new insights about controls on water quality using new tools and models

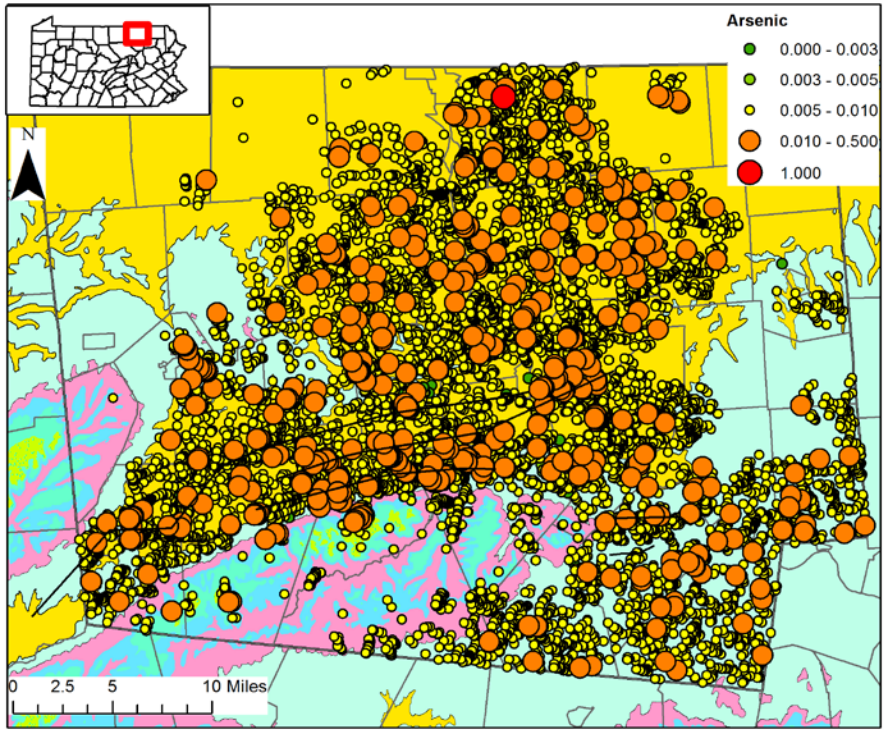


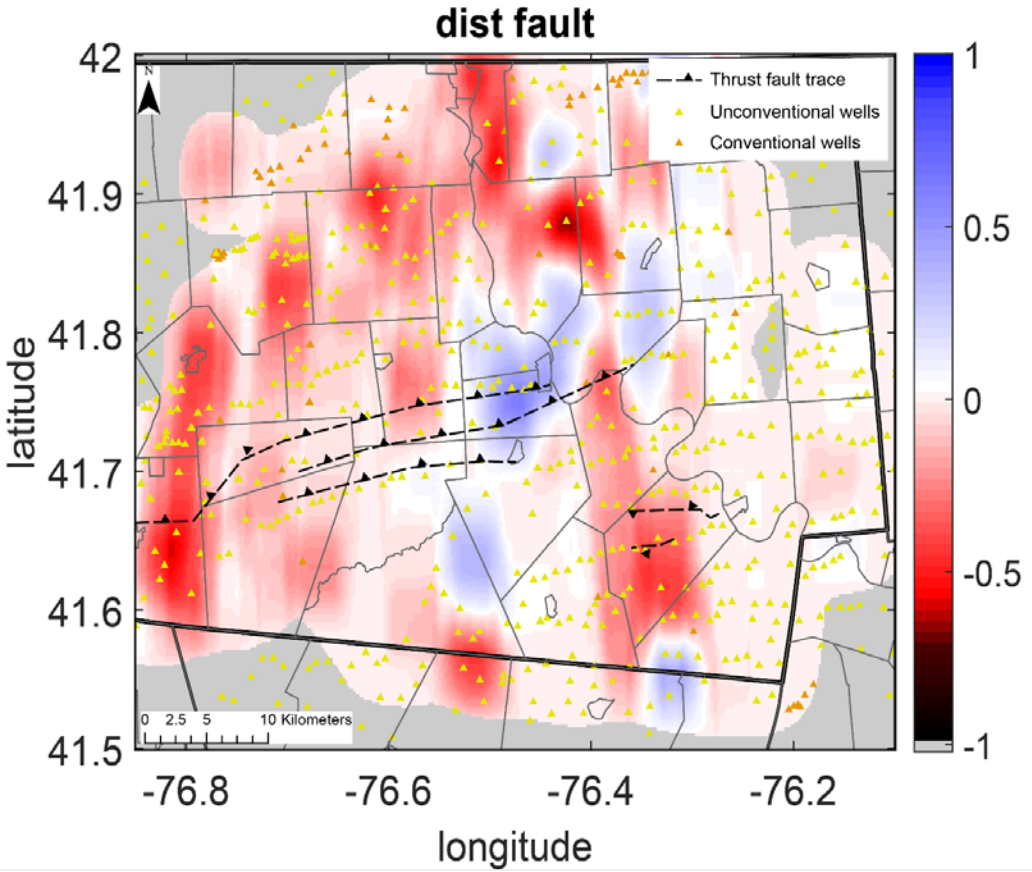


Background concentrations in groundwater



Arsenic concentrations in groundwater (left) and correlation with distance to faults (right)



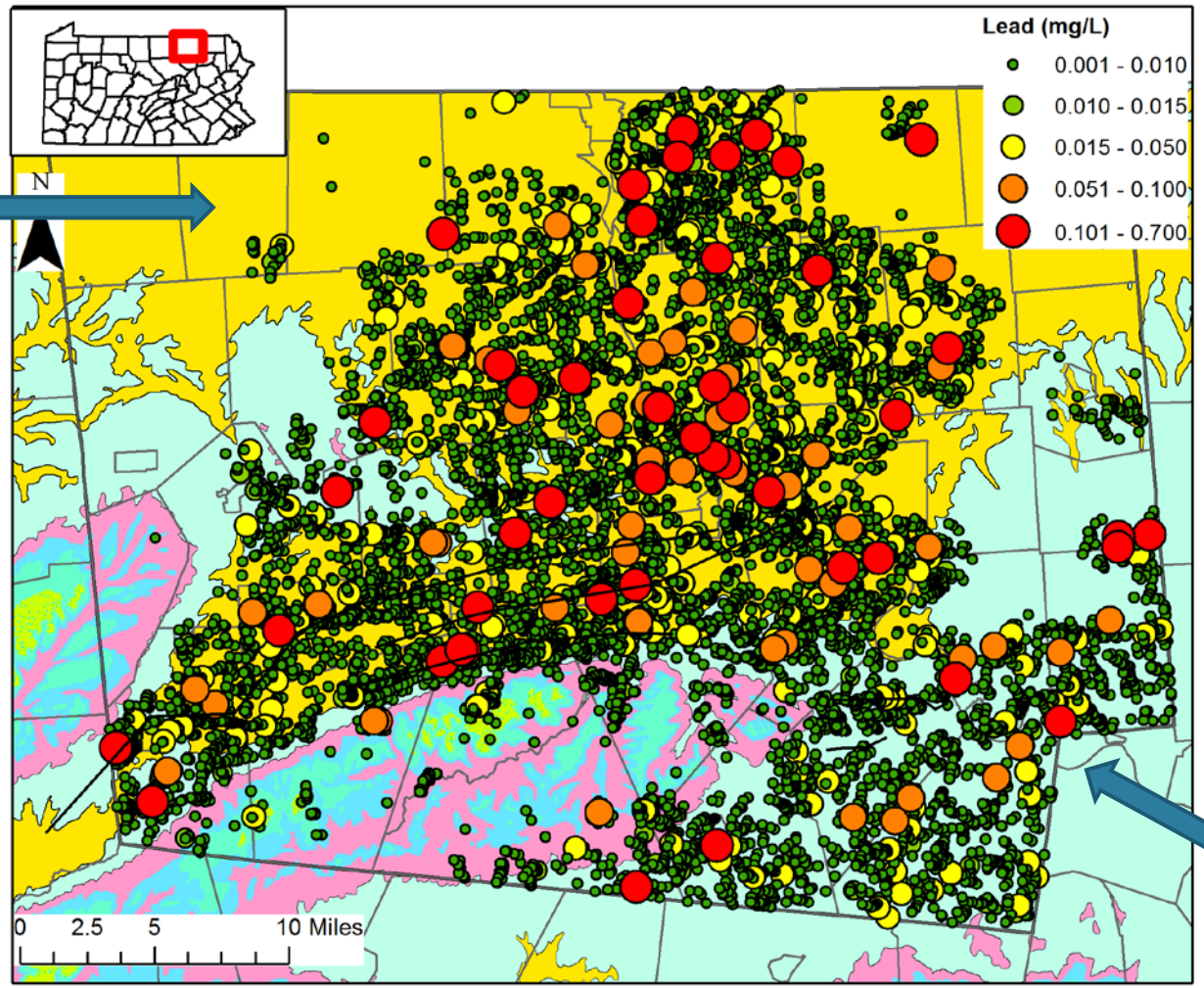


EPA MCL for arsenic is 0.01 mg/L…
orange and red dots on plot

Full 10,936 data analysis reveals high lead is occasionally observed

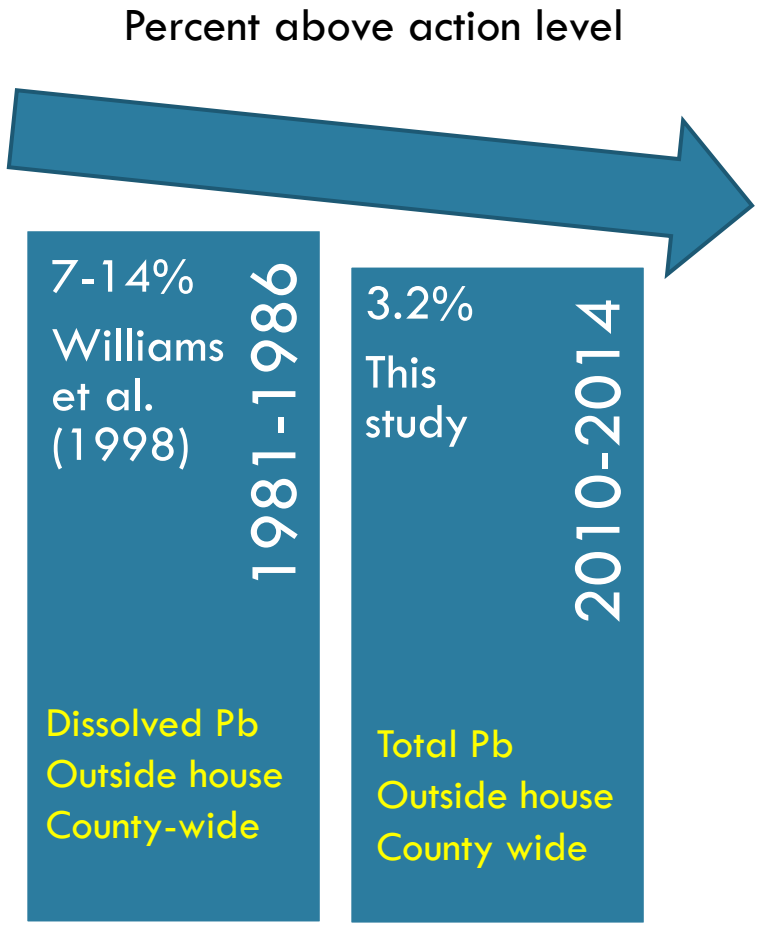
Lock Haven Formation (yellow)

EPA action level For Pb is 0.015 mg/L…all the yellow and red and orange colors on map



Catskill Formation (cyan)

Is this a temporal trend for Pb levels in Bradford groundwater?



Both means and medians of our study and the USGS report are similar

Observations about potential water impacts

- The most commonly cited water impact related to shale gas was contamination by methane (we observed no public data documenting movement of HVHF fluids from the depth of the Marcellus into drinking water resources in PA)
- The volumes of brine produced (>a billion gallons in PA) leads to significant needs for waste water management that may increase in the future if 30,000 shale-gas wells are developed
- A few tens of kilometers of streams in PA have been impacted temporarily by spills or leaks – but data describing these impacts are hard to find
- Disposal of solid wastes from shale-gas wells (precipitates from brines or drilling cuttings) go to landfills and the long-term implications of this waste disposal and their NORMs must be assessed

Observations about monitoring

- Many groups have initiated monitoring programs but no coordinated effort has emerged in PA
- To identify contamination requires knowledge of background conditions. Although assessing background is difficult, work to date has elucidated fundamental controls on water chemistry and has emphasized natural controls and other impacts (coal mining, agricultural contaminants, atmospheric deposition)
- Monitoring networks to detect all spills and leaks would be extremely costly and time-consuming
- We do not agree on the metadata that we must collect

Observations about social science

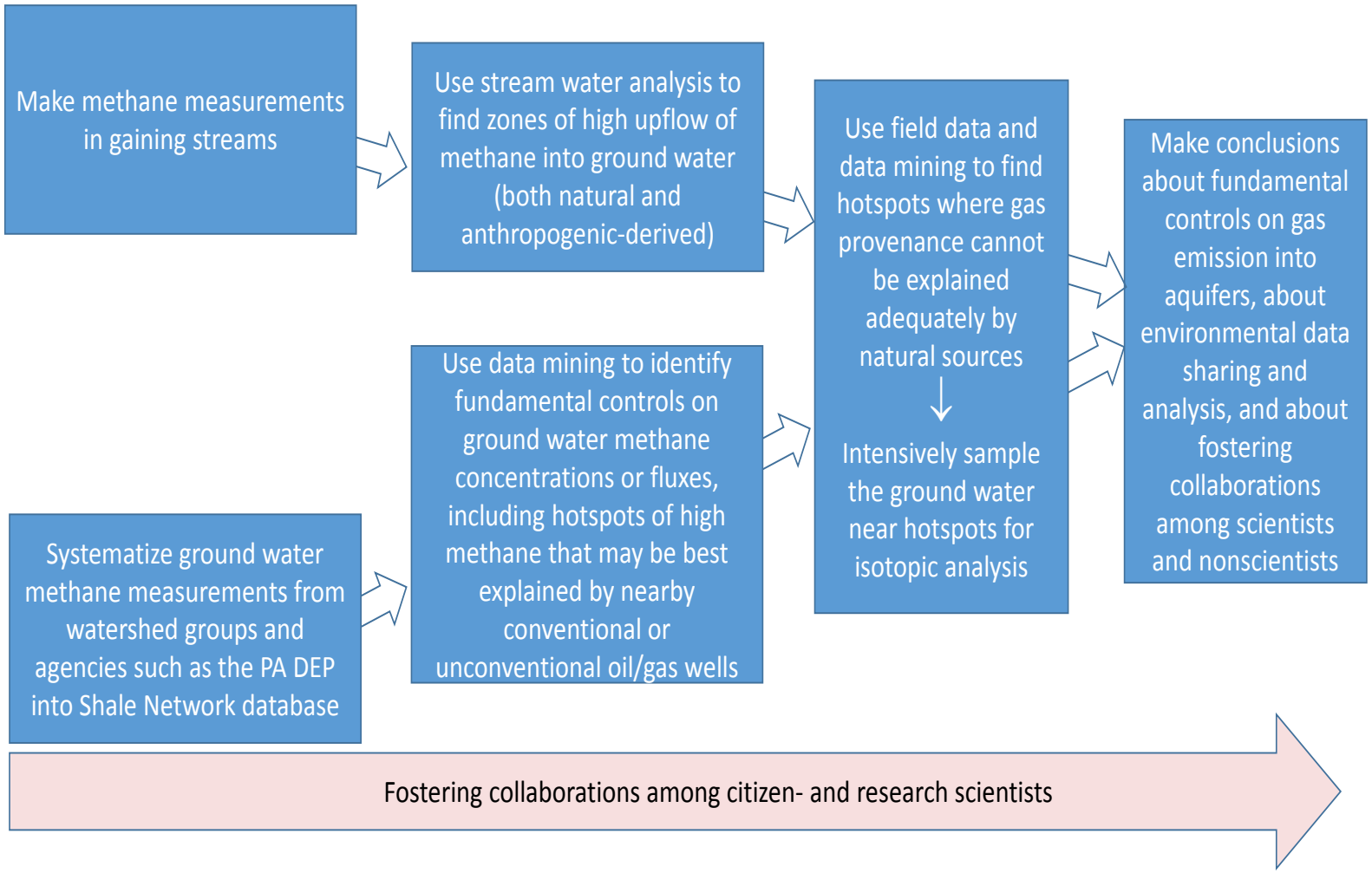
- All entities have reasons not to share data
- Few understand the entire complexity of water quality data, from sampling to analysis to interpretation to publishing online in data cyberinfrastructures
- The rate of reporting by the media outcompeted the rate of scientific publications early on…resulting in a few high-profile "signaling events" that amplified risk perception in some audiences
- Our data from previous workshops shows that participants express increased interest in accessing and sharing water quality data: 63% indicated increased trust in water quality databases
- We have observed that some scientists are resistant to working with nonscientists

Some Thoughts about What is Needed

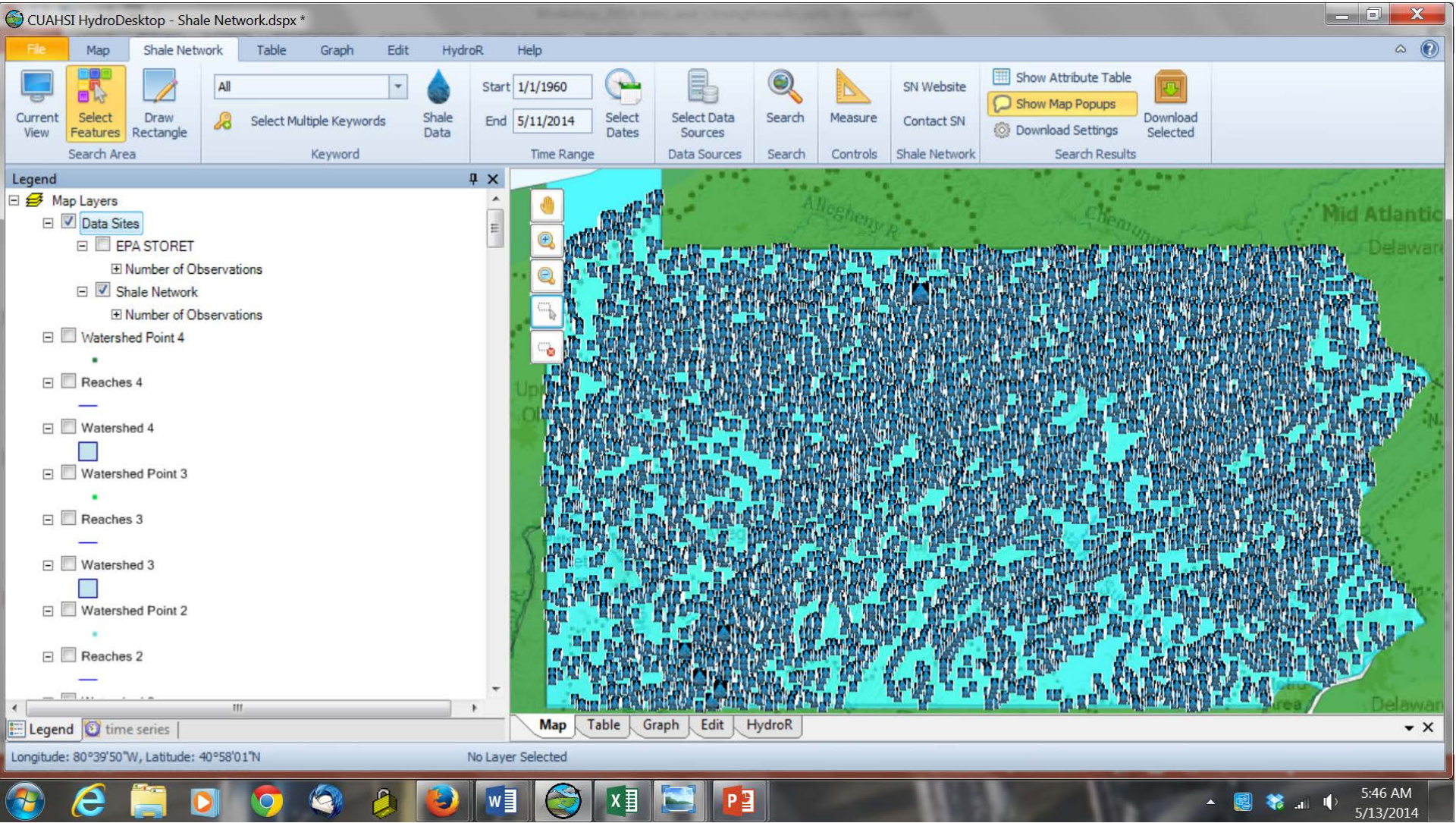
- Public data is a requirement for public confidence in any activity that is related to water quality. Data sharing, even at litigated sites, should be promoted.
- With >10,000 shale gas wells and >300,000 conventional wells, we need methods to look over broad areas for problems and then focus on specific sites.
- Citizen science has a role to play to assess background values: "background" is what we are trying to protect. Social license depends upon finding new ways to incorporate nonscientists into the process of monitoring, measurement, and analysis.

Thanks to EESI personnel: Debbie Lambert, Tracy Bernier, Jennifer Williams, Matt Carroll, Dan Shapich

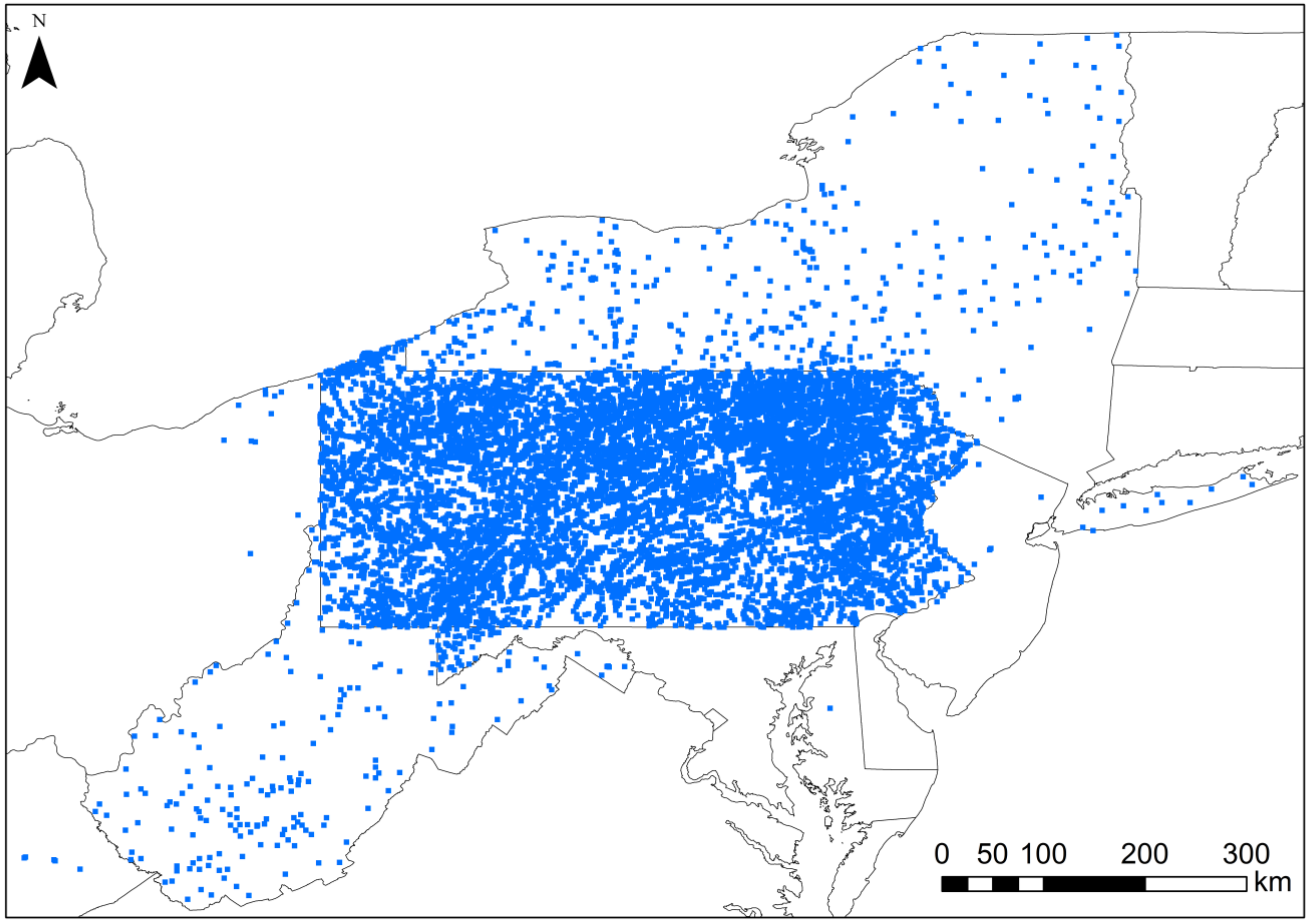
Conceptual model for a way forward?



All data as of April 28 2015 (www.shalenetwork.org): ~24,000 sites



All data uploaded by Shale Network as of April 2016: 26,984 sites



Even though spills as large as 100,000s of gallons were reported, it is difficult to find evidence in public data of significant water quality impacts in PA due to shale gas activities.

This could be because incidents have occurred at relatively low frequency and have been quickly diluted. However…

- A lot of water data are not released to public due to liability or confidentiality issues
- Sample and sensor data for analytes of interest are sparse spatially and temporally
- Pre-existing water quality impairments (e.g. acid mine drainage, road salt) make it difficult to discern shale gas impact
- Even when sensors are deployed, they can malfunction or drift

Correlation of $[CH_4]$ with distance to conventional oil/gas well

1690 data points from Li et al. (2016)

11,000 data points from this study