Preliminary Interpretation of the Impacts of Marcellus Shale Gas Extraction Activities on Small Streams, Based on Volunteer-Collected Data

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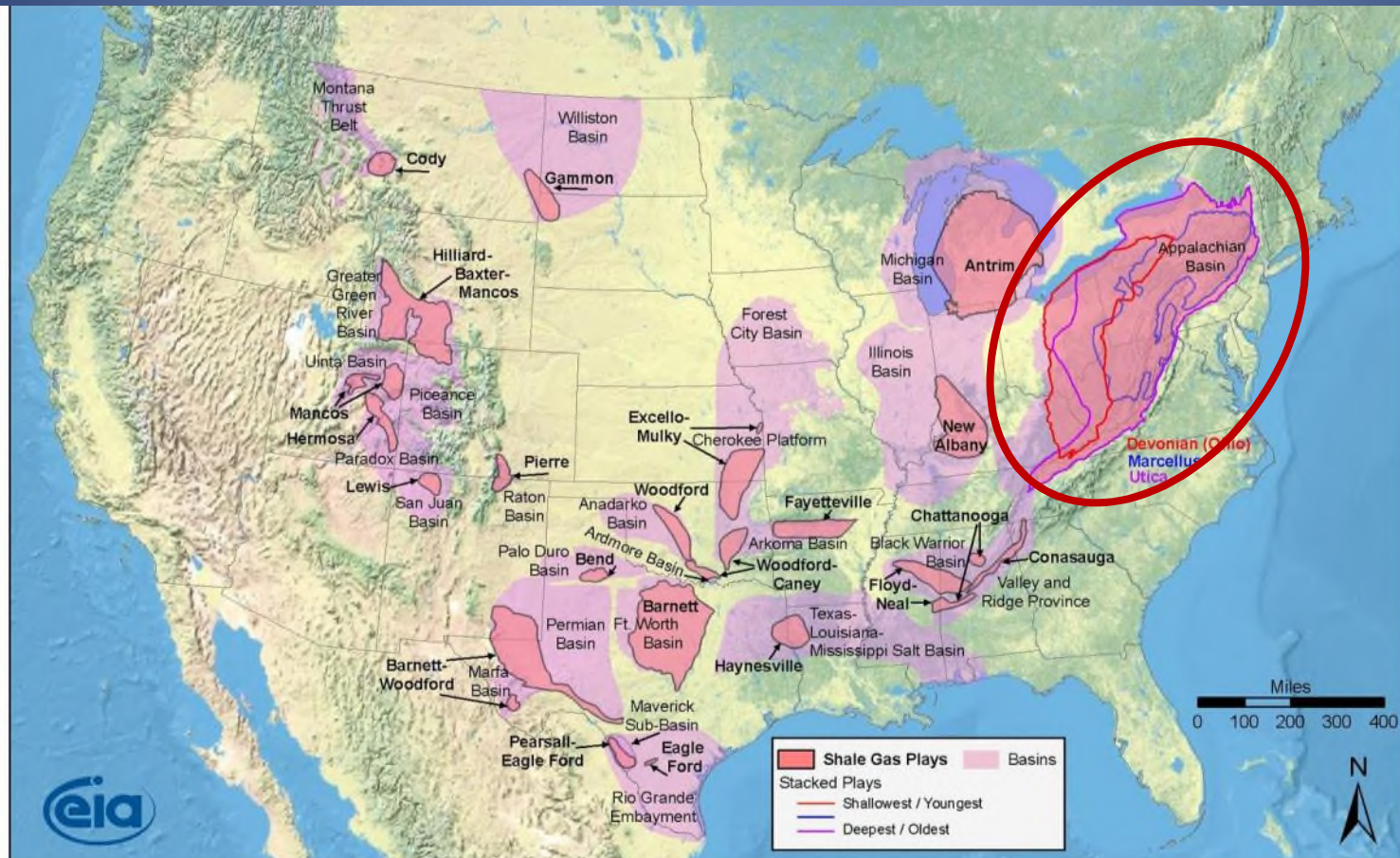
National Monitoring Conference
May 1, 2014

Outline of presentation

I. Marcellus shale distribution, drilling activity and environmental concerns

II. Introduction to ALLARM

III. ALLARM's Shale Gas Volunteer Monitoring Protocol

IV. Data analysis and interpretation

V. Summary of findings

VI. Implications of findings

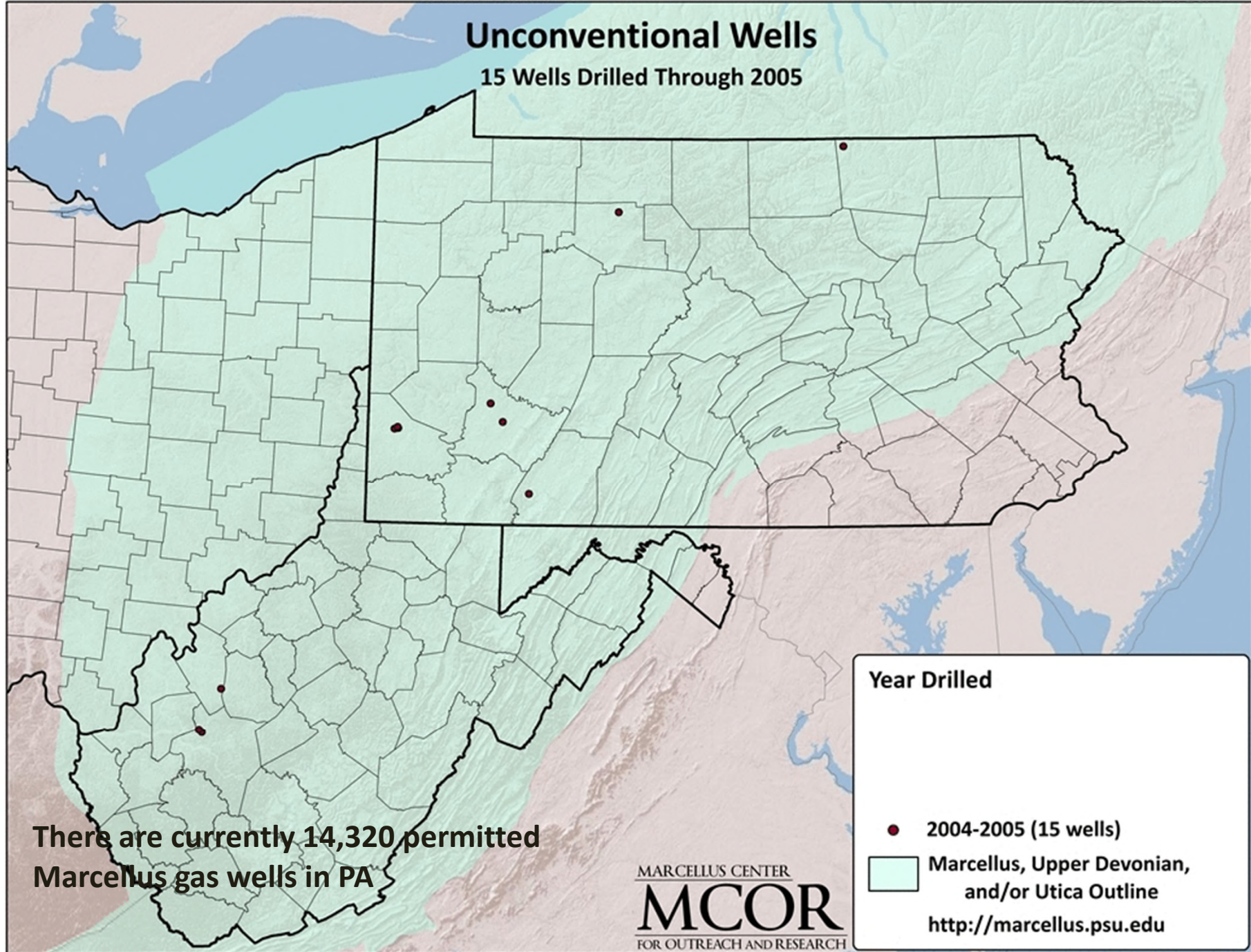# I. Marcellus Shale distribution, drilling activity and environmental concerns

Source: Energy Information Administration based on data from various published studies
Updated: May 28, 2009

From: US Dept of Energy, *Modern Shale Gas Development in the US: A Primer*, 2009

Unconventional Wells
15 Wells Drilled Through 2005

There are currently 14,320 permitted Marcellus gas wells in PA

Year Drilled

● 2004-2005 (15 wells)

Marcellus, Upper Devonian, and/or Utica Outline

http://marcellus.psu.edu

MARCELLUS CENTER
MCOR
FOR OUTREACH AND RESEARCH

Top producing companies in PA as of 12/31/13

Company Name	Estimated value of gas produced to date	Estimated royalties paid out (12.5% of value of gas)
CHESAPEAKE	$ 4,637,973,727	$ 579,742,965
CABOT	$ 2,891,428,811	$361,428,601
RANGE	$ 2,146,347,921	$ 268,293,490
TALISMAN	$ 2,006,312,732	$ 250,789,091
EQT	$ 1,432,417,223	$ 179,052,152

From: http://marcellusgas.org/record_book_co.php?report_type=top_producing_co

Land Use Alteration and Infrastructure Impacts

Access Roads

Well pads

Transport vehicles

Compression stations

Cleaning stations

Pipelines

www.ltresources.com.au

Forest fragmentation

Erosion/ Sedimentation

Surface and groundwater pollution

Air pollution

Pictures by: Amy Bergdale, US EPA

Water-related impacts

- Water consumption
  - Impact on small remote streams
  - Impact on water supplies

- Contamination of surface and ground water from gas extraction activities:
  - Poor casing of wells
  - Accidental spills
  - Flooding of well pads
  - Poor handling, treatment and disposal of fracking and flowback fluids
  - Methane migration

- Runoff from well pads, pipelines, increased trucking activity and access roads

http://www.nytimes.com/2011/10/20/us/rush-to-drill-for-gas-creates-mortgage-conflicts.html

II. Introduction to ALLARM

Alliance for Aquatic Resource Monitoring

Educate. Engage. Empower.

ALLARM Background

- Founded in 1986 as a project of the Environmental Studies Department at Dickinson College, the Alliance for Aquatic Resource Monitoring provides technical support to communities to help them use science as a tool to investigate their stream health concerns.

- ALLARM employs 12-14 students during the school year who are actively involved in community collaboration, educational workshops, laboratory analysis, policy research, stream testing, and outreach.

Combining the power of science with the power of communities.

ALLARM History

| 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |

Acid Rain Monitoring

Watershed-based Technical Assistance
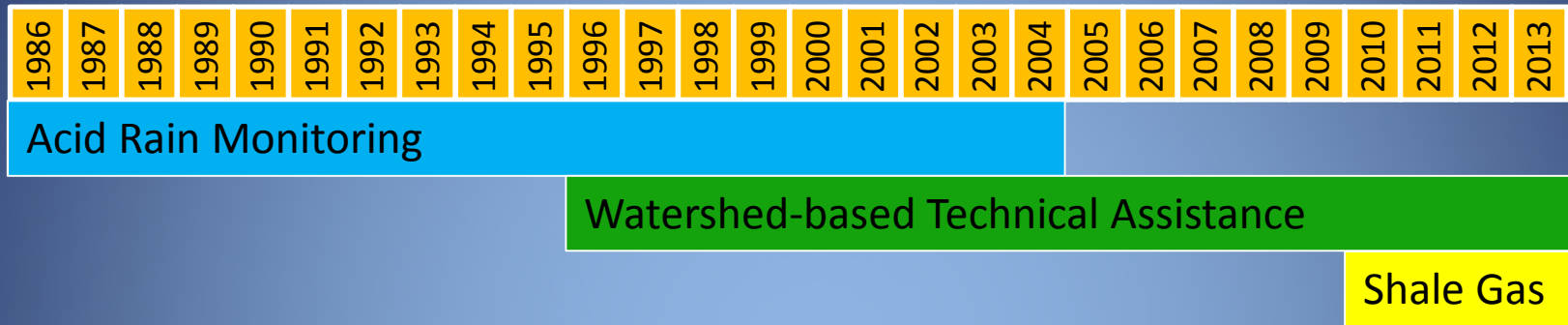
Shale Gas

Monitoring Program	Region	Volunteers	Outreach
Acid Rain	Statewide	Individuals	Minimal
Watershed-based TA	South central PA	Groups	Intensive
Shale Gas	Marcellus & Utica	Groups & Individuals	Moderate

ALLARM Monitoring Assistance
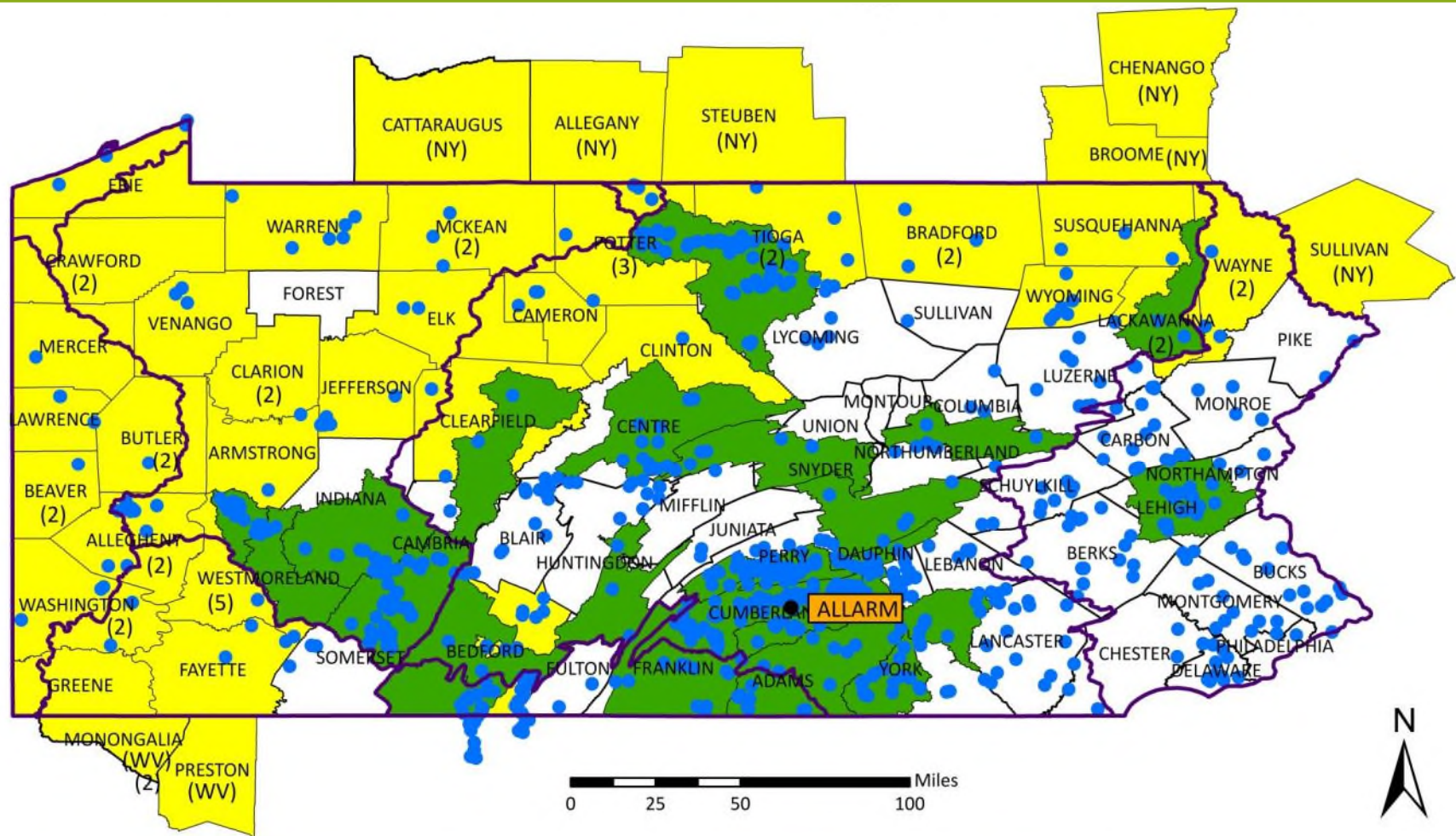
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www.dickinson.edu/ALLARM
ALLARM@dickinson.edu
717.245.1565

March 2014

- Acid Rain Sites
- Traditional Technical Assistance
- Shale Gas Workshops
- 6 Major PA Watersheds

Data Sources: ALLARM, NYS Office of Cyber Security, PA DOT, PSU, USGS, WVDEP

Version 3.0

Alliance for Aquatic Resource Monitoring

Shale Gas Extraction:
Volunteer Monitoring Manual

February 2013

Visit ALLARM's Online Toolkit for training videos, voice over
PowerPoints, and additional resources:

http://blogs.dickinson.edu/marcellusmonitoring

III. ALLARM's
Shale Gas
Volunteer
Monitoring
Protocol

Intended data use

Red flag protocol:

Goal: early detection and reporting of surface water contamination by shale gas extraction activities.

What Do We Monitor?

1. Chemical Monitoring: Indicator and signature chemicals

Parameters	Method	Frequency
Conductivity and TDS	Meter	Weekly
Barium and Strontium	Certified lab	2x/year and to confirm pollution event

2. Visual Assessment:

(Weekly)

Land disturbances
Spills and discharges
Gas migration/leakages
Pipeliines

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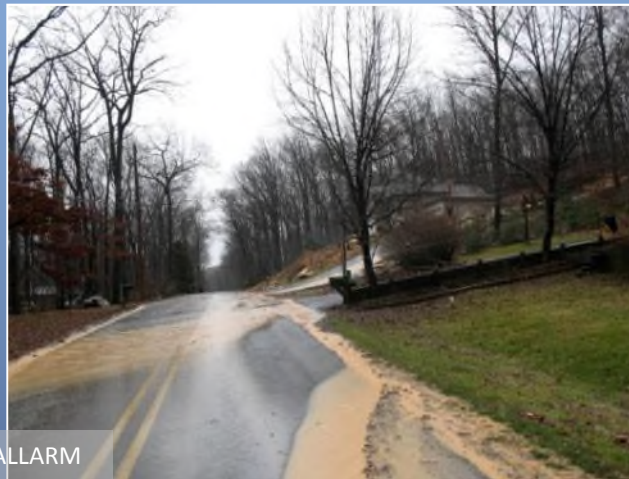
3. Stream Stage:

(Weekly)

Quality Assurance/Quality Control

Standard QA/QC Practices:
- Training requirements
- Care/calibration of equipment
- Replicates
- Documentation of procedures
- Split sample analysis in our lab

Data Use: Decision Trees

CHEMICAL MONITORING DECISION TREE

Baseline data available

No baseline data available

Is TDS > 3x baseline TDS at comparable flow?

Is TDS > 3x the previous week TDS or 2x upstream TDS?

YES

YES

Is either Ba or Sr > 3x baseline concentrations at comparable flow ?

Is either Ba or Sr > 3x previous week or upstream concentration?

YES, then notify

YES, then notify

PA DEP Regional Office
PA Fish and Boat Commission
Local Watershed Association
Facility Owner/Operator

Report monitoring information when values exceed criteria in decision trees

Online Monitoring Toolkit

Building a Monitoring Community

Trainers and Partners:
- PA County Conservation Districts
- Delaware Riverkeeper Network
- Mountain Watershed Association
- PA Association for Sustainable Agriculture
- Sierra Club
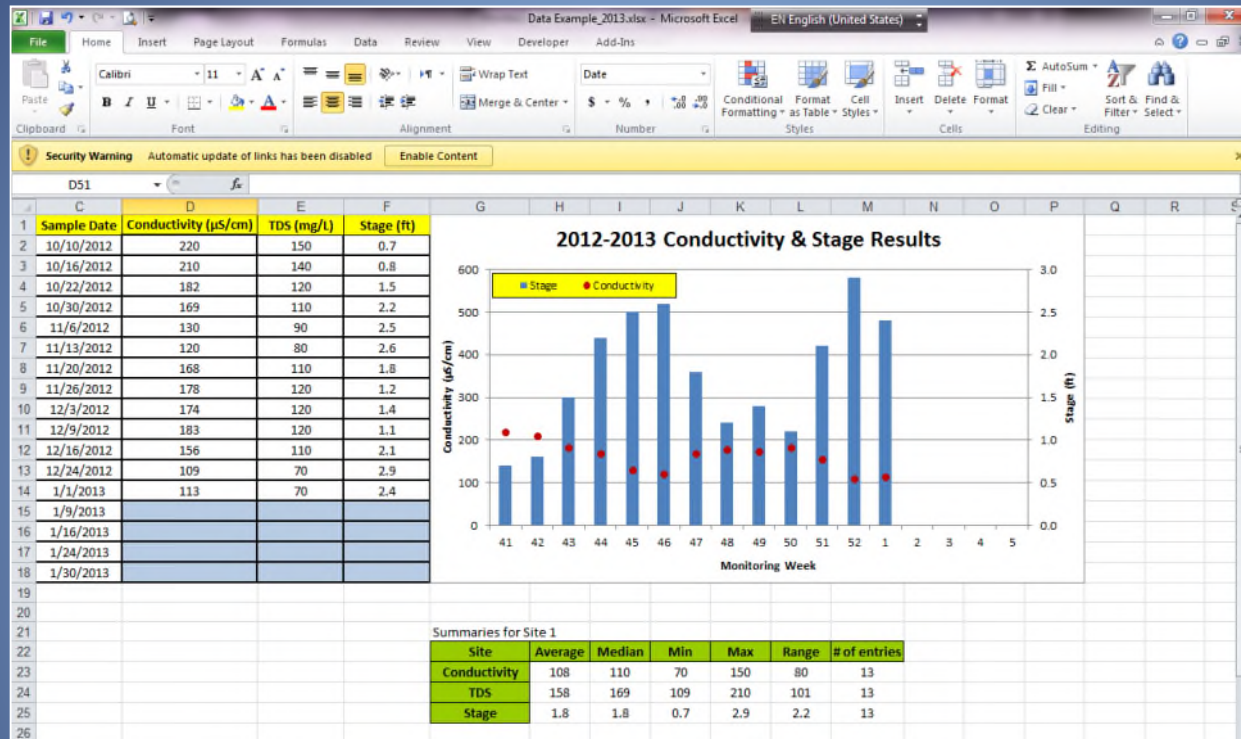- Trout Unlimited
- Waterdogs
- Shale Network

Agency involvement:
- Department of Environmental Protection
- Environmental Protection Agency
- National Water Quality Monitoring Council
- Susquehanna River Basin Commission

Over 2,000 volunteers trained in 55 workshops to date

IV. Data analysis and Interpretation

Characteristics of Phase I data set

Nature of complete data set for conductivity

State	Number of observations	Number of sites	Median # obs/site
PA	2653	172	10
NY	1567	107	11
TOTAL	4220	279	

Nature of analysis data set for conductivity

State	Number of observations	Number of sites	Number of groups	Median # obs/site
PA	1879	71	14	24
NY	1116	45	5	18
TOTAL	2995	116	19	

Criteria for choosing sites for analysis

All sites chosen had at least 8 data points distributed over at least 8 months and had passed QA/QC

Map of ALLARM site locations
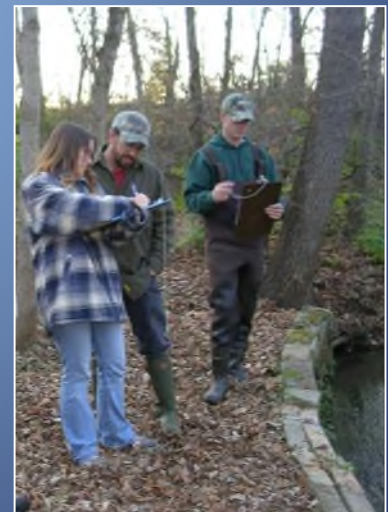
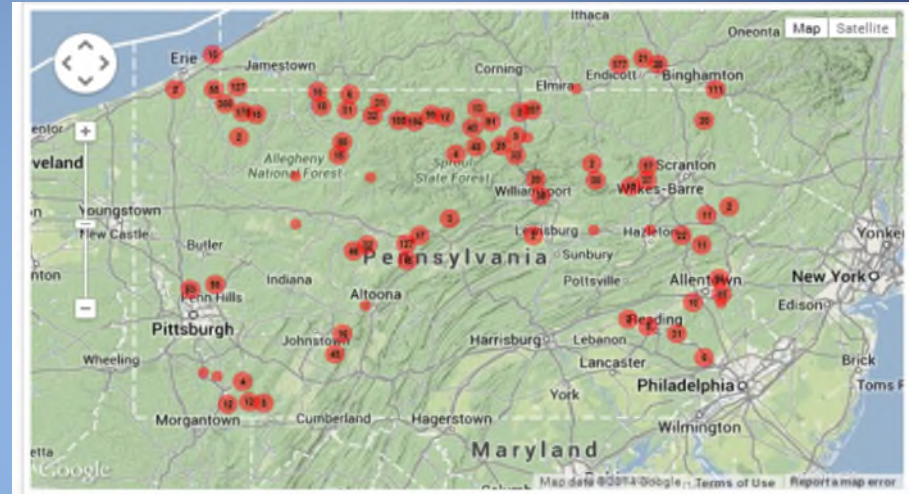Shale Gas Volunteer Monitoring: Site Locations
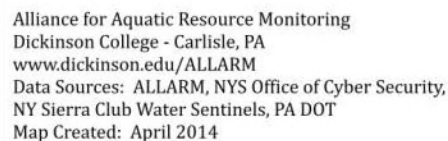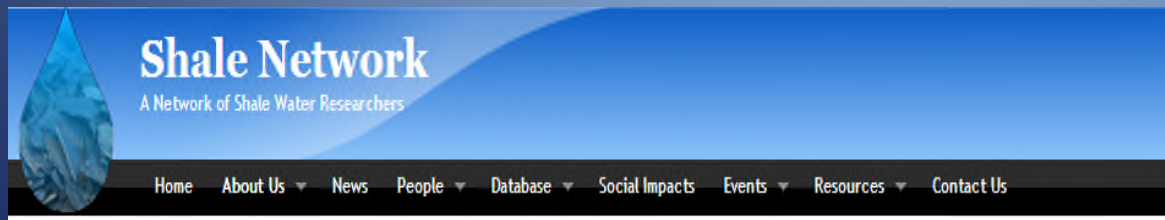
Anticipated data for Phase II analysis

Delaware Riverkeeper Network
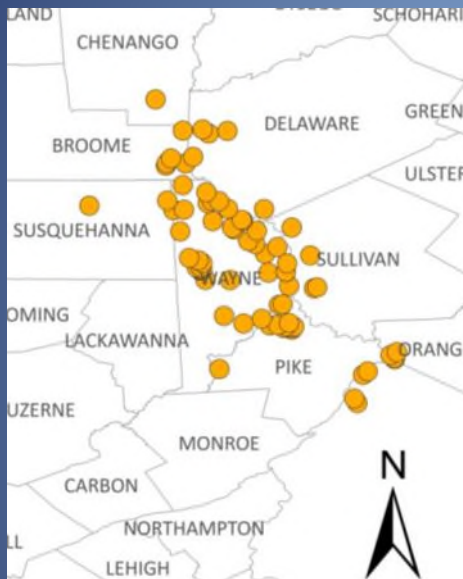
Trout Unlimited Coldwater Conservation Corps

http://www.citsci.org/cwis438/websites/citsci/map/CitSciMap_Clustering.php?WebSiteID=7

Additional ALLARM sites in NY and PA

The ShaleNetwork compiles data collected by scientists and citizens and makes them publically available.

Data analysis methods

- Identification of outliers
- Compilation of visual assessement reports
- Stream stage and conductivity relationship
- Watershed delineation
- Quantification of watershed size, land use, rock types, abandoned mine drainage, and drilled well density
- Stepwise multiple regression to evaluate the relative strength of causative factors on conductivity

Example of watershed delineations using digital elevation models in GIS
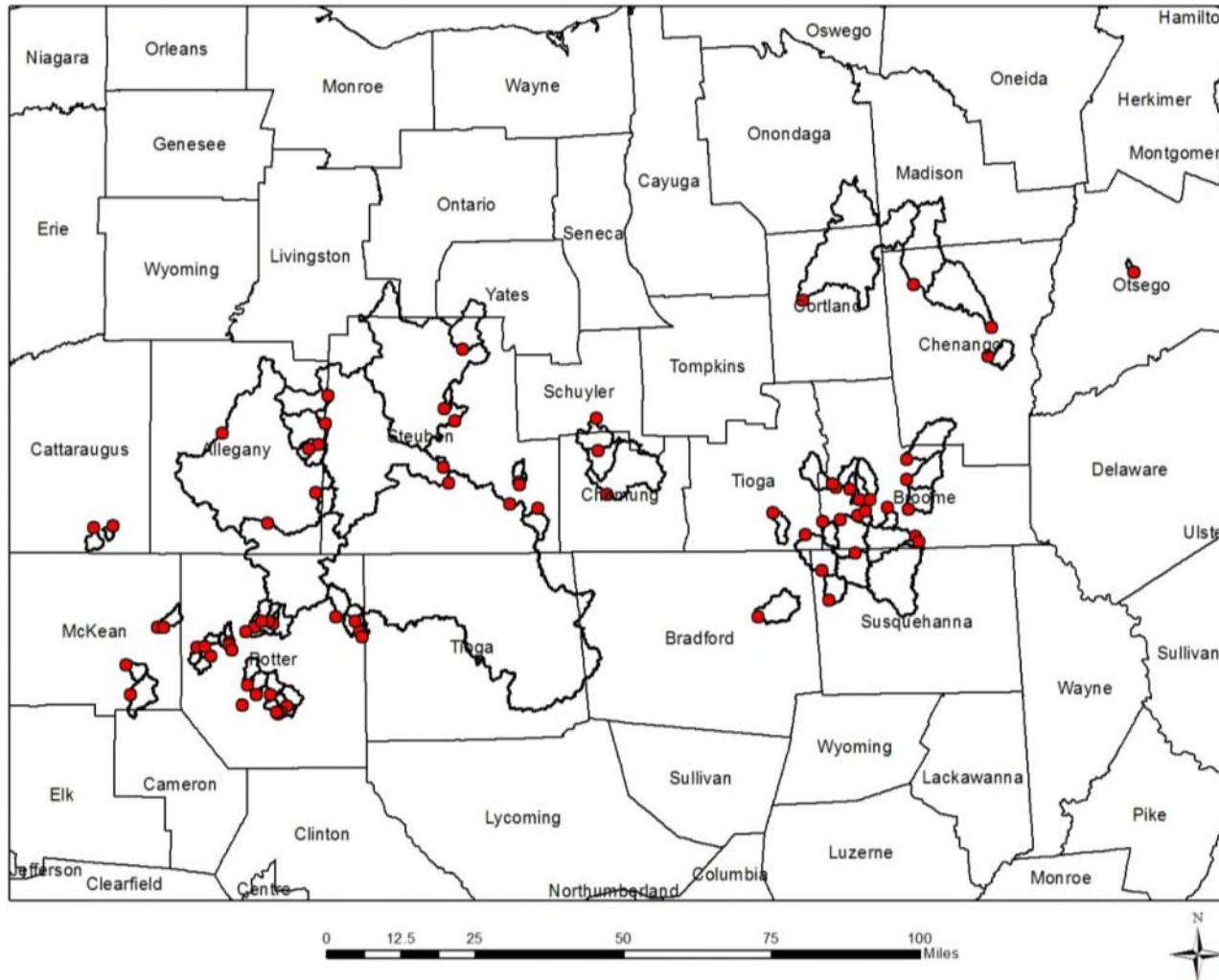
Region covers part of the northern tier in PA and southern NY

Results related to identification of chemical contamination events

Volunteers have not yet identified and reported flowback water contamination events based on water chemistry, although data analysis shows that rare events may have occurred.

Brannon Run, Venango County, PA (38)
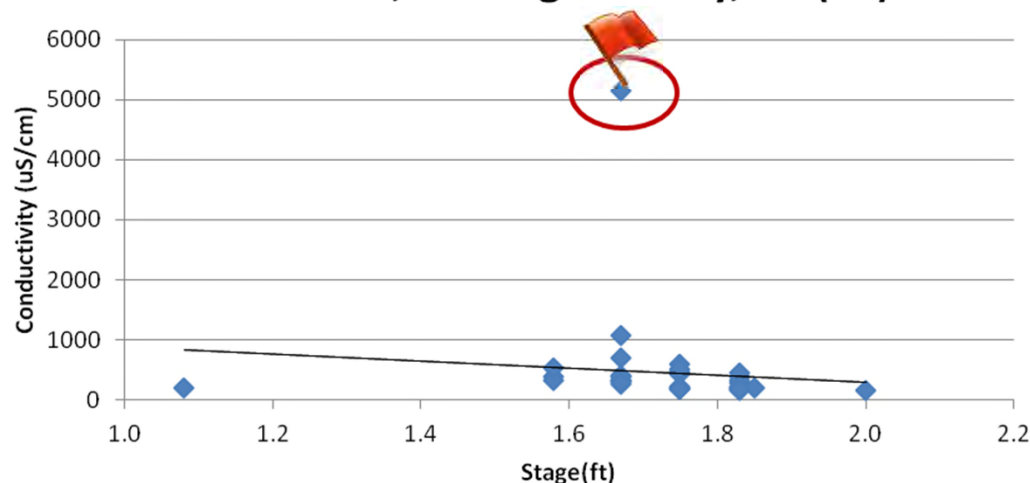
Catfish Run 1, Allegheny County, PA (57)
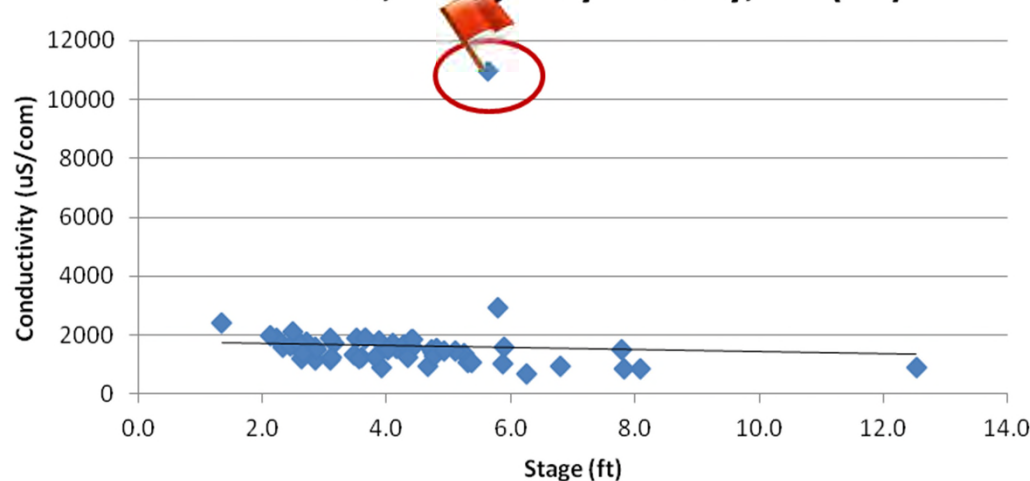
Results related to visual assessment

- Volunteers have 🚩 documented and reported sediment and erosion violations, spills and discharges, gas leakages, bentonite blowouts from pipeline construction, and illegal dumping of water

Sediment plumes in stream coming from a well pad access road

Photo courtesy of PA Council of Trout Unlimited

Photos courtesy of PA Council of Trout Unlimited
Potter County, PA

Access road that was reported by volunteer and that company was required to stabilize

BEFORE

AFTER

Photos courtesy of PA Council of Trout Unlimited

Spills and Discharges

Photo courtesy of Delaware Riverkeeper Network

Drilling fluid spill at Cabot site
Dimock, PA
September 2009

Photos courtesy of Delaware Riverkeeper Network

Gas Migration or Leakages

ALLARM

ALLARM

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Pipeline Spills and Discharges
(bentonite blowouts)

Photos courtesy of Mountain Watershed Association

Photos courtesy of Marcellus Outreach Butler

Illegal Dumping

Wetzel County Action Group

Wetzel County Action Group

Mountain Watershed Association

What were the results in terms of our unintended data use?

- Volunteers expressed a strong desire to have their data used as baseline data, especially since most sites were not downstream from drilled wells (yet).

- In response to this request, conductivity patterns in relation to land use, geology, watershed size and well locations were explored.
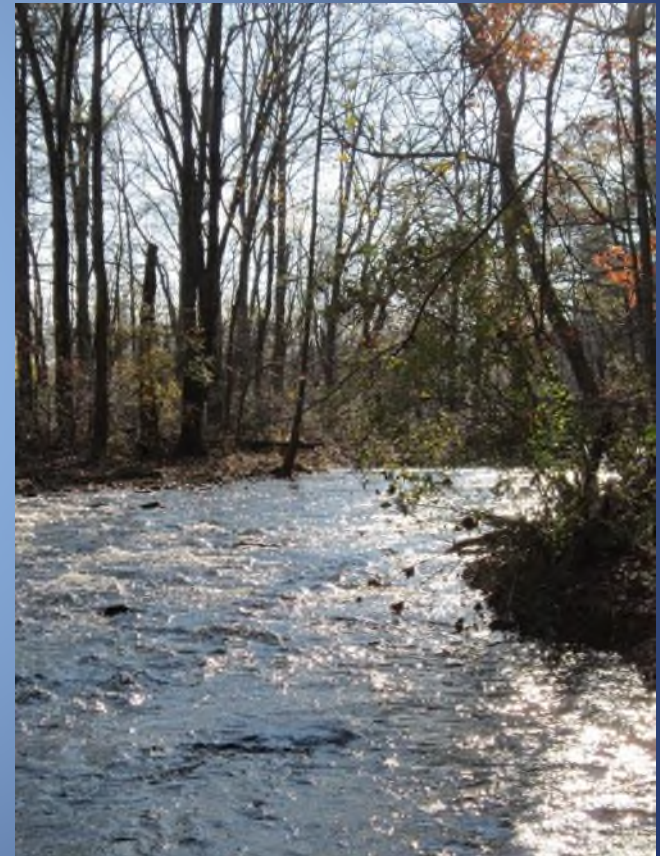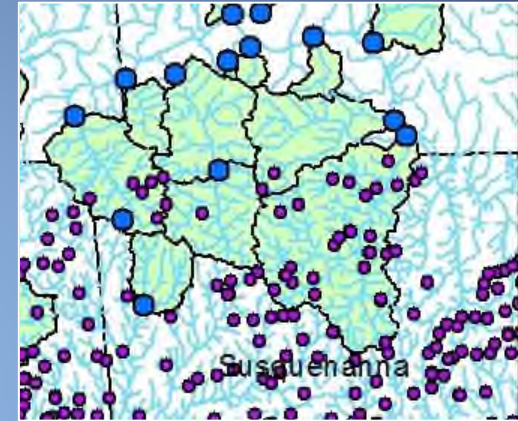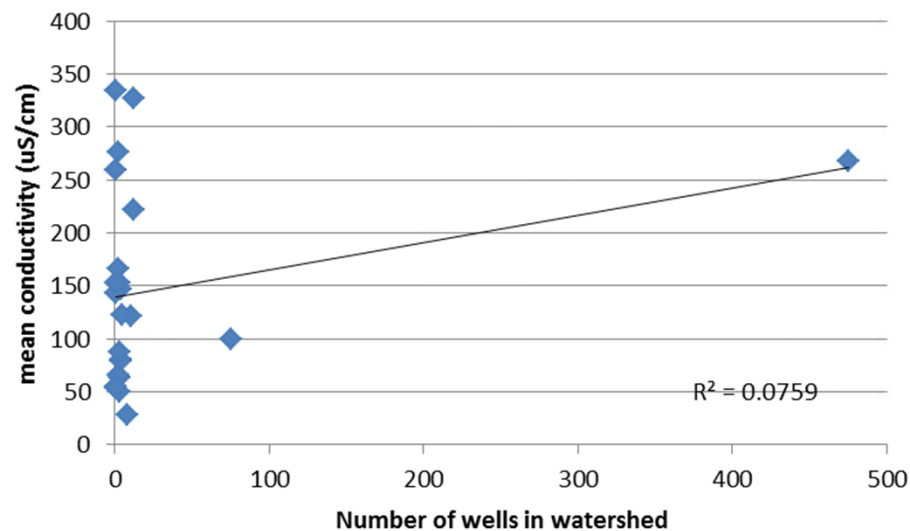
Watershed size distributions and relationship to mean conductivity

- 58% of watersheds monitored had areas less than 10 square miles; 89% were less than 50 square miles.

- There was no relationship between mean conductivity and watershed size in our data set.
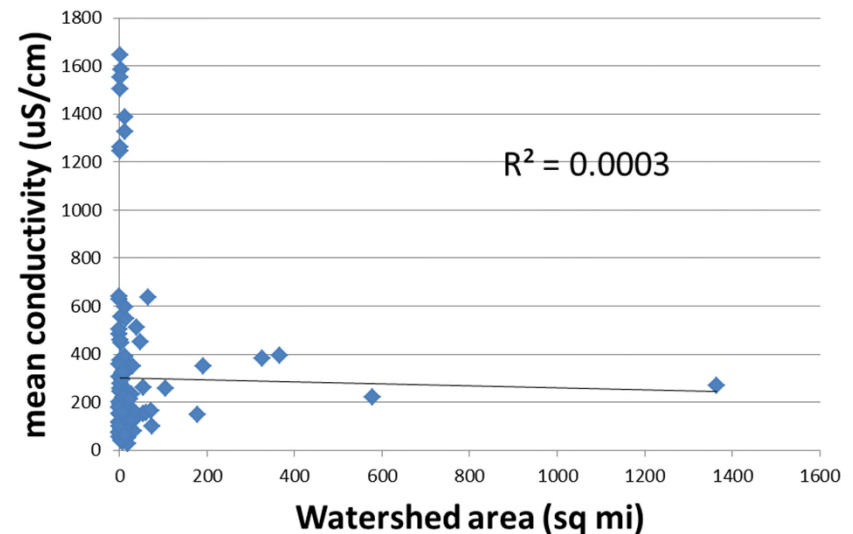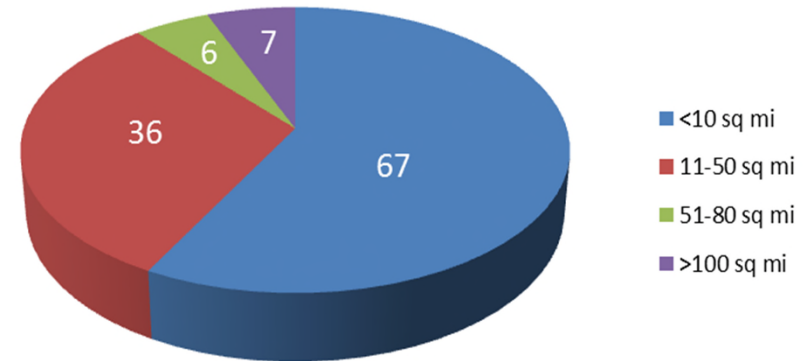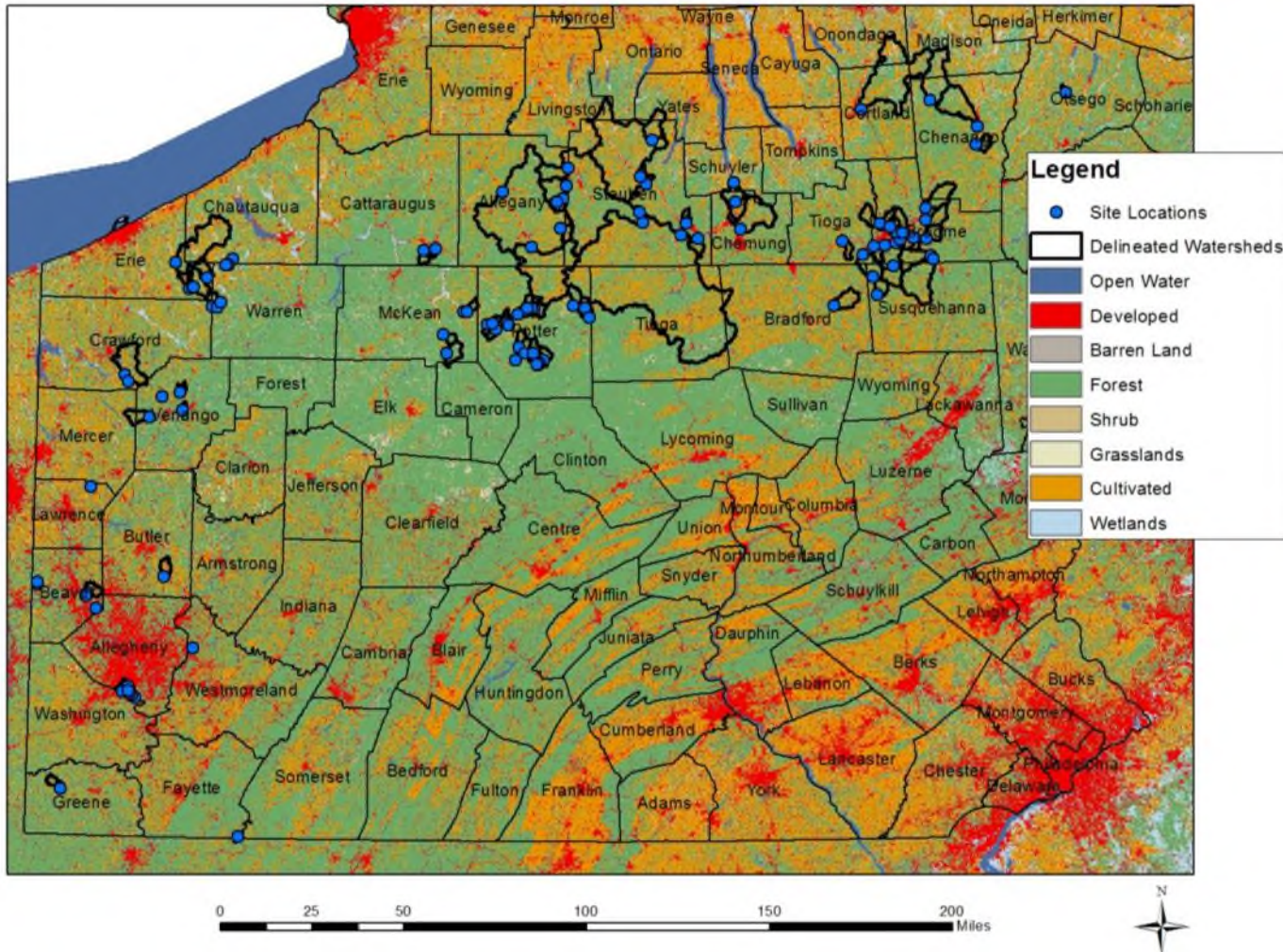
Relationship between number or density of wells and mean conductivity
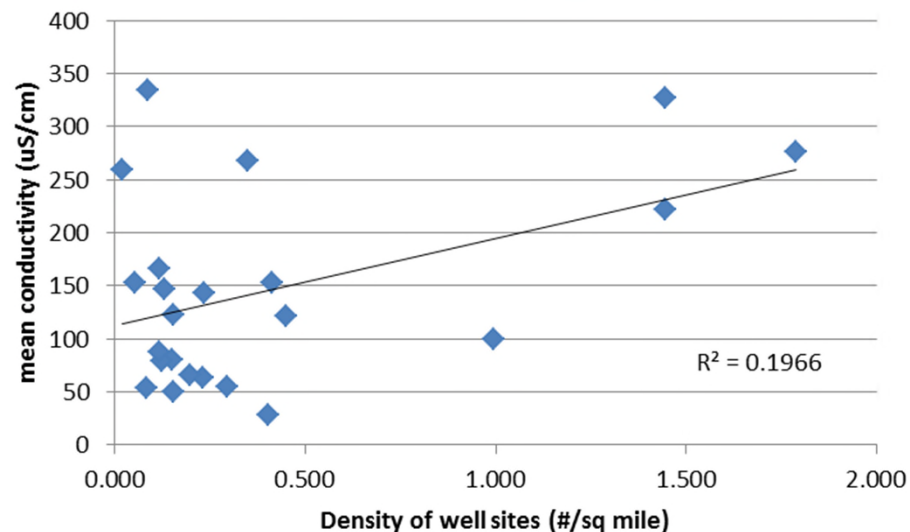
There was no significant relationship between the number or density of wells in the watershed and the mean conductivity of the streams, but only 23 sites has drilled wells at time of sampling.
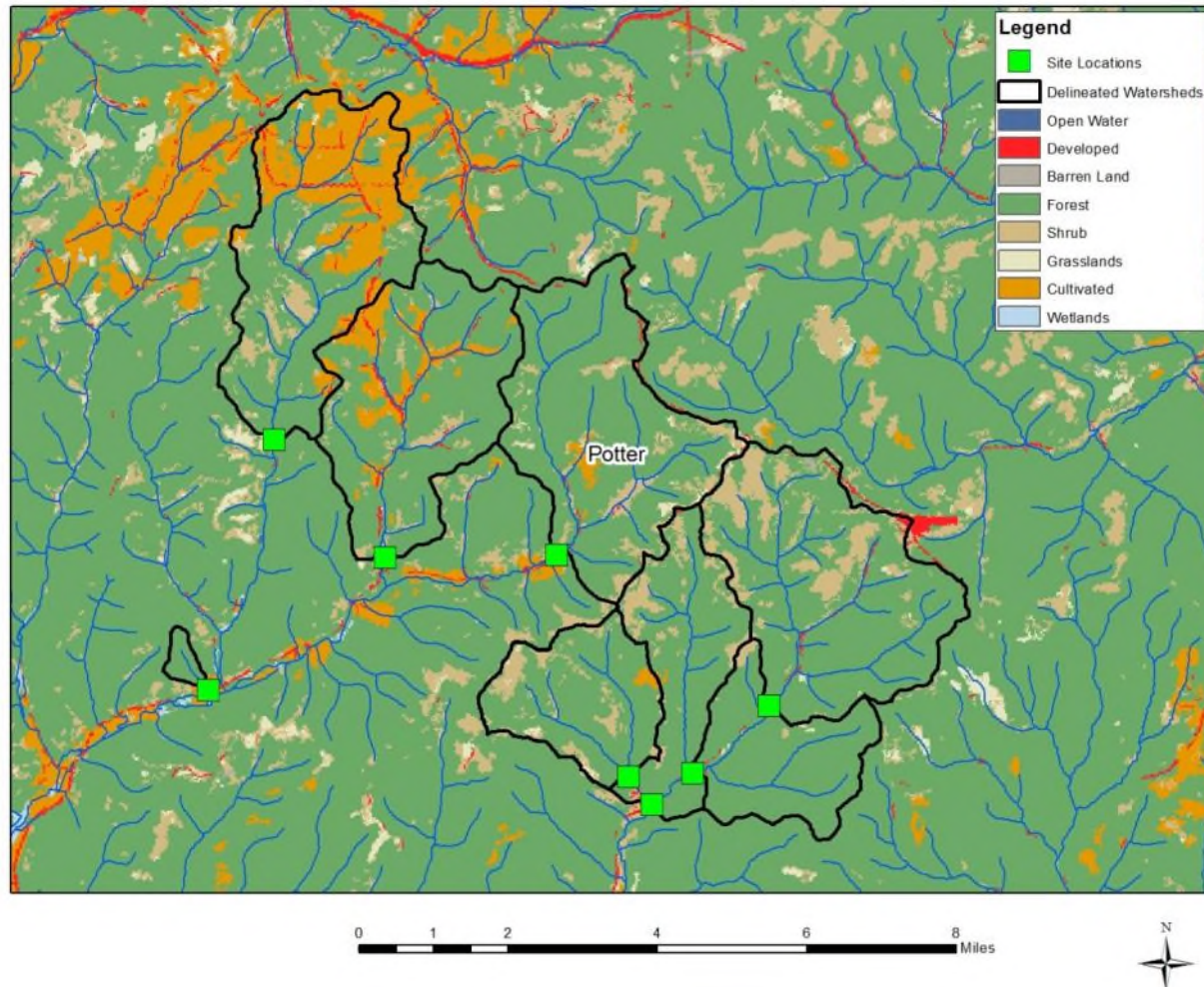
Land Use Map showing dominant land uses in PA

USGS NLCD 92 Land Cover Classes, aggregated to one digit

- Water
- Developed
- Barren
- Forested upland
- Shrubland
- Non-natural woody
- Herbaceous upland natural/semi-natural vegetation
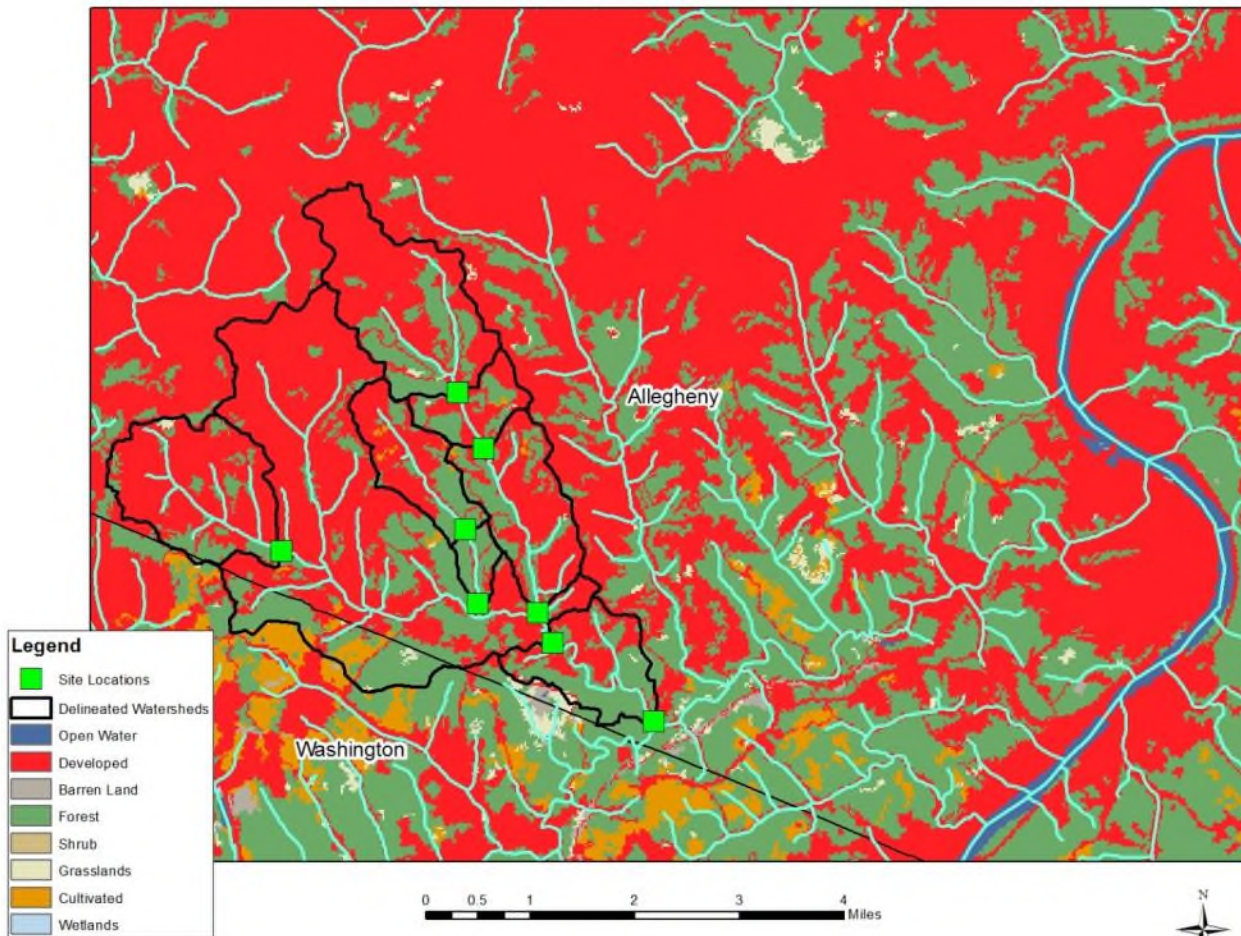- Herbaceous planted/cultivated

Legend

- Site Locations
- ▭ Delineated Watersheds
- Open Water
- Developed
- Barren Land
- Forest
- Shrub
- Grasslands
- Cultivated
- Wetlands

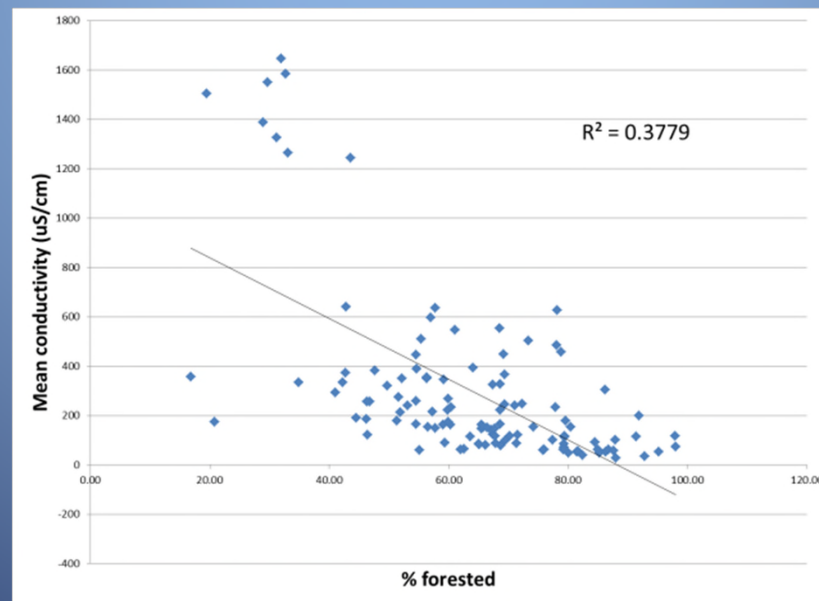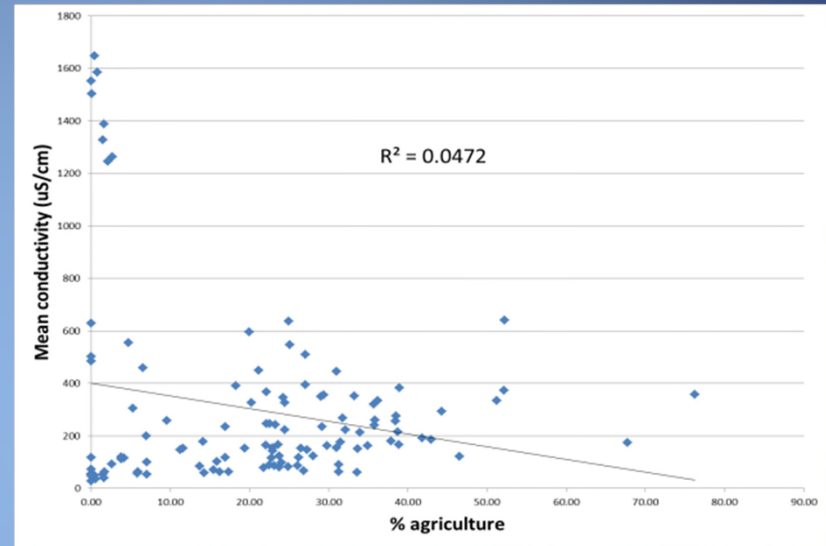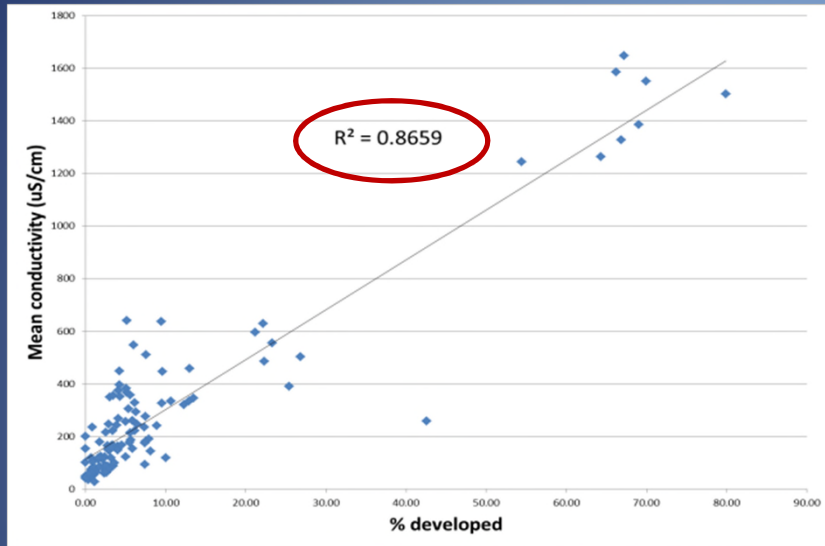# Example of predominantly forested region in Potter County

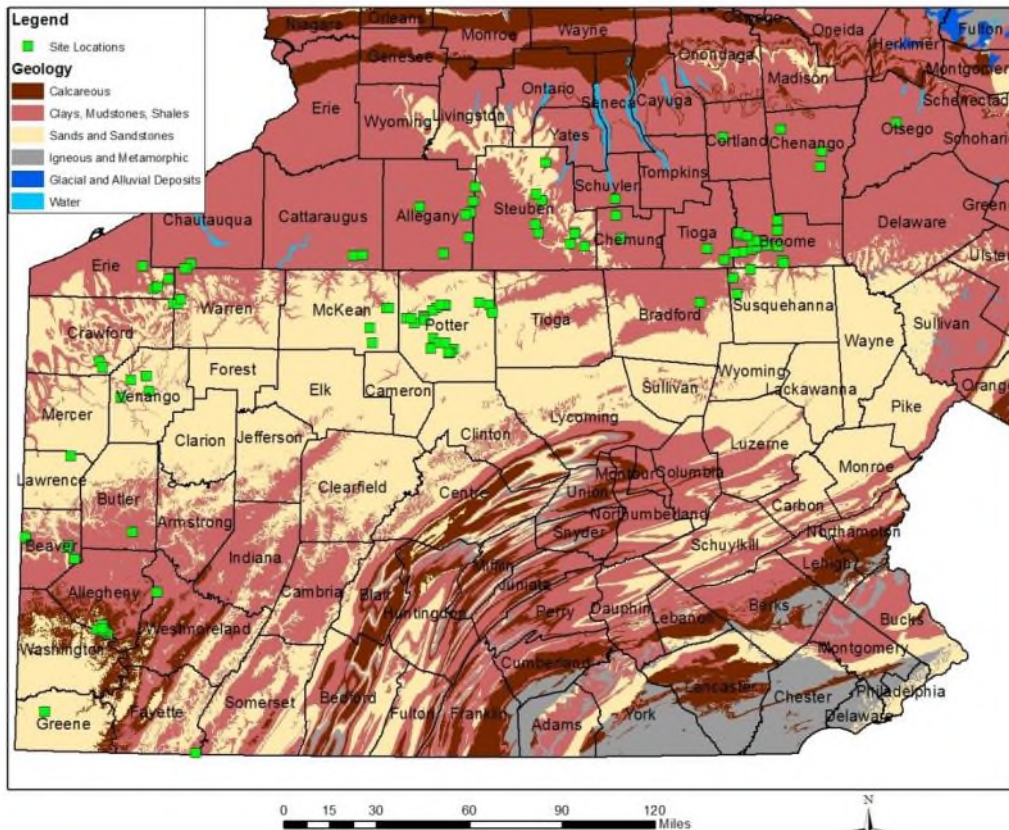# Example of predominant developed region in Allegheny County

Developed = 30%-100% impermeable cover

Relationship between mean conductivity and land use (N=116)

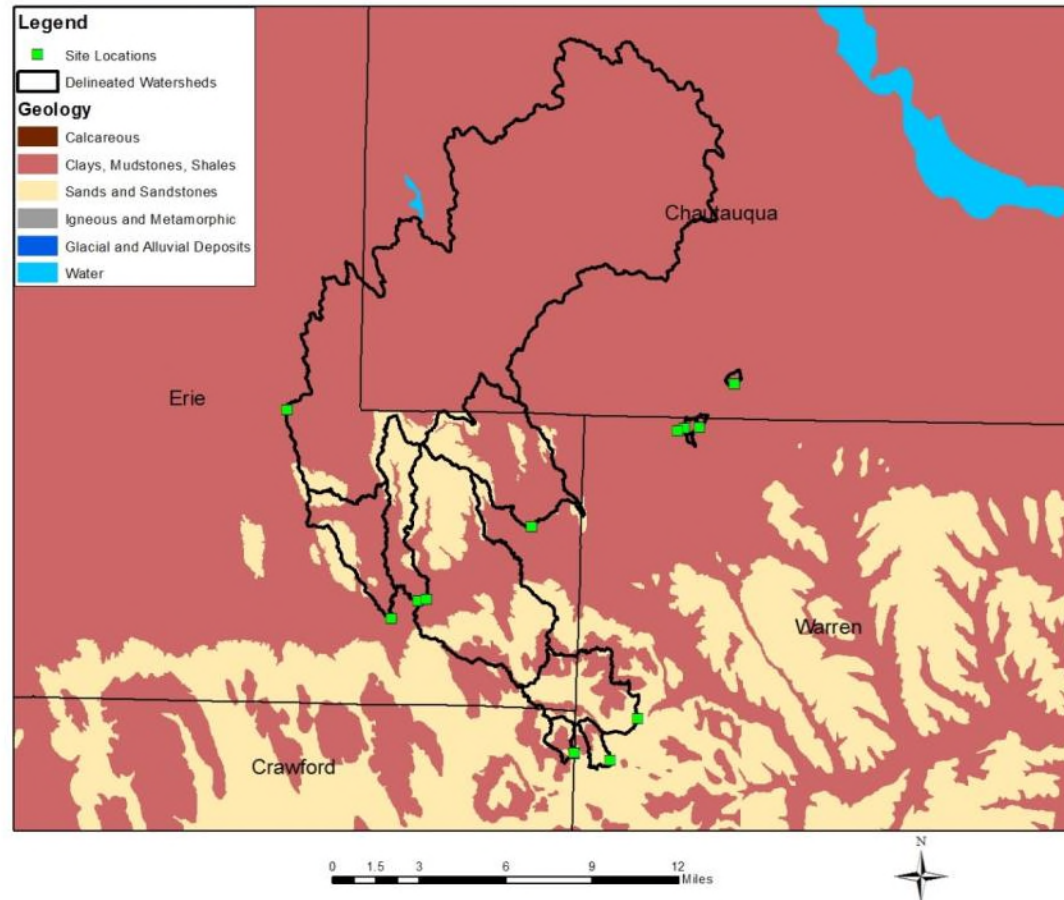# Geologic map showing dominant lithologies in the sampling area

New York State Geological Survey, PA Geological Survey [PA DCNR], US Geological Survey, aggregated to three major lithologies:

- Sands and sandstones
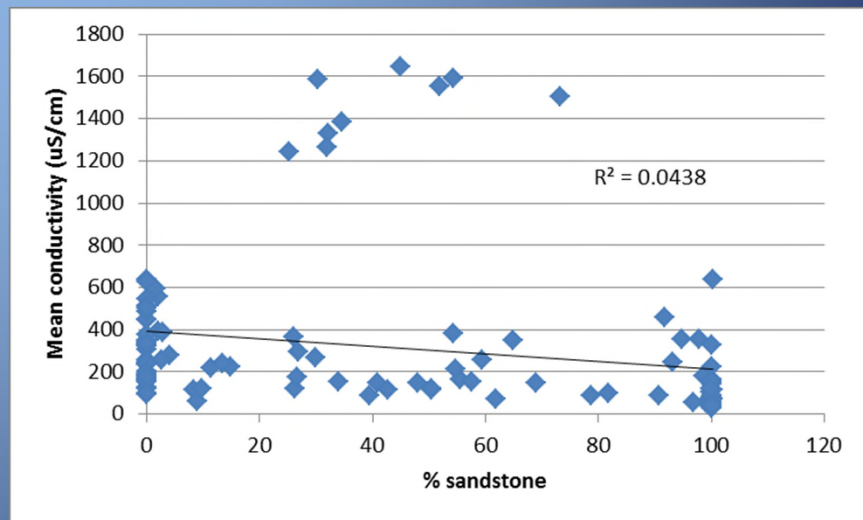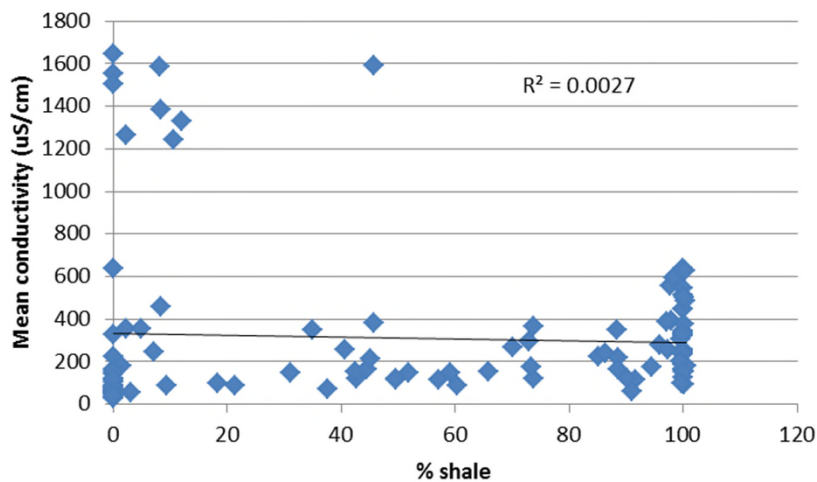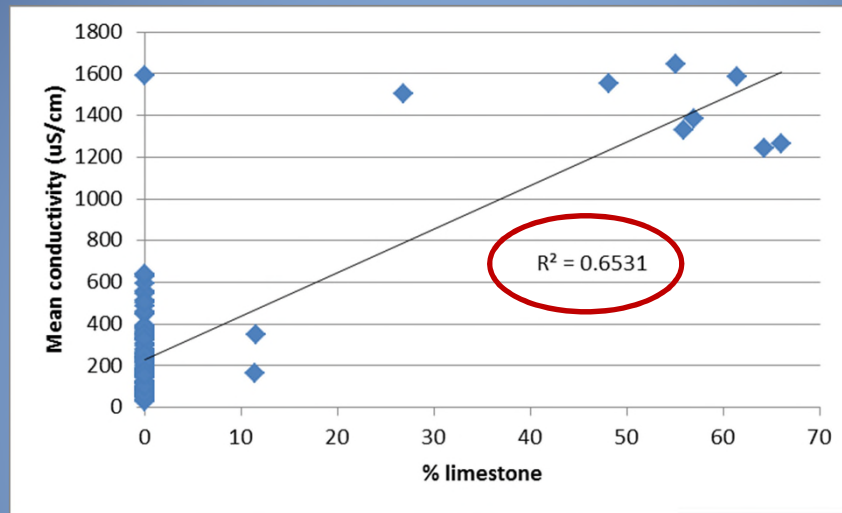- Calcareous rocks
- Clays, mudstones and shales

Example of watersheds in northwestern PA and southwestern NY

Predominantly sandstones and shales

Relationship of mean conductivity to surface geology in watershed

Stepwise multiple regression

- A stepwise multiple regression was conducted to evaluate which independent variables were necessary to predict mean conductivity.

- Four variables entered the equation in this order

8 variables used:
- % land use (developed, agriculture and forested)
- % geology (sandstone, shale and limestone
- Watershed size
- Drilled well density

Variable	Adjusted R^2	Coefficient
% developed	0.865	14.7
% limestone	0.874	6.9
% agriculture	0.884	1.9
% shale	0.887	0.57

V. Summary of the most important findings

- Volunteers have not yet identified and reported flowback water **contamination events** based on water chemistry.

- Volunteers have reported multiple cases of **visual pollution** related to shale gas extraction activities.

- Mean conductivity values were not related to watershed size or drilled wells, but were significantly related to **land use and geology.**
  - The two major predictors of mean conductivity in these streams is the **percent of development** and the **percent of limestone** in the watersheds.
  - **Well drilling** did not leave a detectable signal in these data, although this could not be tested conclusively due to the small number of drilled wells.

VI. Implications for future volunteer study designs and activities

- These data will be very useful as baseline data for **future documentation of shale gas impacts** on water quality, since most sites have not yet experienced drilling. This speaks for an **intentional study design** for volunteer monitors to capture this opportunity.

- It would be desirable to **intentionally target watersheds** whose characteristics (land use and geology) are under-represented here.

- If data are to be useful as baseline data, the development of a **central, user-friendly database** is desirable.

Implications for future volunteer study designs and activities (cont')

- Consideration should be given to **the analysis of additional parameters** and possibly to ratios of indicator elements (Brantley, S.L. et al., 2014), once the well activity is being monitored..

- It would be desirable for future study design to involve **monitoring of high risk streams** (Yue et al., in prep).

- The results of this analysis support the effort to **expand the volunteer network** and to include more sites and involve more partners.

Acknowledgements

- The authors wish to thank:

  - ALLARM Directors: Julie Vastine and Katie Tomsho.
  - GIS Specialists: Amanda Vandenburg and Jim Ciarroca
  - Funders: Dickinson College, Colcom Foundation, Foundation for PA Watersheds, National Science Foundation, Consortium for Scientific Assistance to Watersheds (CSAW), and Heinz Endowments