Understanding Methane in Shallow Groundwater from Extensive Pre-Drill Sampling*

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Abstract

On behalf of Chesapeake Energy Corporation, sampling of over 14,000 water wells has been conducted from 2009 to the present, from shale-gas development areas across Pennsylvania, Ohio, and West Virginia. Sampling was conducted prior to Marcellus/Utica Shale-related exploration, drilling, and production activities in the vicinity of these water wells. The pre-drill samples have been analyzed for methane, ethane, and propane as well as many inorganic parameters.

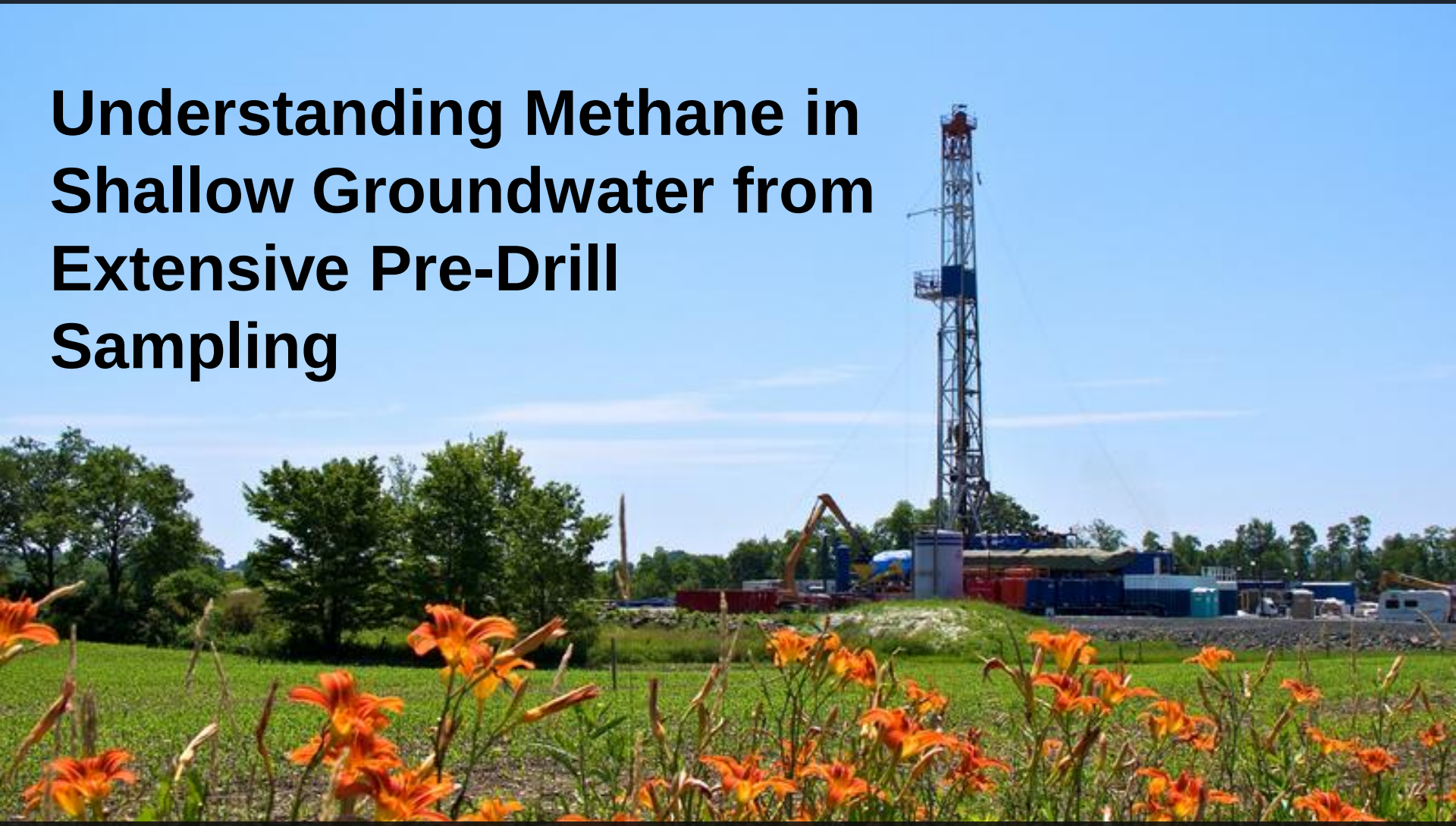
This presentation will explore the occurrence and distribution of methane in groundwater prior to unconventional gas development. GIS-based mapping and statistics will be used to evaluate the geographic distribution and relationship to bedrock geology. The relationships between methane and other parameters can also help explain methane occurrence, including parameters such as ethane and propane, alkalinity, TDS and major ions, barium, etc.

Understanding methane in shallow groundwater will lead to improved decision-making when evaluating potential impacts of shale-gas development on water supplies and stray gas occurrence.

Reference Cited

Williams, J.H., L.E. Taylor, and D.J. Law, 1998, Hydrogeology and Groundwater Quality of the Glaciated Valleys of Bradford, Tioga and Potter Counties, Pennsylvania: USGS, Water Resources Division, in cooperation with the Pennsylvania Geological Survey, Water Resource Report 68, 98 p.

Understanding Methane in Shallow Groundwater from Extensive Pre-Drill Sampling



John Boulanger, PG - AECOM
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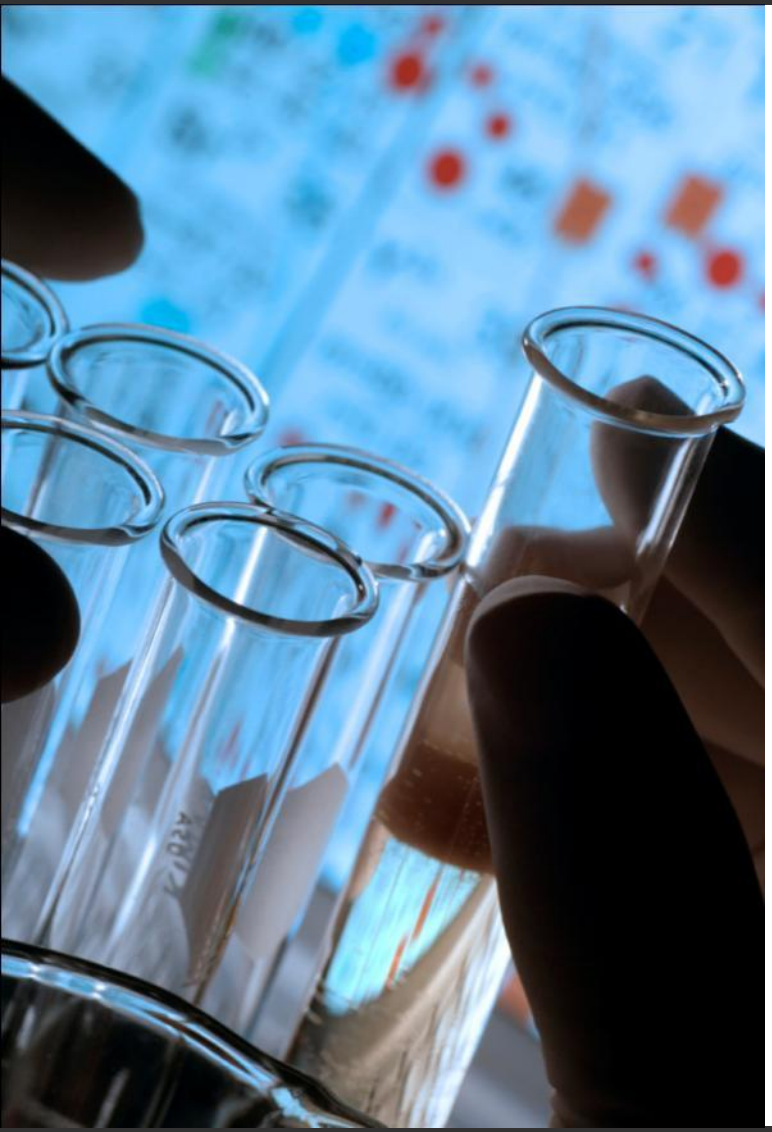
Bert Smith, PG - Chesapeake
Mark Hollingsworth - Chesapeake

Presentation Outline

- Overview of Sampling Program
- Summary of Methane in Groundwater
- Regional differences
  - Northeastern PA
  - Eastern OH / Northern WV / Southwestern Pennsylvania
- Summary of Preliminary Findings

Baseline (Pre-Drill) Sampling Program



Samples collected on behalf of Chesapeake Energy

- Four independent national consulting firms
- Independent commercial laboratories

Water supplies within 1,000 to 4,000 ft radius of planned gas well

- Property owner surveys
- Identification of water supply sources
- Permission for sampling

Water supplies sampled 6-9 months prior to pad construction

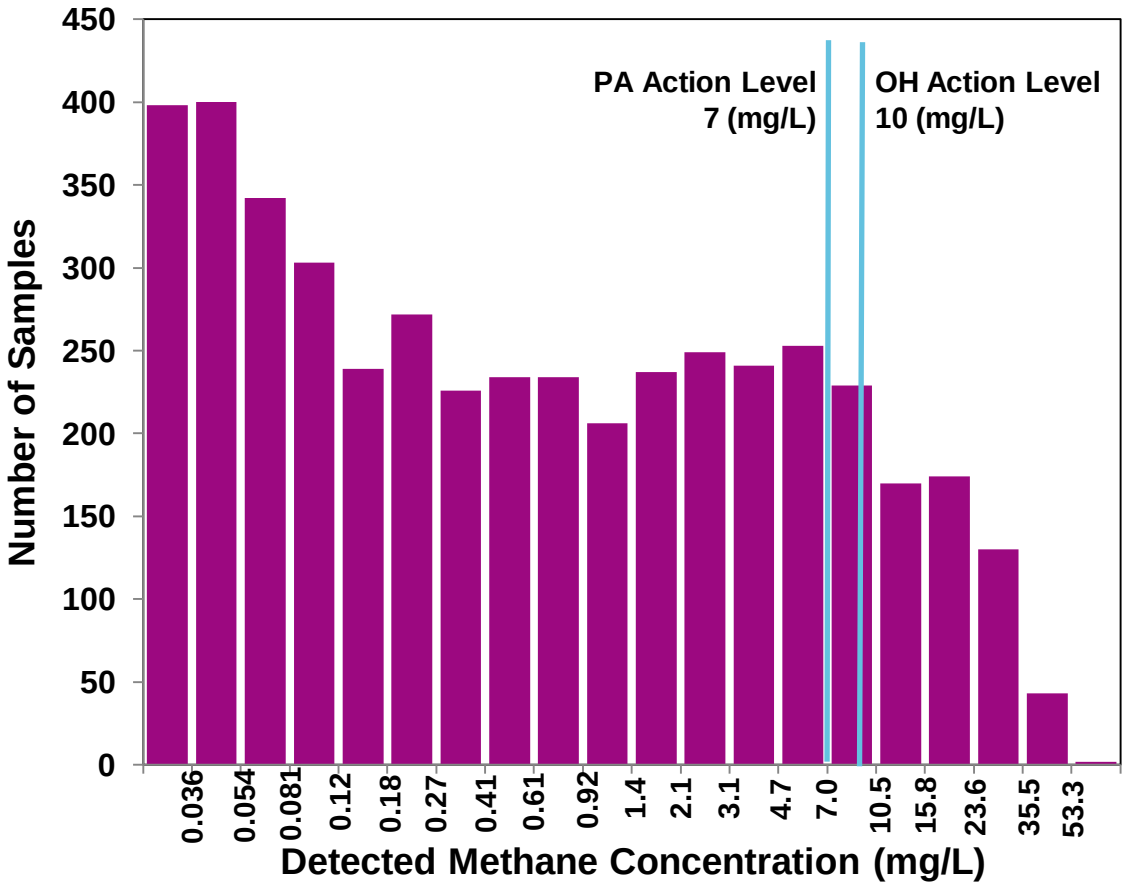
- Groundwater samples from actively used water wells
- Analysis for methane plus metals, inorganics, BTEX, etc.
- QA/QC program by independent consultants

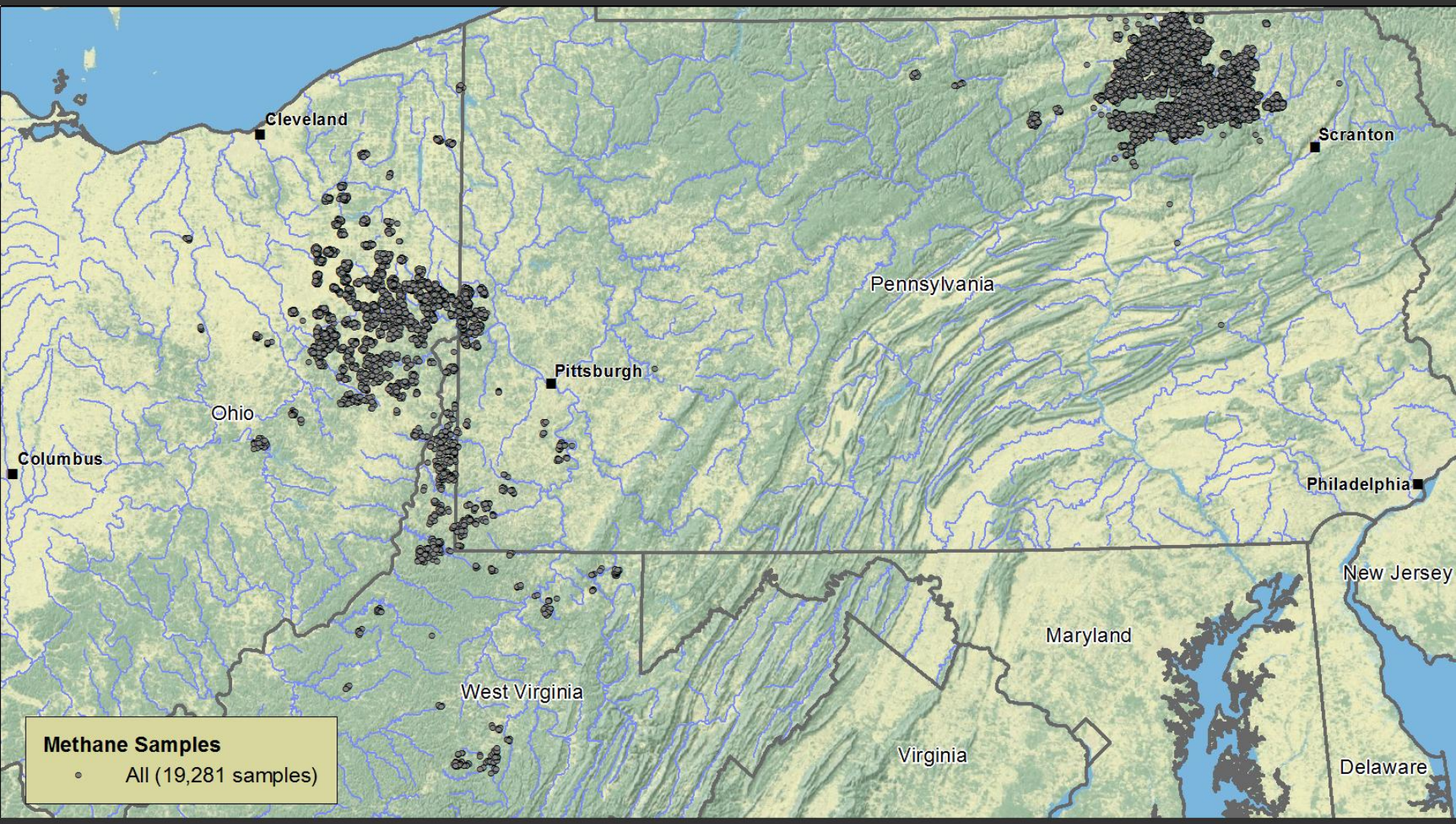
Results provided to well owners and agencies

- Approximately 20,000 samples in PA, OH, WV, 2009-2012
- Results provided to well owners and state agencies as required

Summary of Methane in Groundwater

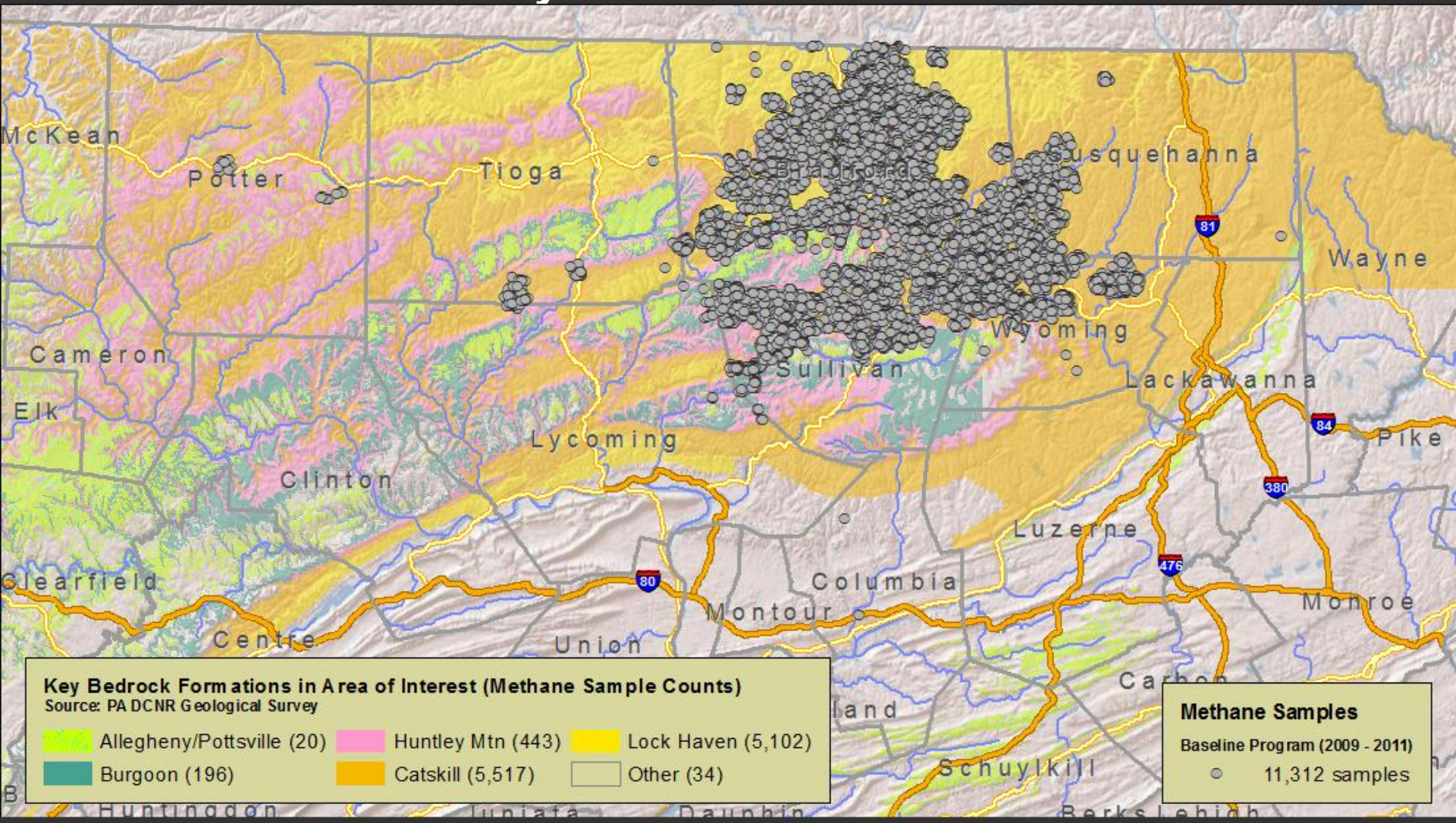
- **19,281** water wells sampled in PA, OH, WV
- Methane detected in **5,617** wells (29.1%)
- State Action Levels:
  - Greater than PA Action Level of 7 mg/L in **748** wells (3.9%)
  - Greater than OH Action Level of 10 mg/L in **255** Ohio wells (4.1%)





Baseline Samples Analyzed for Methane
BASELINE METHANE (2009-2011)

Northeastern Pennsylvania – Further Evaluation



Northeastern Pennsylvania
BASELINE METHANE

Chesapeake ENERGY
AECOM

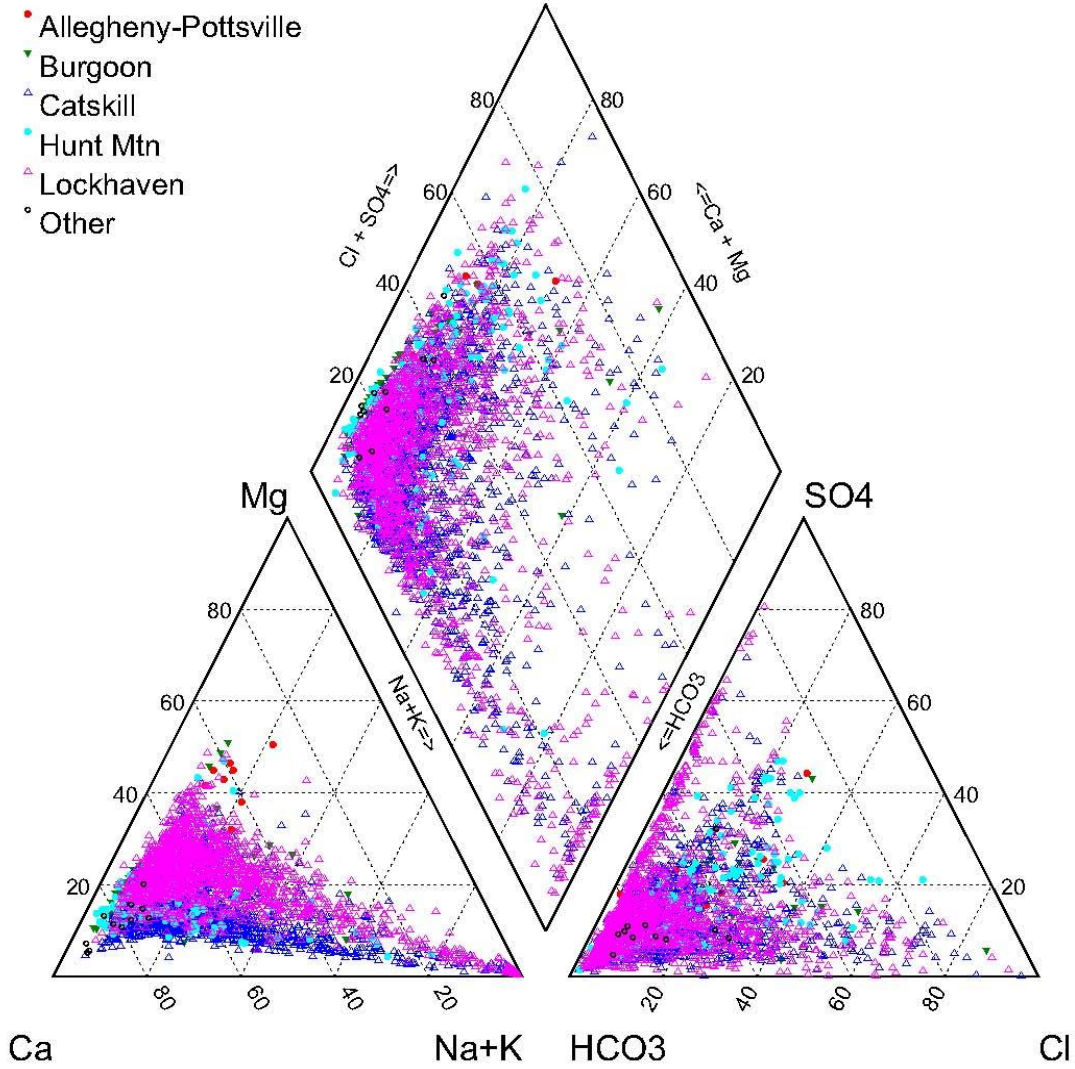
Geological Units – Northeastern Pennsylvania

- Allegheny-Pottsville Formations Undifferentiated (Lower Pennsylvanian)
  - Shale, sandstone, conglomerate, and thin beds of limestone and **coal**.
  - Commonly occurs in upland areas.
- Burgoon Sandstone (Mississippian)
  - Sandstone with minor interbedded shale.
  - Occurs mostly on hilltops and upland areas.
- Huntley Mountain Formation (Mississippian and Devonian)
  - Interbedded sandstone and shale.
  - Occurs mostly on hilltops and upland areas.

- Catskill Formation (Upper Devonian)
  - Interbedded shale, sandstone, and siltstone.
  - Typically occurs in upland areas, with some occurrence in glaciated valleys.
- Lock Haven Formation (Upper Devonian)
  - Interbedded shale, sandstone, and siltstone.
  - Underlies most major valleys.
- Other (Devonian to Quaternary)
  - Unconsolidated glacial and alluvial deposits, to mostly interbedded sequences of shale, sandstone, and siltstones.
  - Topography varies, with unconsolidated deposits typically in valleys, and bedrock formations mostly on hilltops or upland areas.

Samples with Methane Not Detected

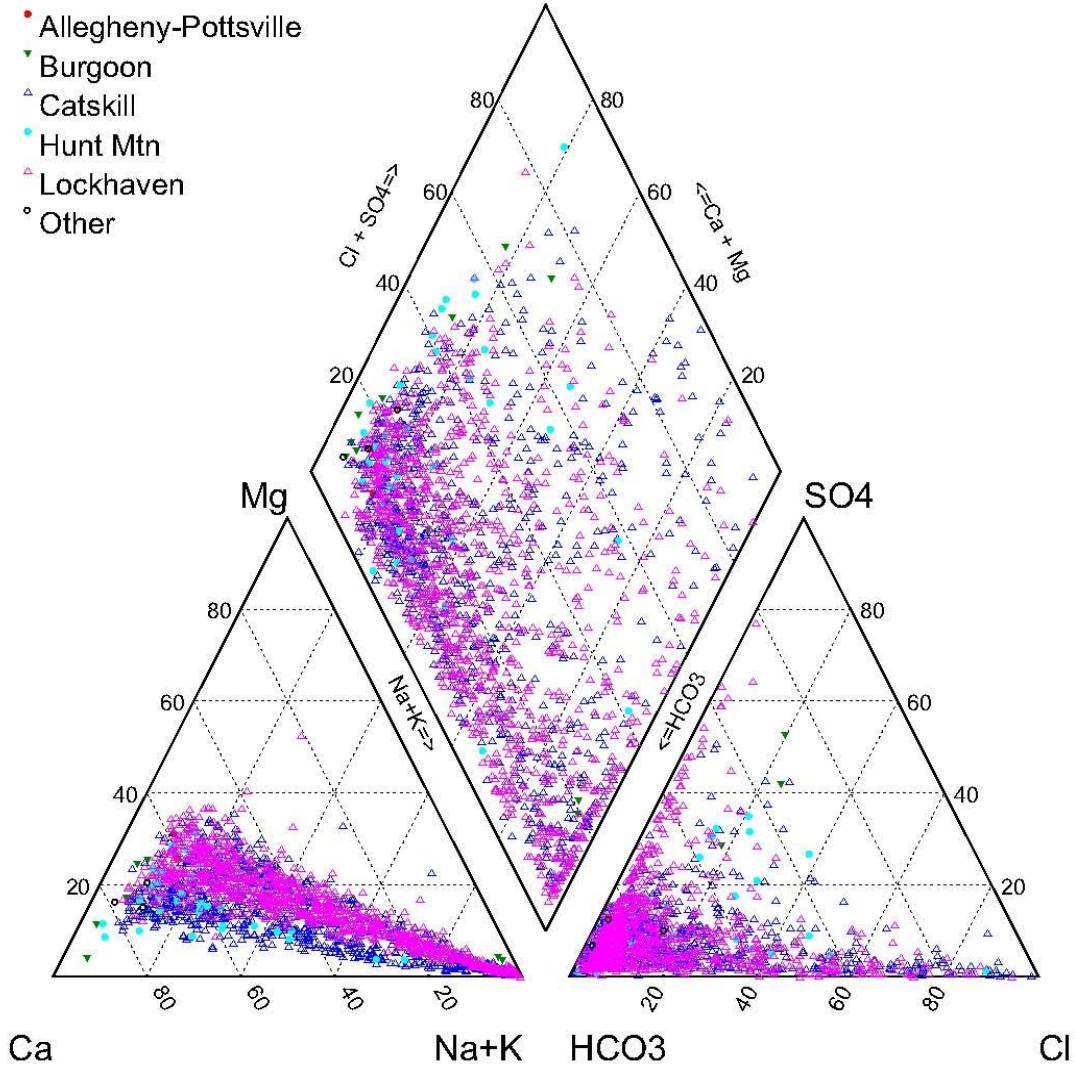
Northeastern PA



- Predominantly Ca-HCO_3-type water
- Catskill and Lock Haven Formations have greater proportions of Na, Cl

Samples with Methane up to 3 mg/L

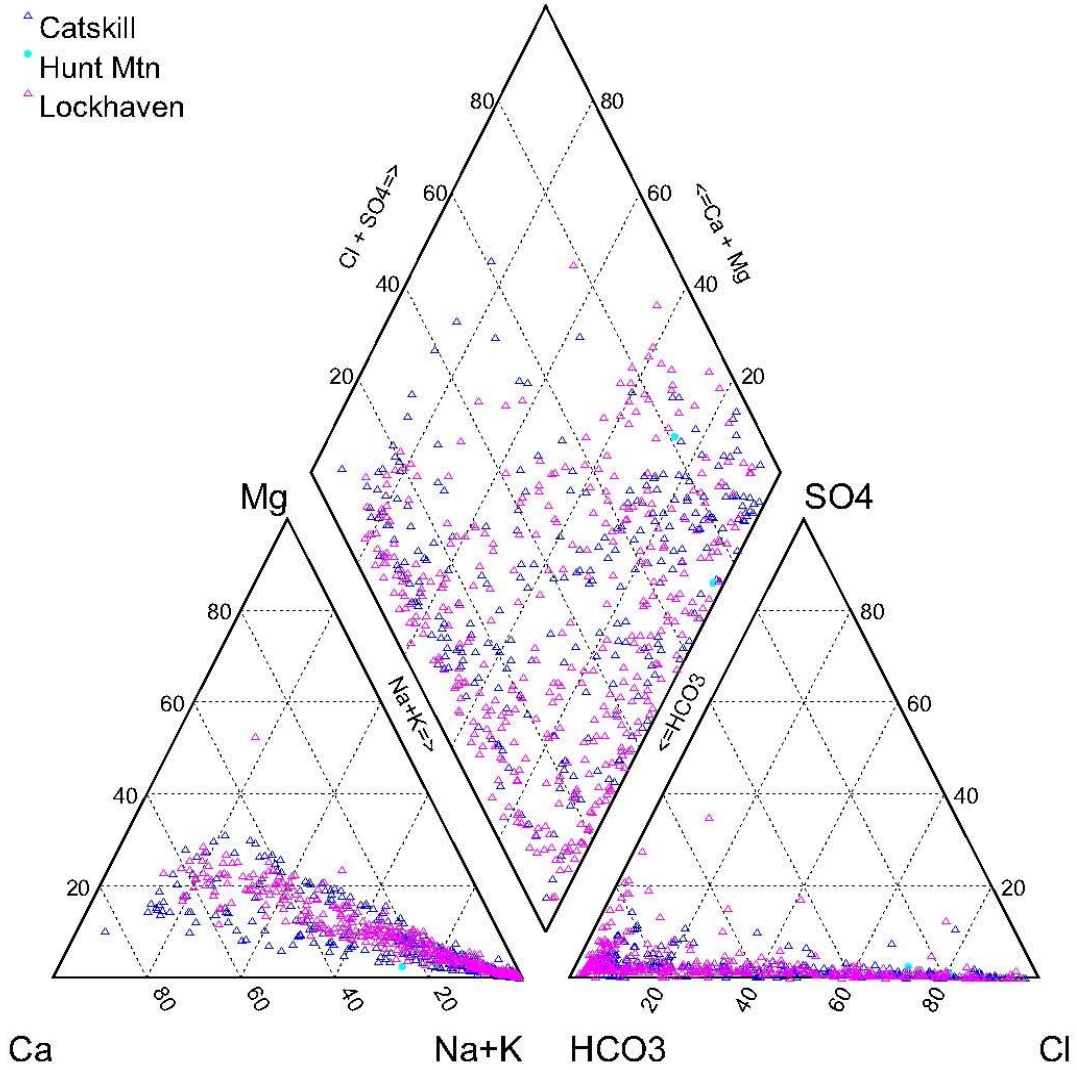
Northeastern PA



- Predominantly Ca-HCO_3-type water
- Increasing Na and Cl content
- Na-HCO_3 and Na-Cl water types in Catskill and Lock Haven Fms

Samples with Methane ≥ 3 mg/L

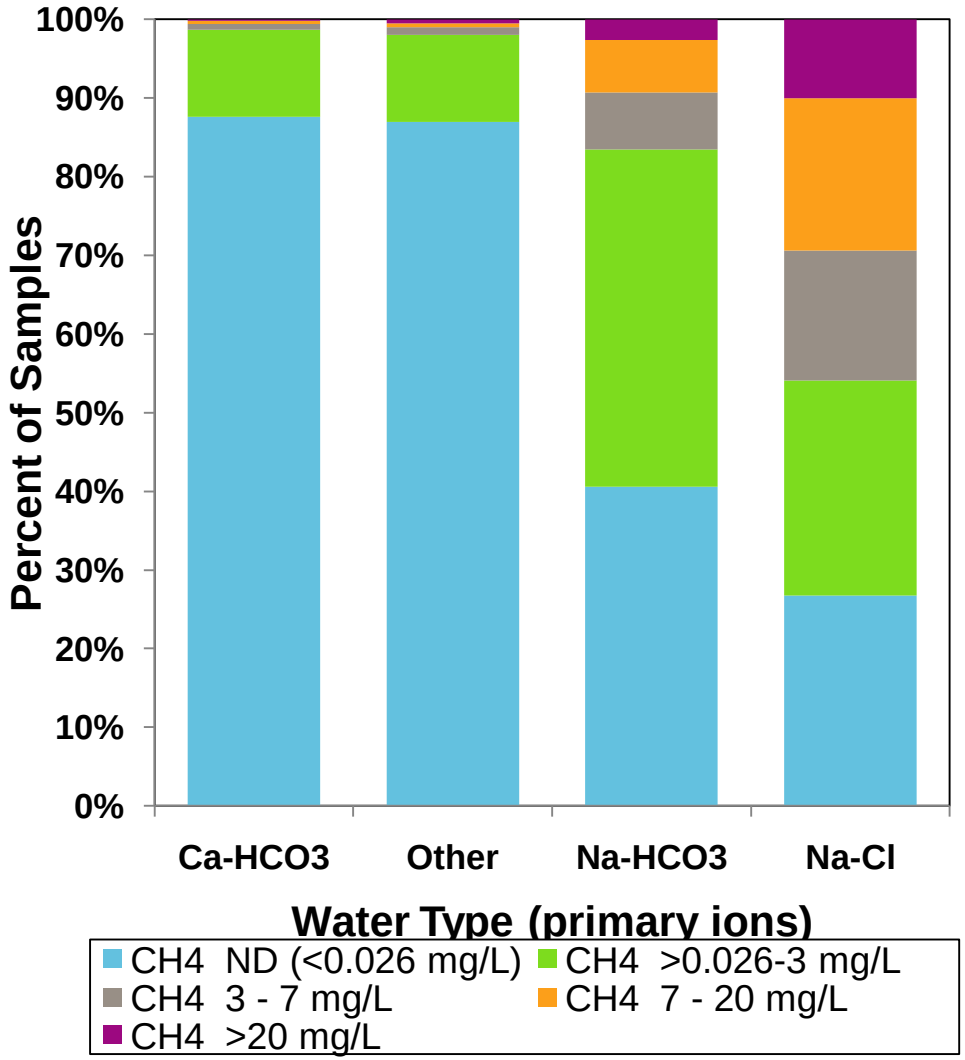
Northeastern PA



- Predominantly Na-HCO_3 and Na-Cl type waters
- Sulfate depleted (<20%)
- Samples almost entirely from Lock Haven and Catskill Formations

Methane and Water Type

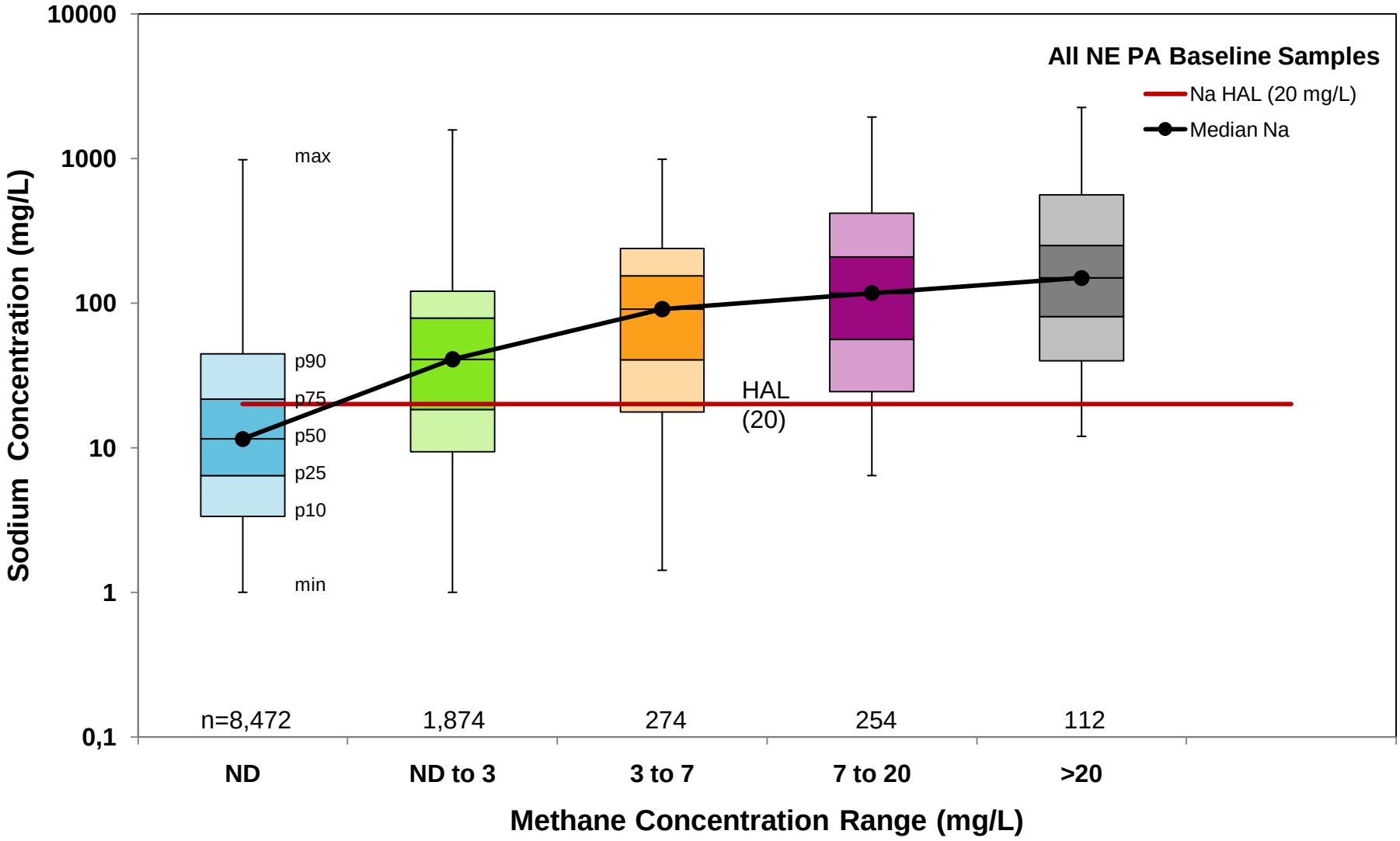
Northeastern PA



	CH_4 3-7 mg/L	CH_4 7-20 mg/L	CH_4 >20 mg/L
Ca-HCO_3	22%	15%	13%
Na-HCO_3	48%	48%	43%
Na-Cl	29%	37%	43%
Other	1%	1%	2%
Na-HCO_3 and Na-Cl	77%	85%	86%

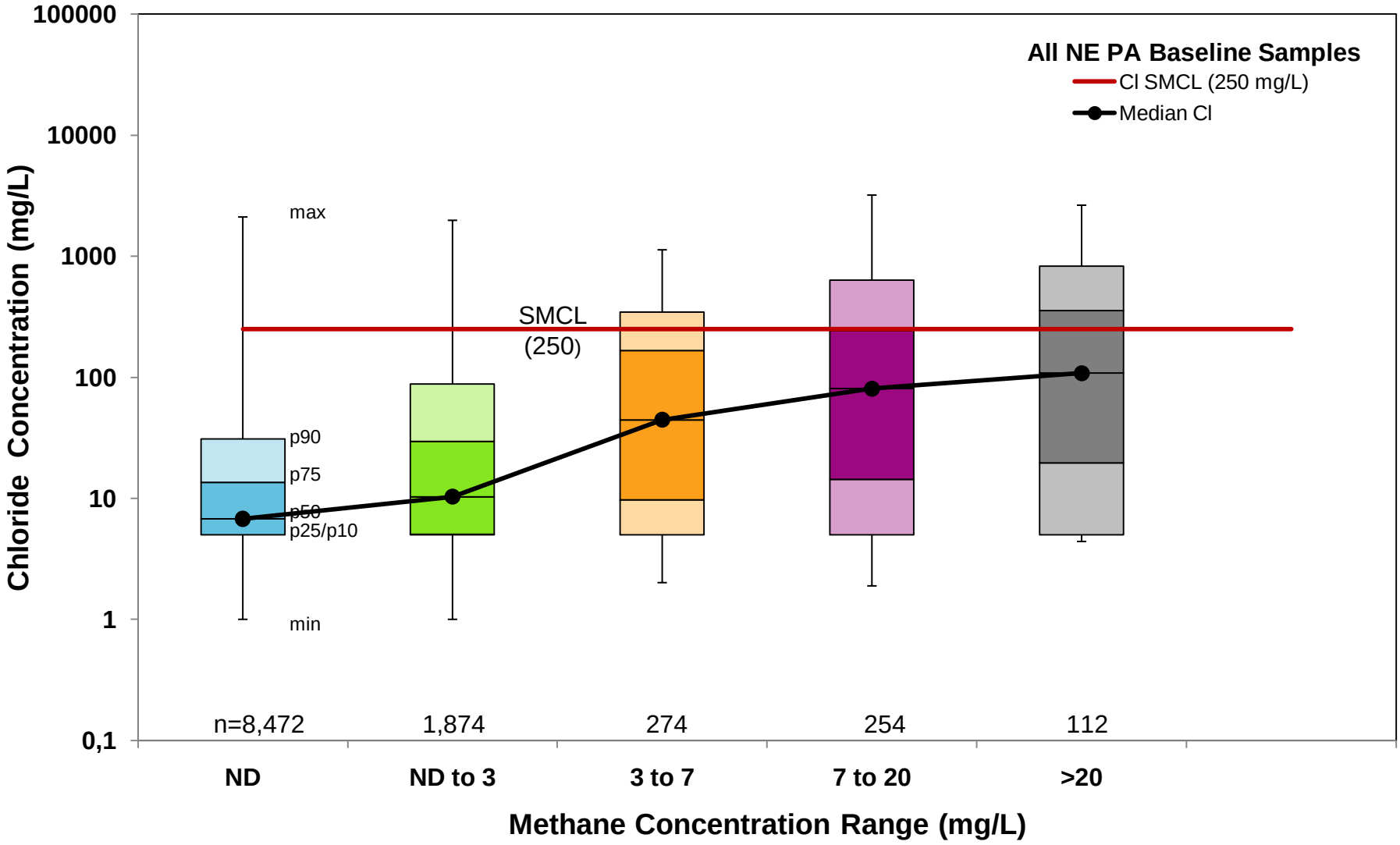
Methane and Sodium

Northeastern PA



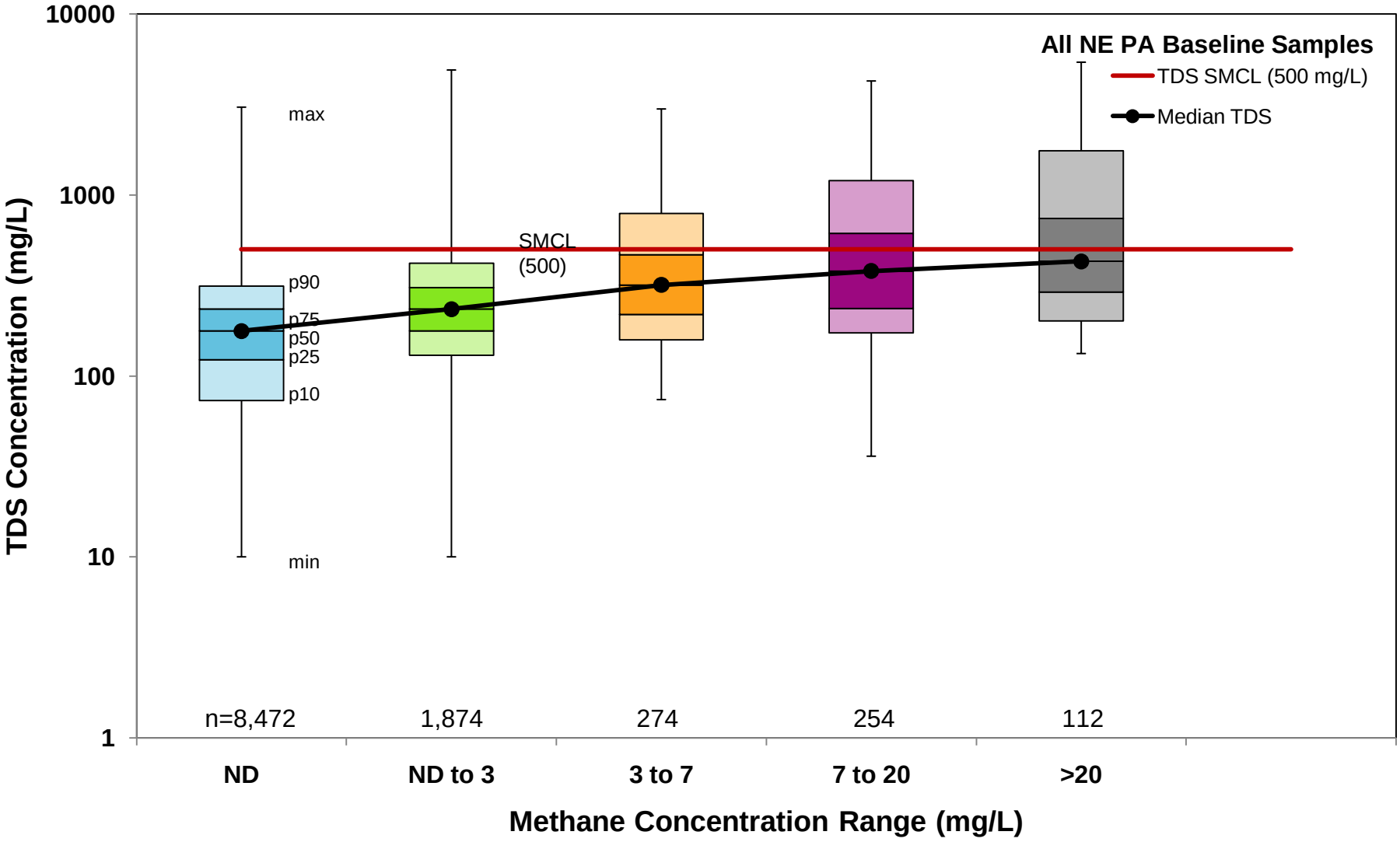
Methane and Chloride

Northeastern PA



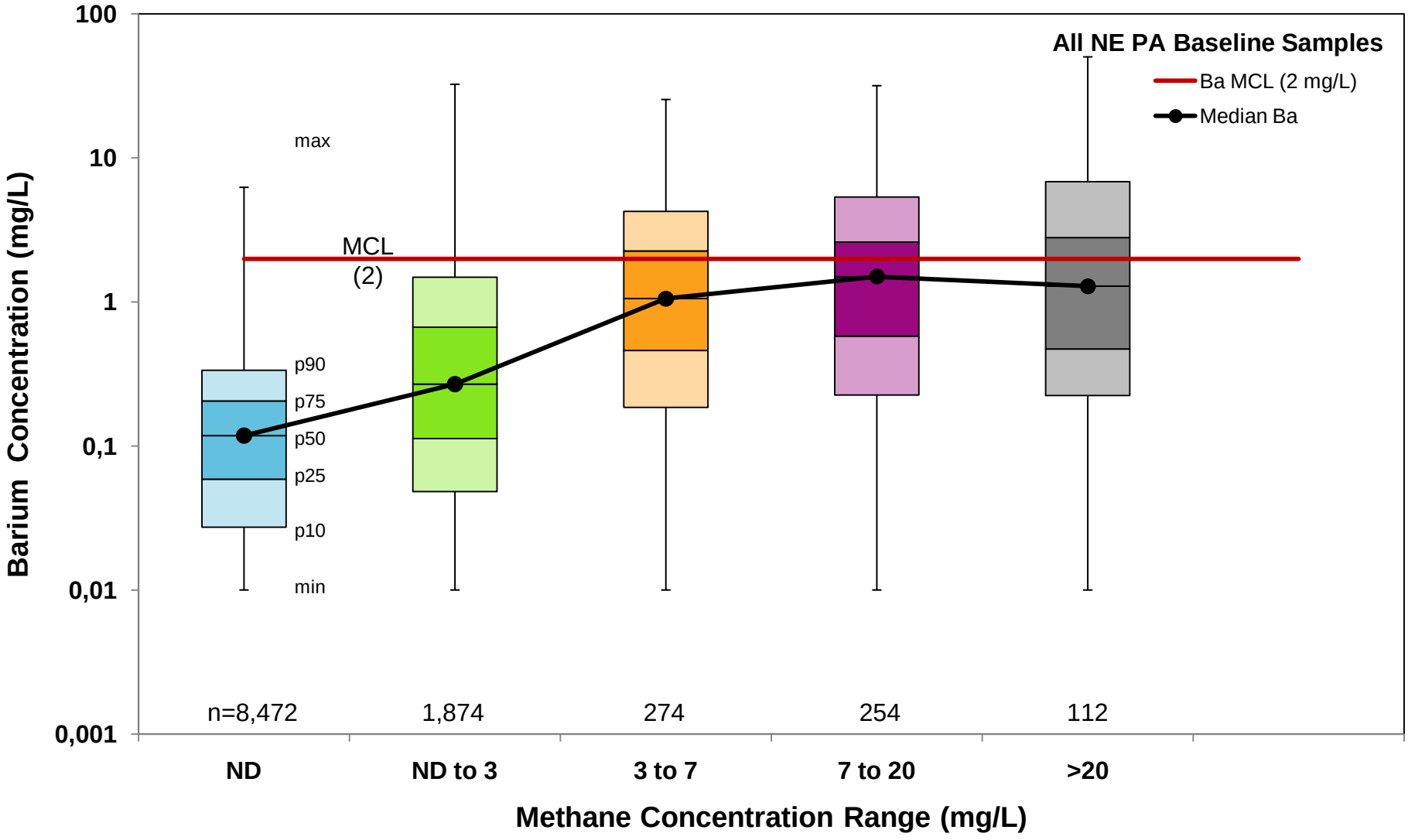
Methane and TDS

Northeastern PA



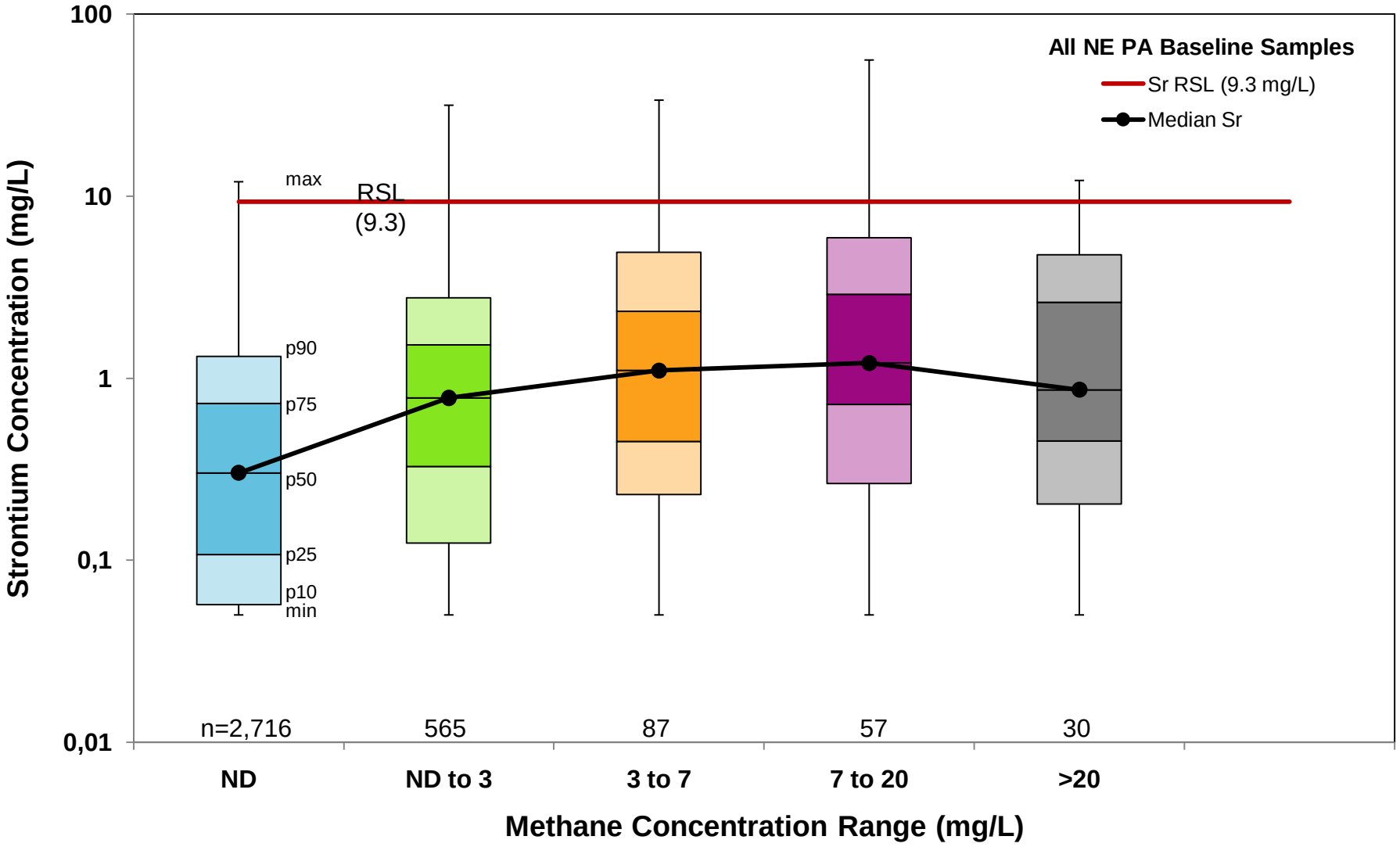
Methane and Barium

Northeastern PA



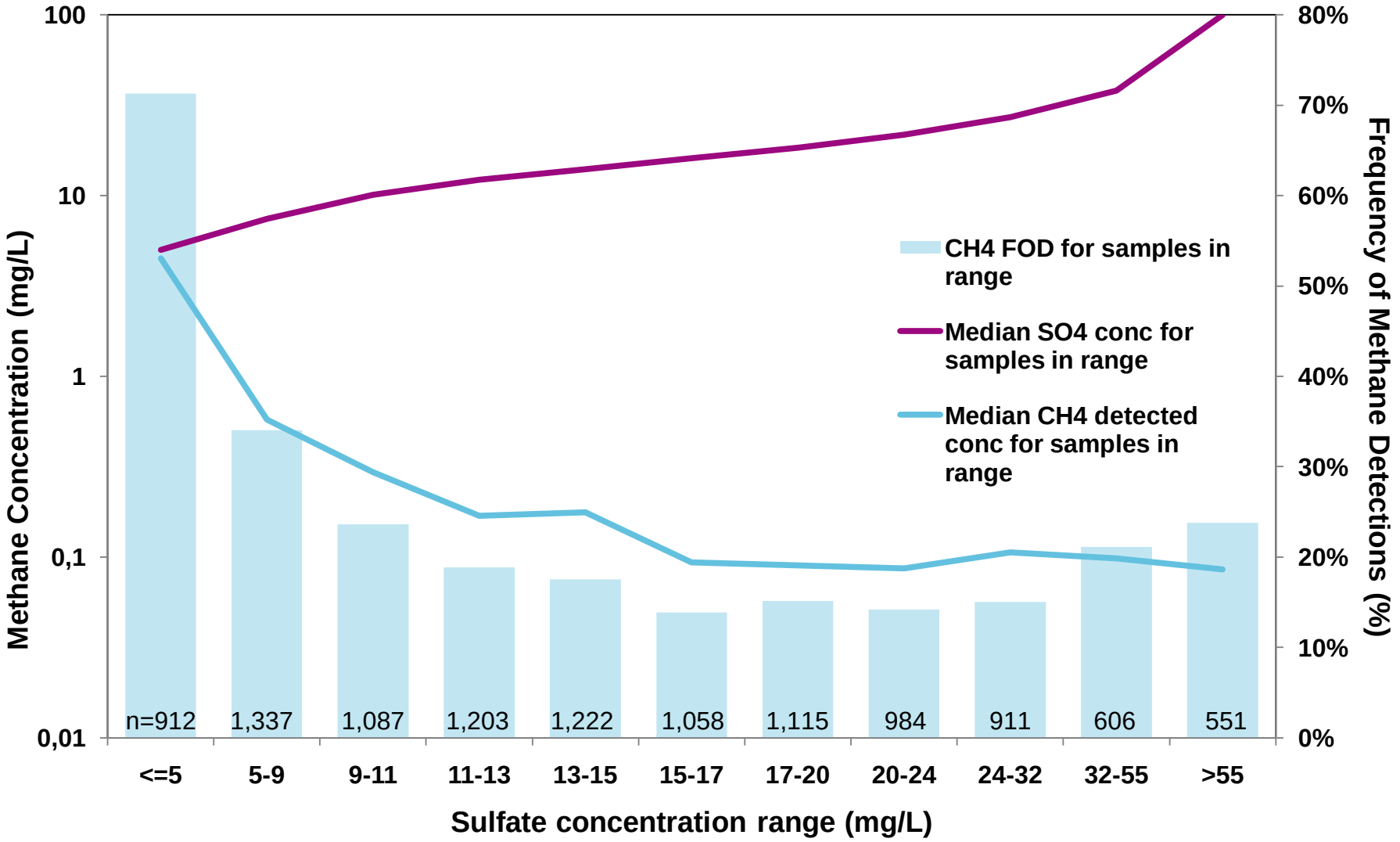
Methane and Strontium

Northeastern PA



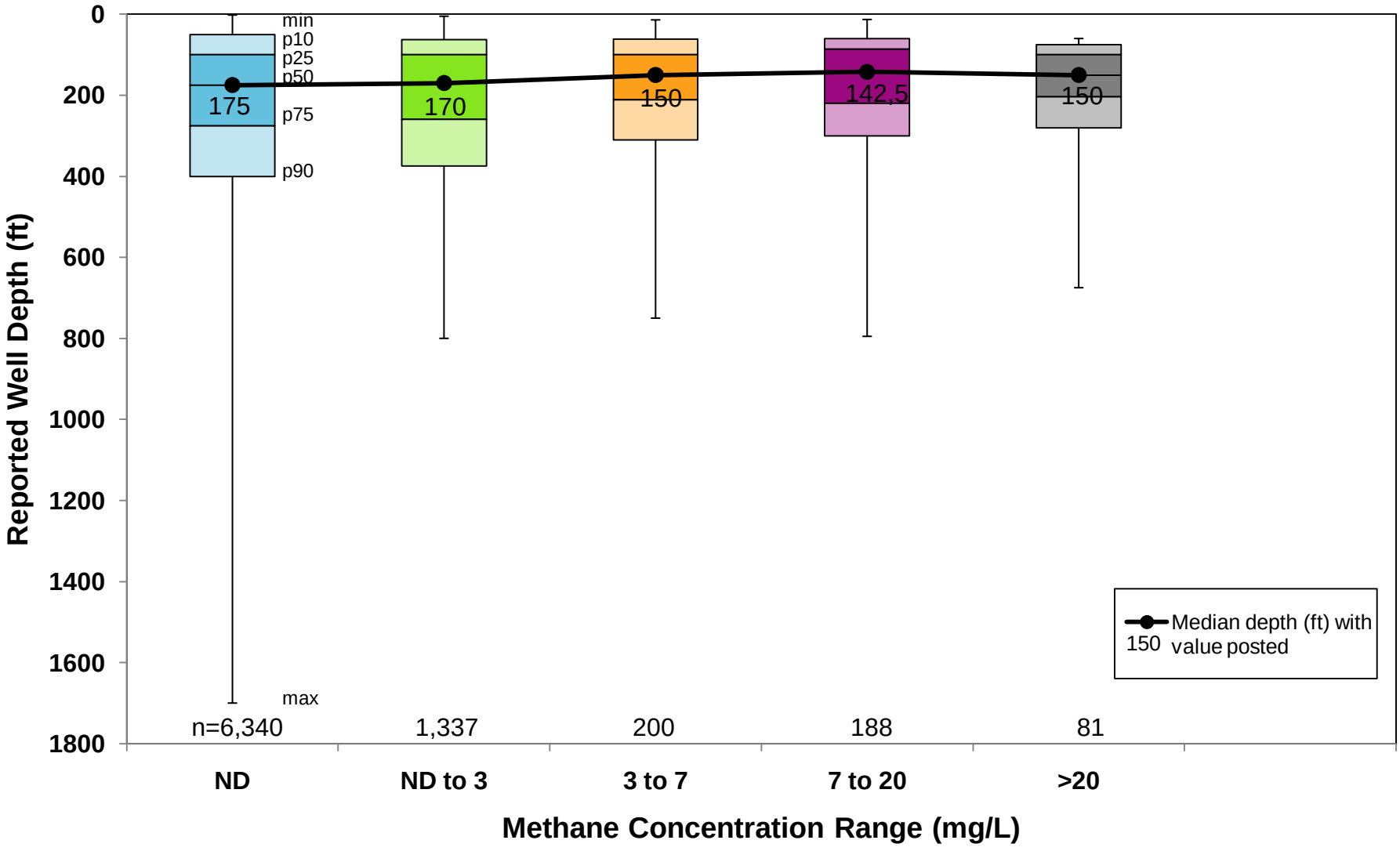
Methane Occurrence Inversely Related to Sulfate

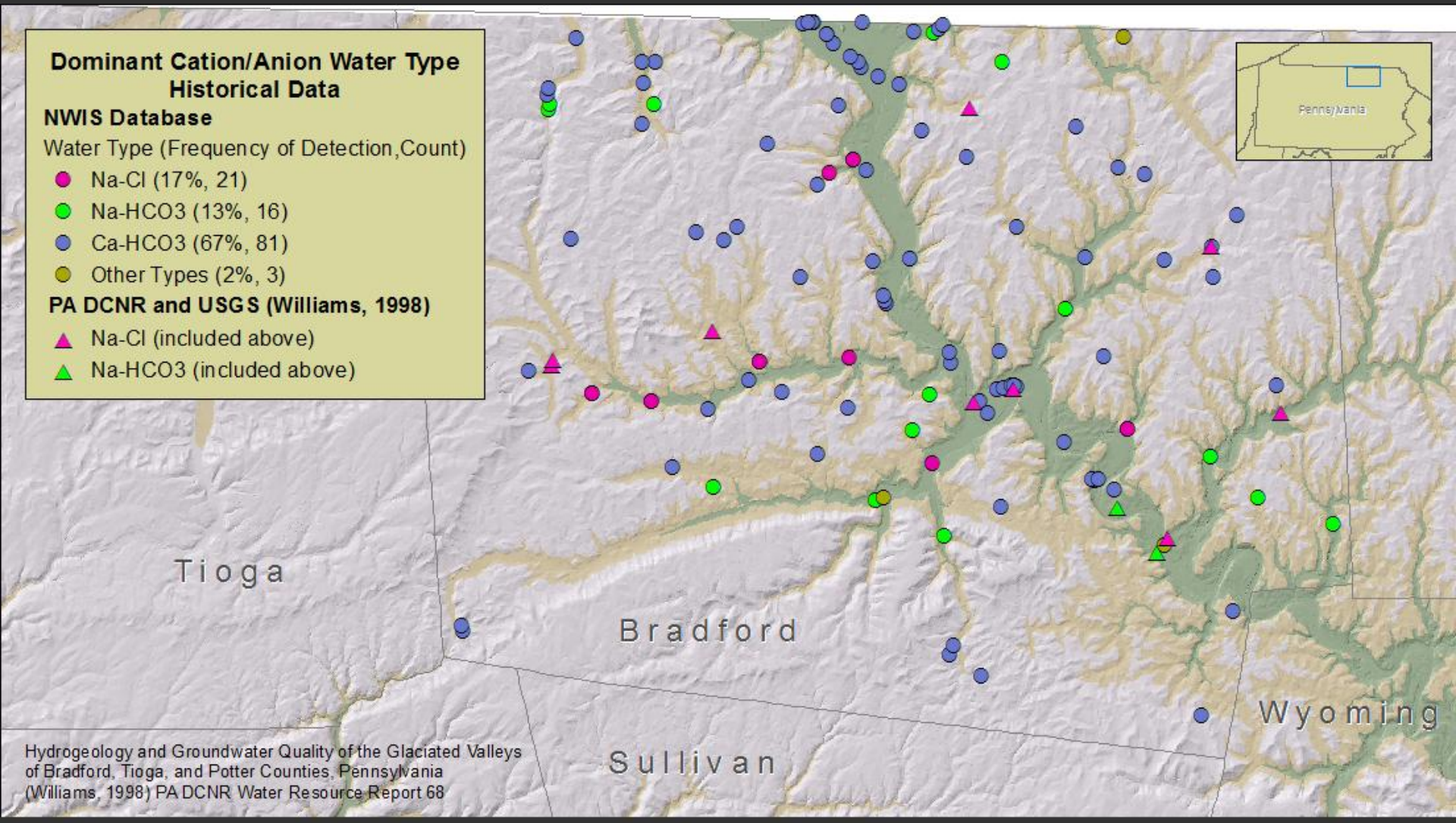
Northeastern PA



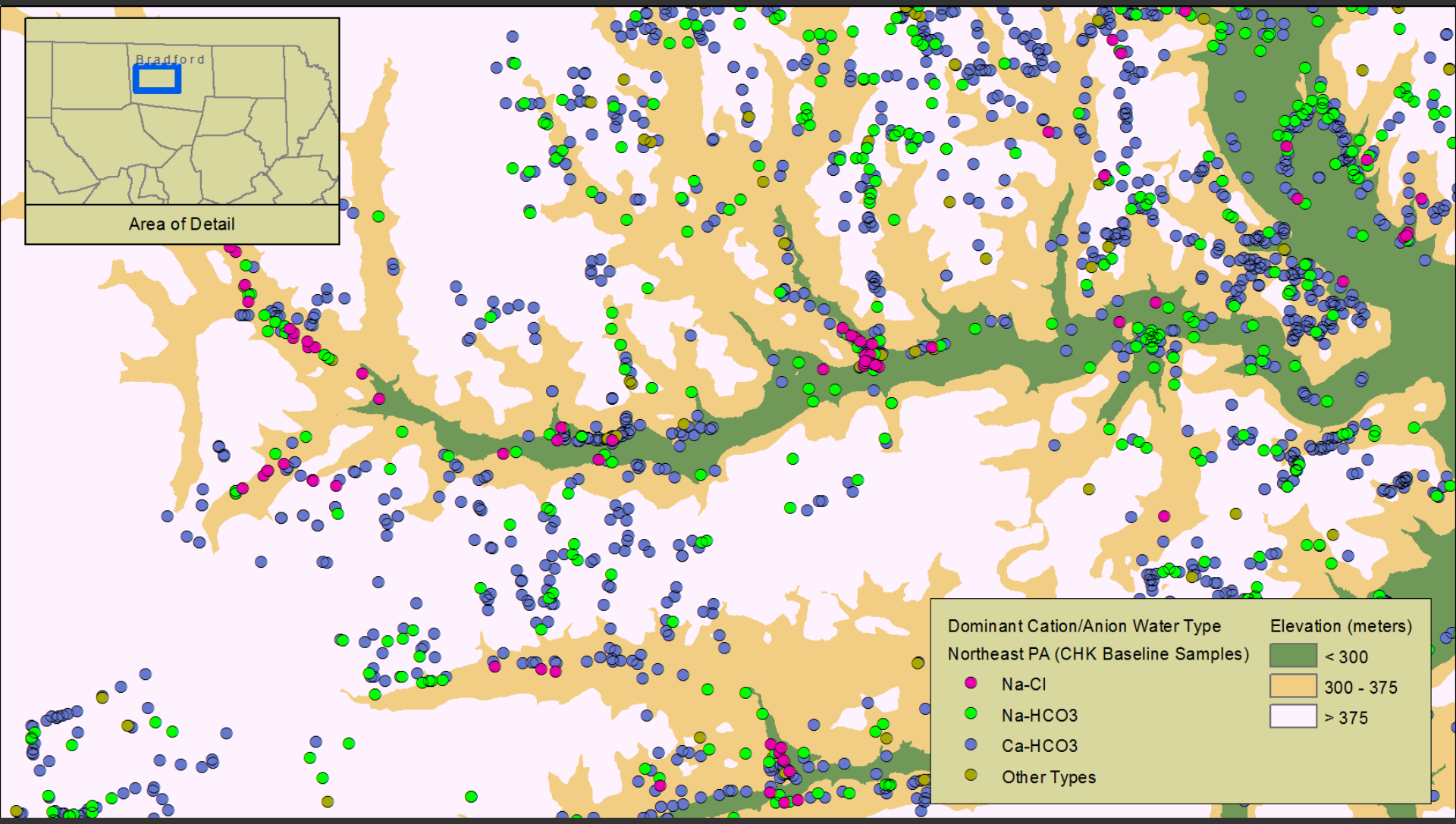
Methane and Well Depth

Northeastern PA





Water Type Distribution, Bradford County, PA
HISTORICAL DATA (1930-2006)



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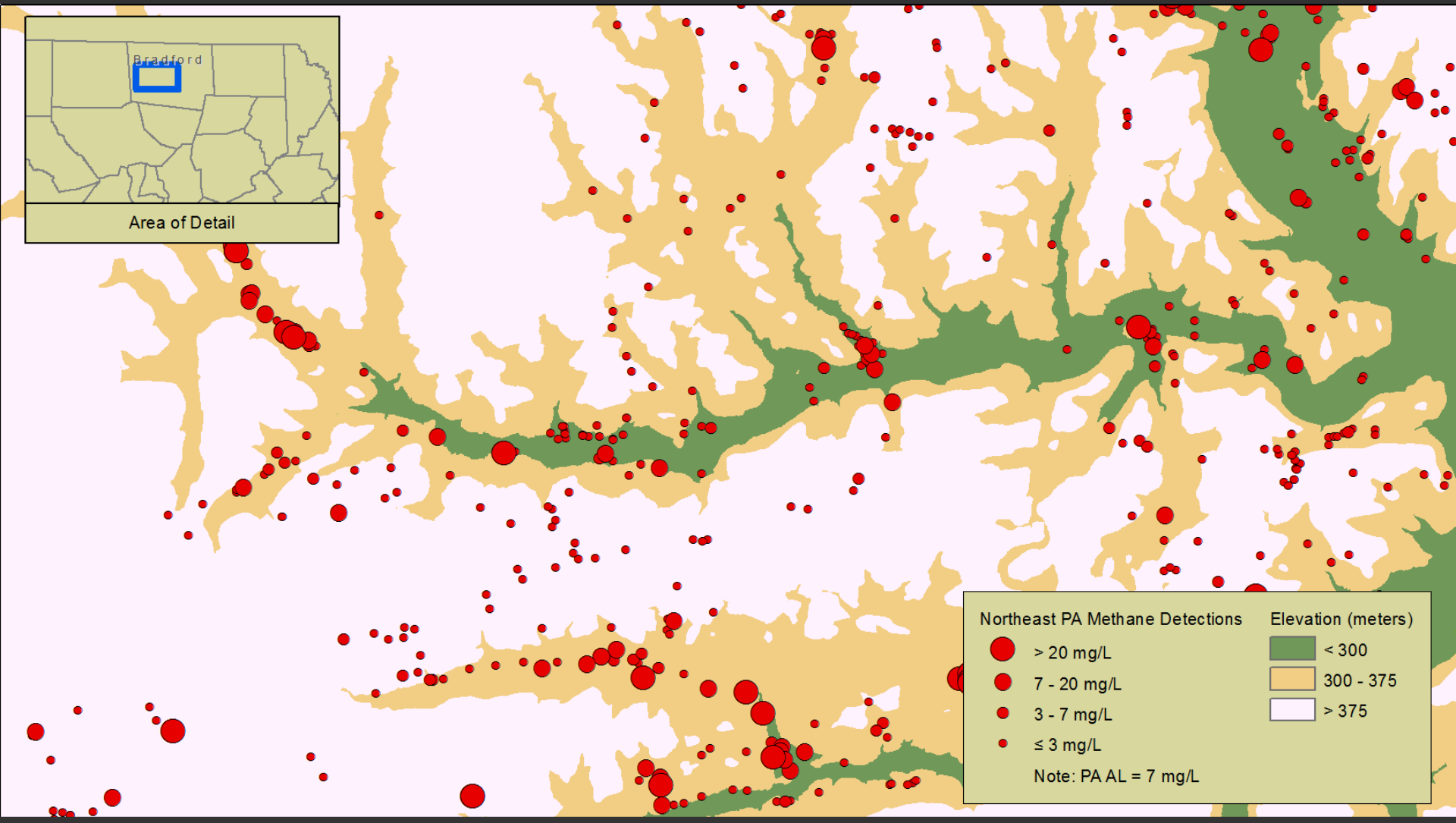
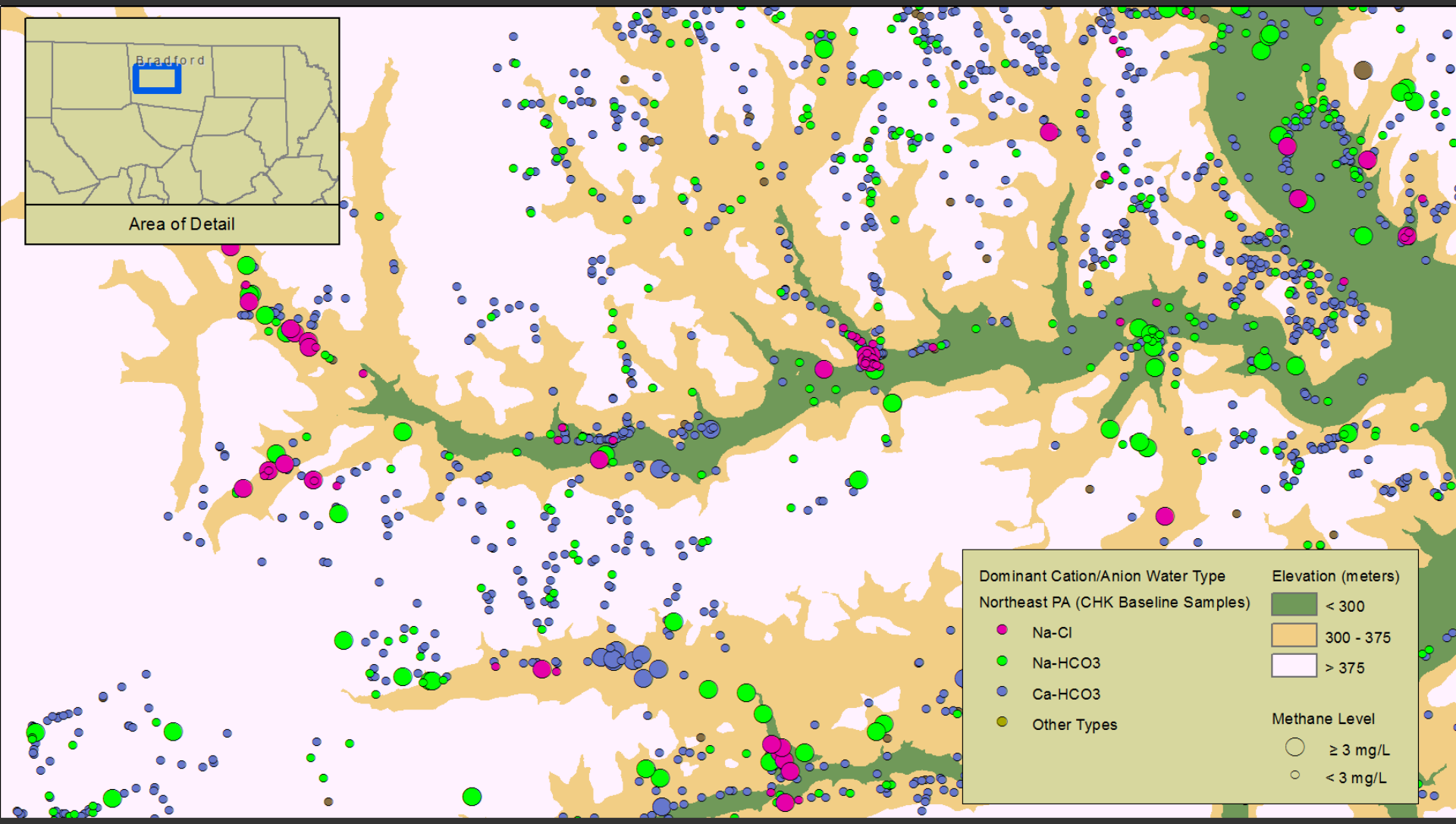
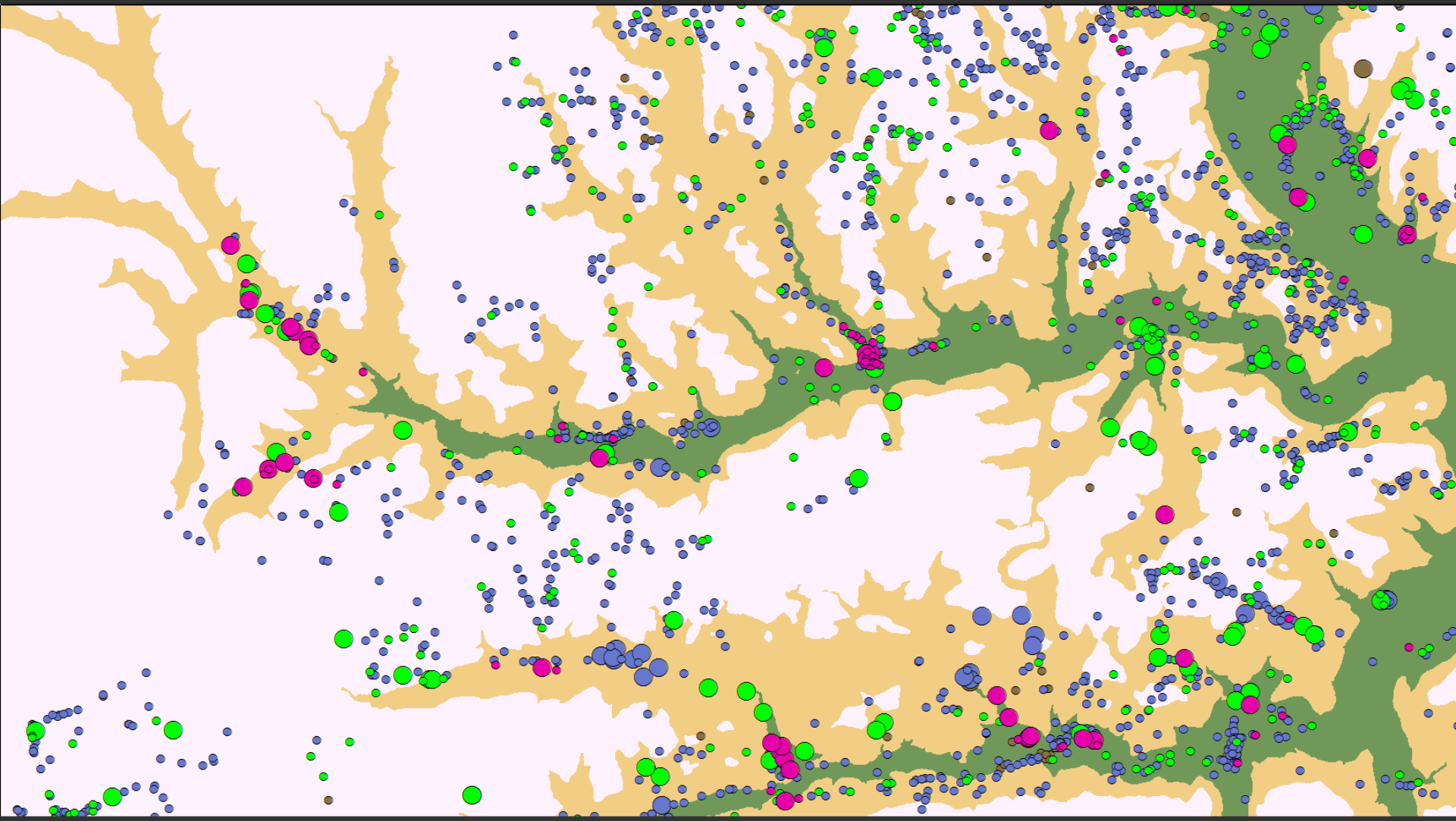
Water Type Distribution vs. Elevation
CHK BASELINE DATA (2009-2011)



Methane Distribution vs. Elevation
CHK BASELINE DATA (2009-2011)

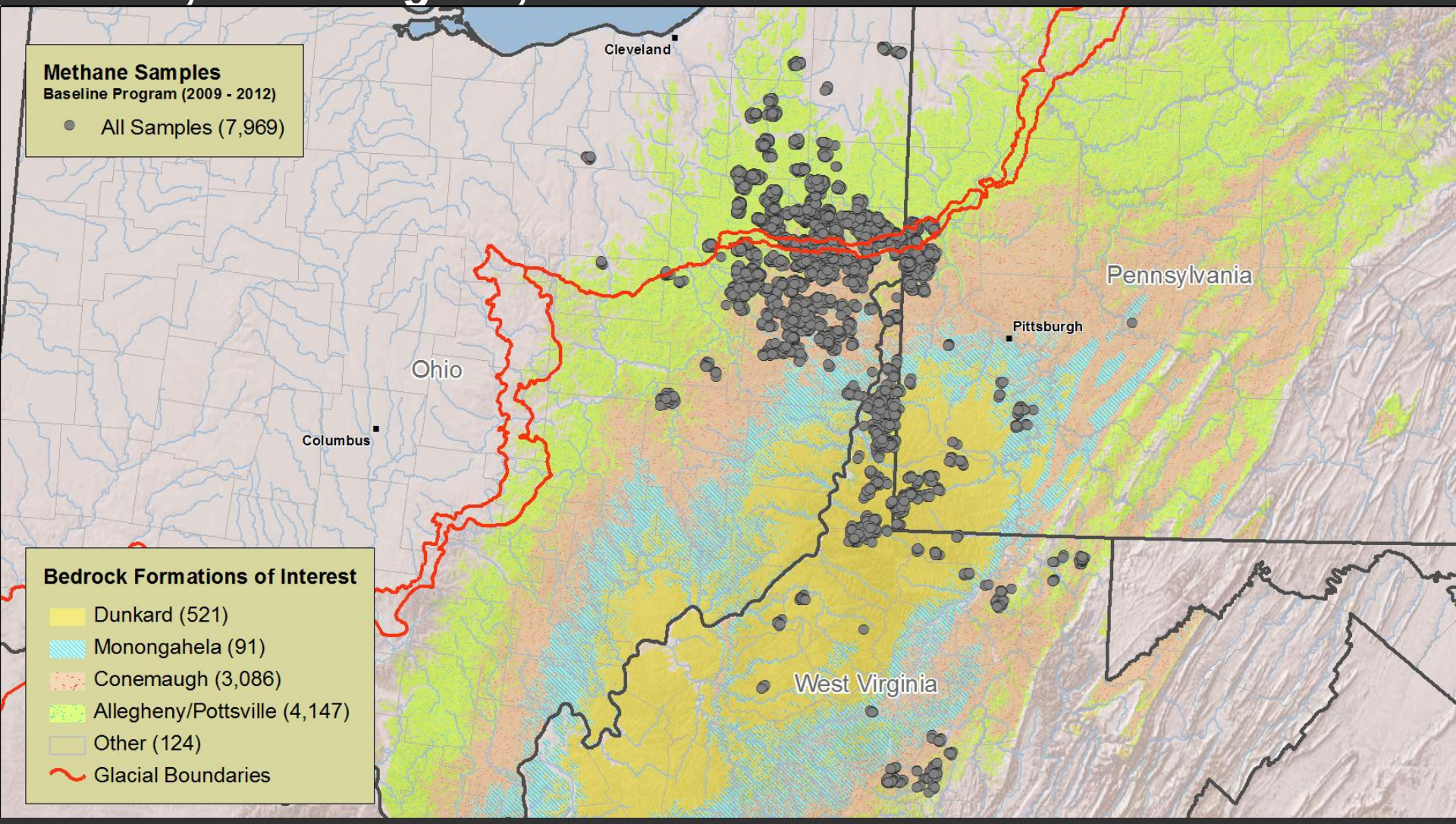


Water Types and Methane Distribution vs. Elevation
CHK BASELINE DATA (2009-2011)



Water Types and Methane Distribution vs. Elevation
CHK BASELINE DATA (2009-2011)

Ohio, West Virginia, Southwest PA: Further Evaluation



Southwestern Pennsylvania, Ohio, and West Virginia
BASELINE METHANE

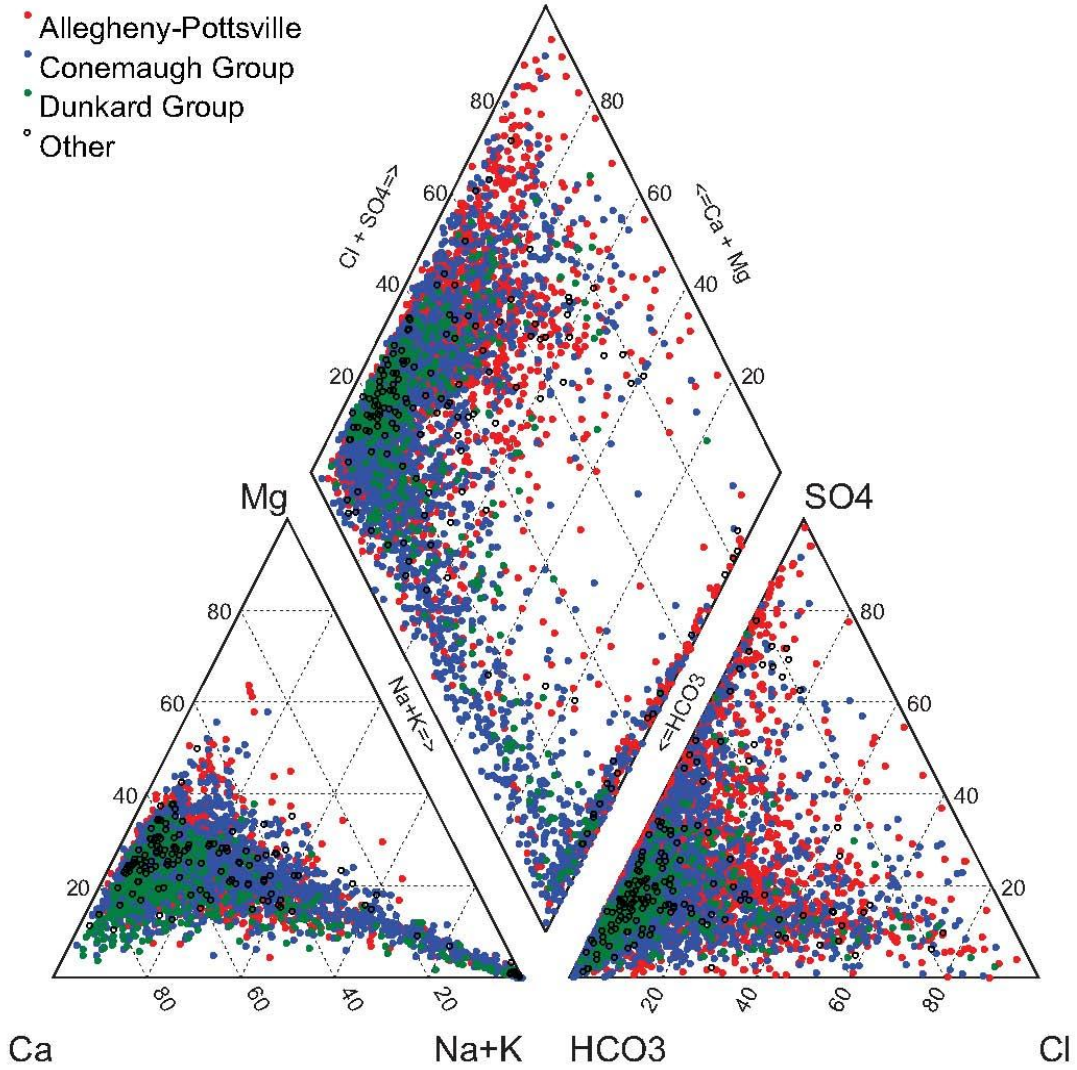
Geological Units – OH-WV-SW PA

- Dunkard Group (Upper Pennsylvanian-Lower Permian)
  - Non-marine cyclic sequences of sandstone, siltstone, red and gray shale, limestone, and **coal**.
  - Includes Greene, Washington and Waynesburg Formations.
  - Occurs on hilltops and upland areas
- Monongahela Group (Pennsylvanian)
  - Non-marine cyclic sequences of sandstone, siltstone, red and gray shale, limestone, and **coal**
  - Includes Pittsburgh and Uniontown Formations.
  - Includes unusually thick layers of **coal** (5-10 ft)

- Conemaugh Group (Middle Pennsylvanian)
  - Mostly non-marine cyclic sequences of red and gray shale, siltstone, and sandstone, with thin limestones and **coal**.
  - Includes Casselman and Glenshaw Formations.
  - Occurs on hilltops and upland areas.
- Allegheny and Pottsville Formations, undivided (Lower Pennsylvanian)
  - Sandstone, shale, some **coal**, and conglomerate.
  - Commonly underlies alluvial valleys, but also occur in upland areas where folded.
- Other (Devonian to Quaternary)
  - Along the glaciated Allegheny Plateau of northeastern Ohio, glacial deposits and alluvium cover much of the bedrock.
  - In northeastern Ohio, Mississippian and Devonian rocks (commonly sandstone and shale) underlie unconsolidated glacial and alluvial deposits.
  - Throughout the region topography varies, with unconsolidated alluvial and/or glacial deposits typically in valleys, and bedrock formations mostly on hilltops or upland areas.

Samples with Methane Not Detected

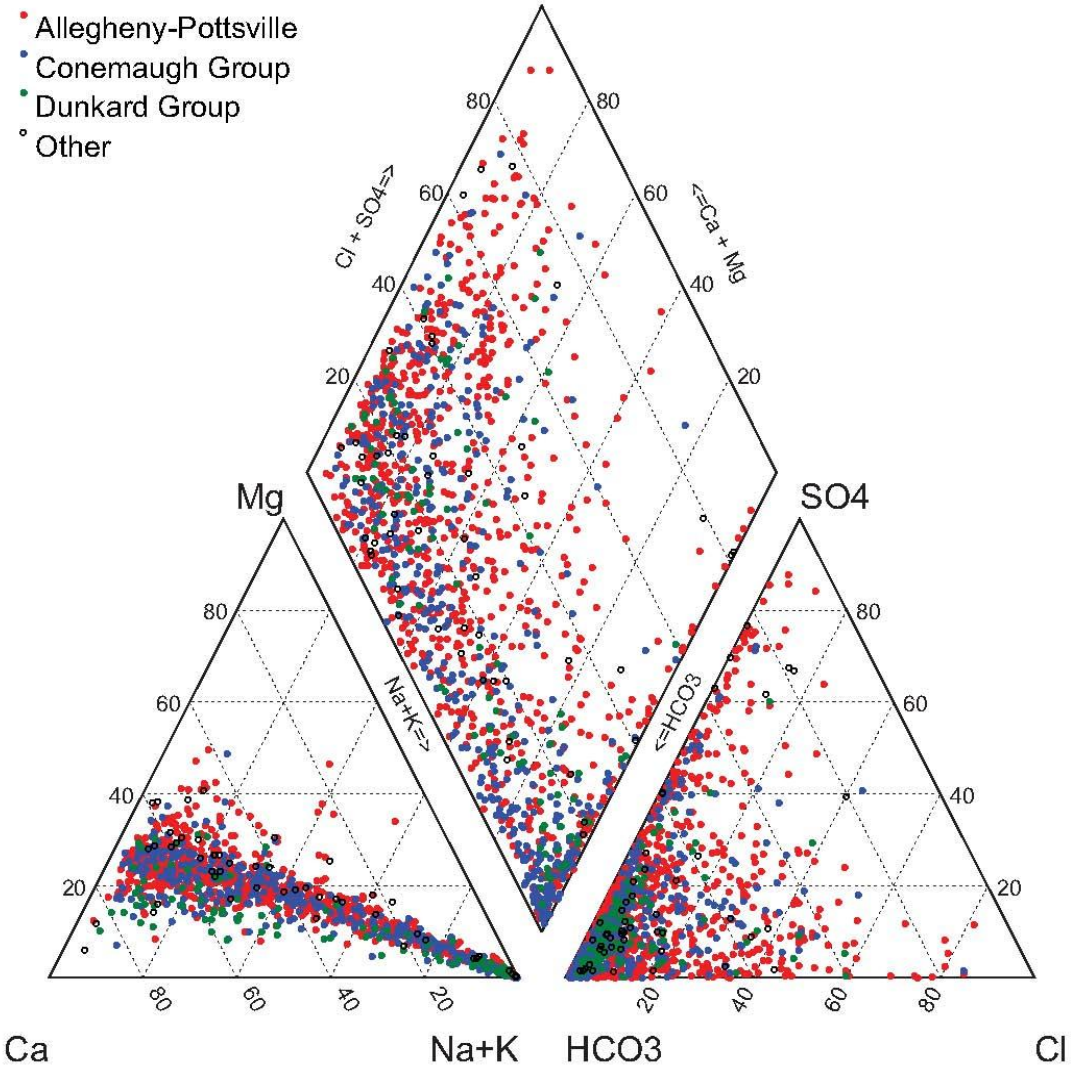
Ohio – West Virginia – Southwestern PA



- Predominantly Ca-HCO_3-type water
- Other water types include Ca-Cl, Ca-SO_4, Na-HCO_3

Samples with Methane up to 3 mg/L

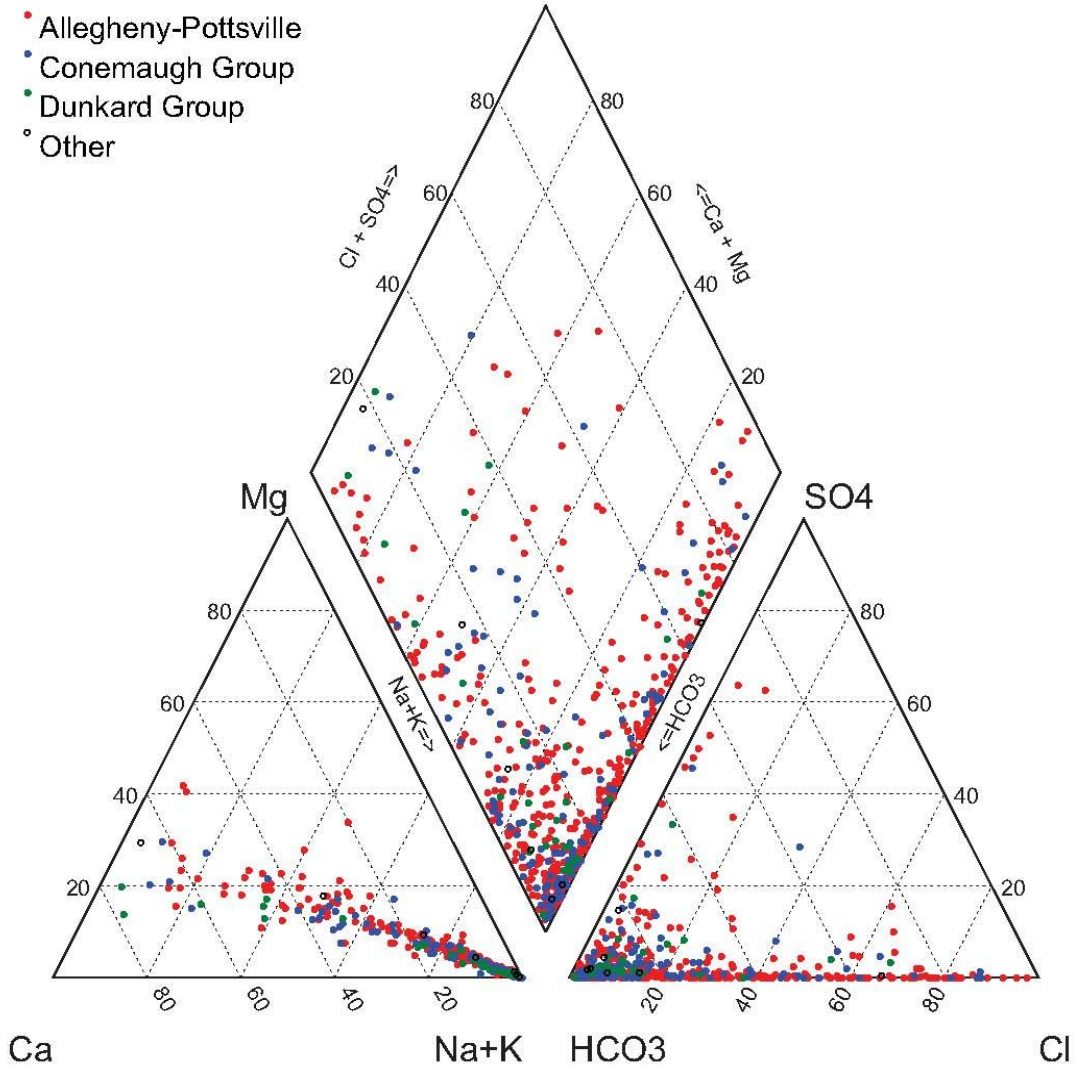
Ohio – West Virginia – Southwestern PA



- Predominantly Ca-HCO_3-type water
- Increasing Na

Samples with Methane ≥ 3 mg/L

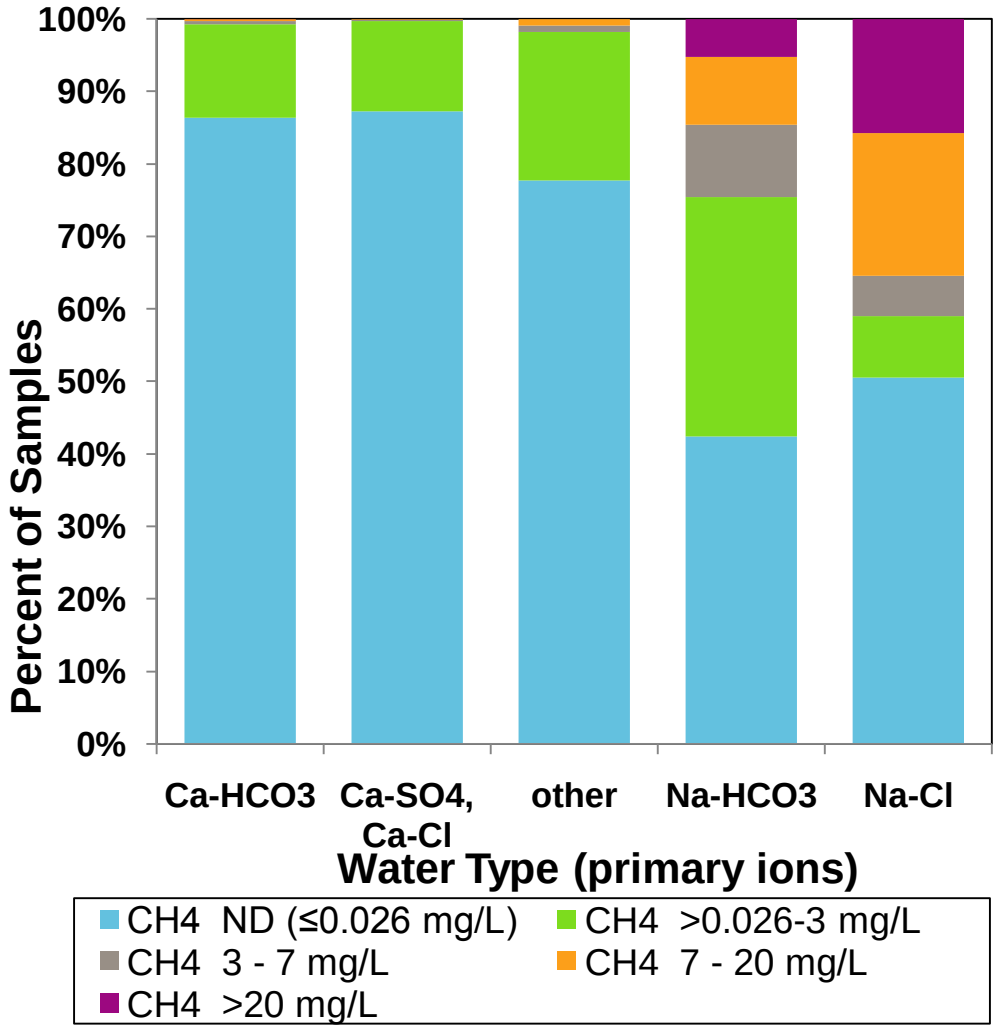
Ohio – West Virginia – Southwestern PA



- Predominantly Na-HCO_3
- Also Na-Cl type waters
- Sulfate generally depleted
- Lower percentage of all Ca-type waters

Methane and Water Type

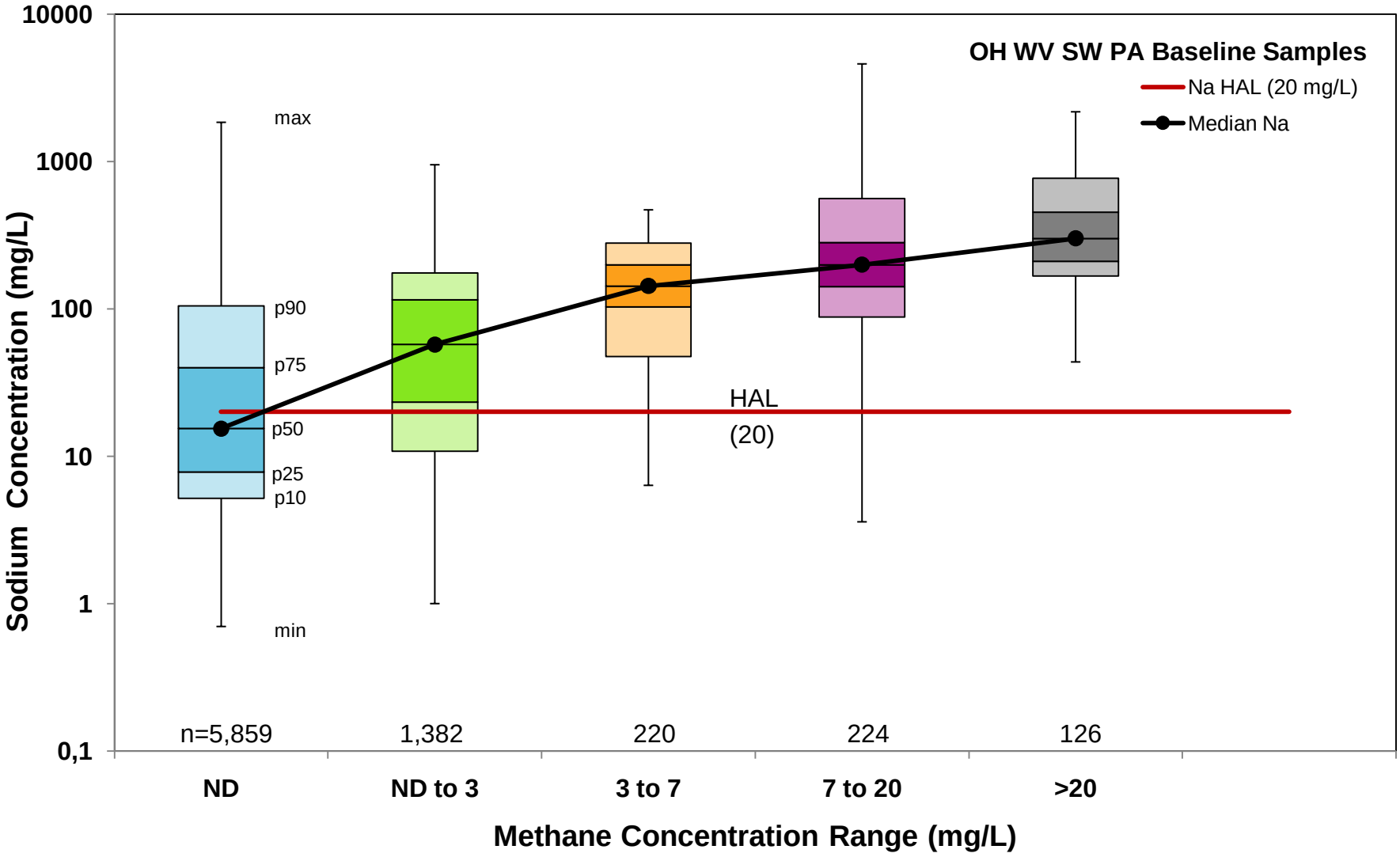
Ohio – West Virginia – Southwestern PA



	CH4 3-7 mg/L	CH4 7-20 mg/L	CH4 >20 mg/L
Ca-HCO_3	10%	5%	1%
Ca-SO_4, Ca-Cl	0.5%	0.5%	0%
Na-HCO_3	84%	78%	77%
Na-Cl	5%	16%	22%
Other	0.5%	0.5%	0%
Na-HCO_3 and Na-Cl	89%	94%	99%

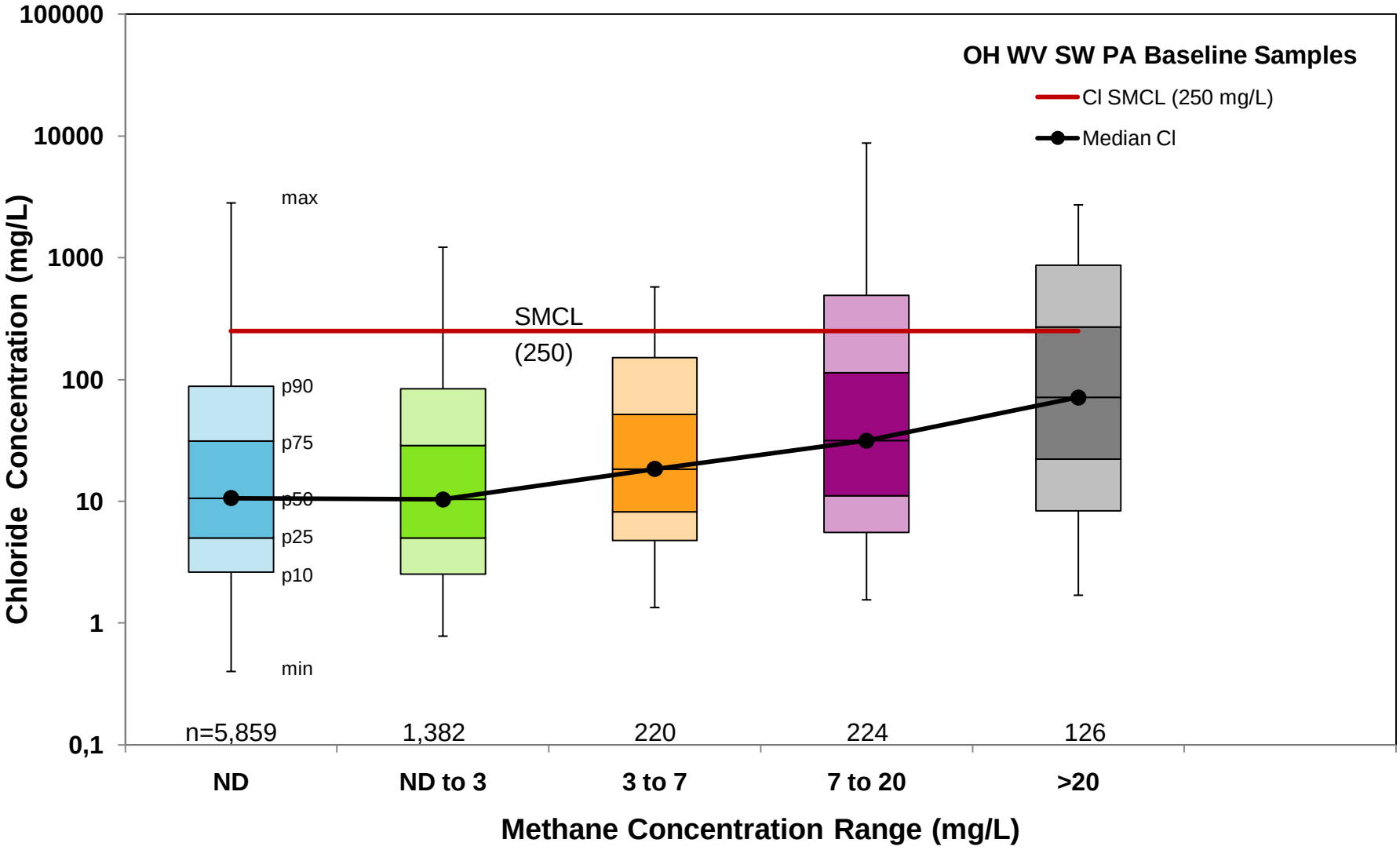
Methane and Sodium

Ohio – West Virginia – Southwestern PA



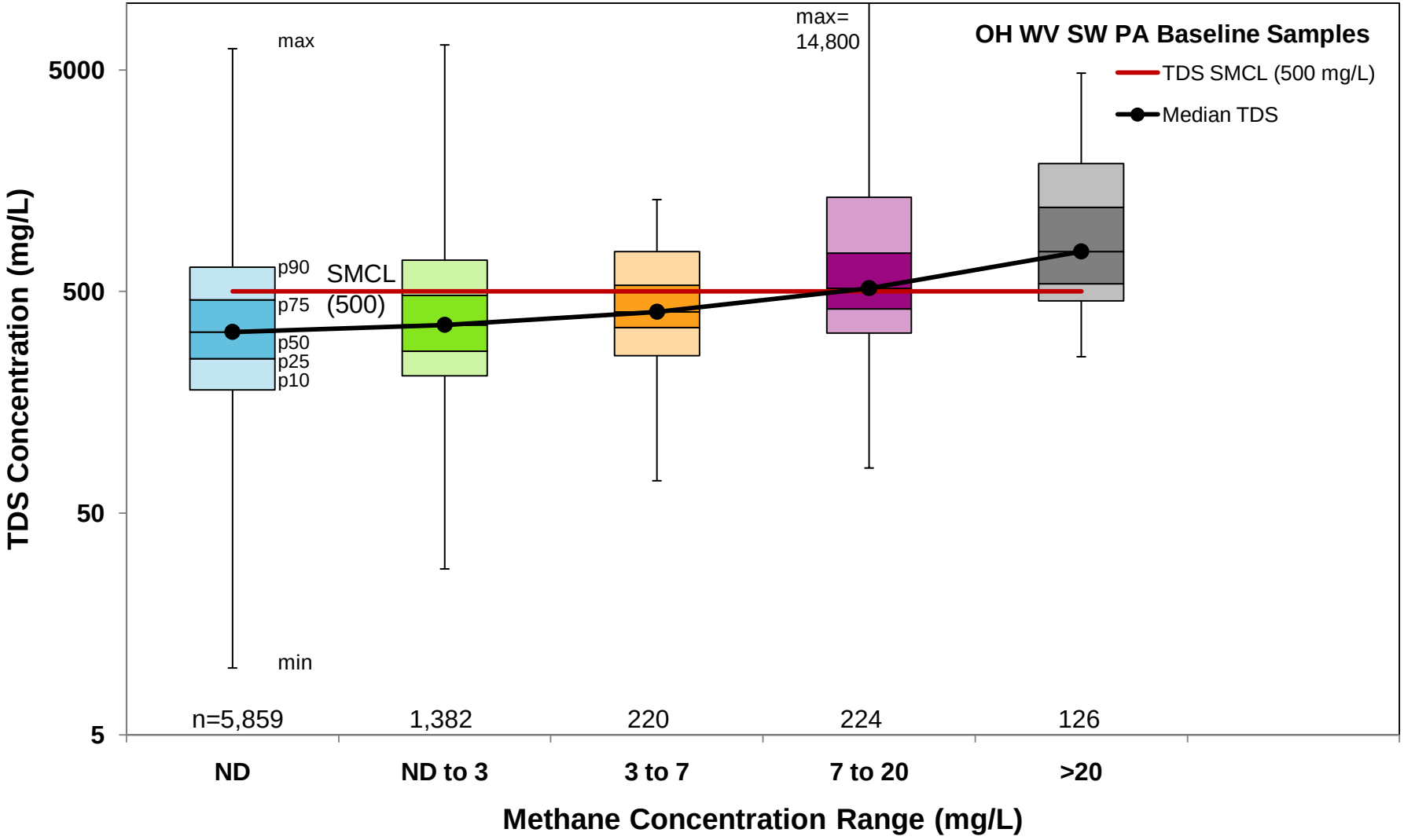
Methane and Chloride

Ohio – West Virginia – Southwestern PA



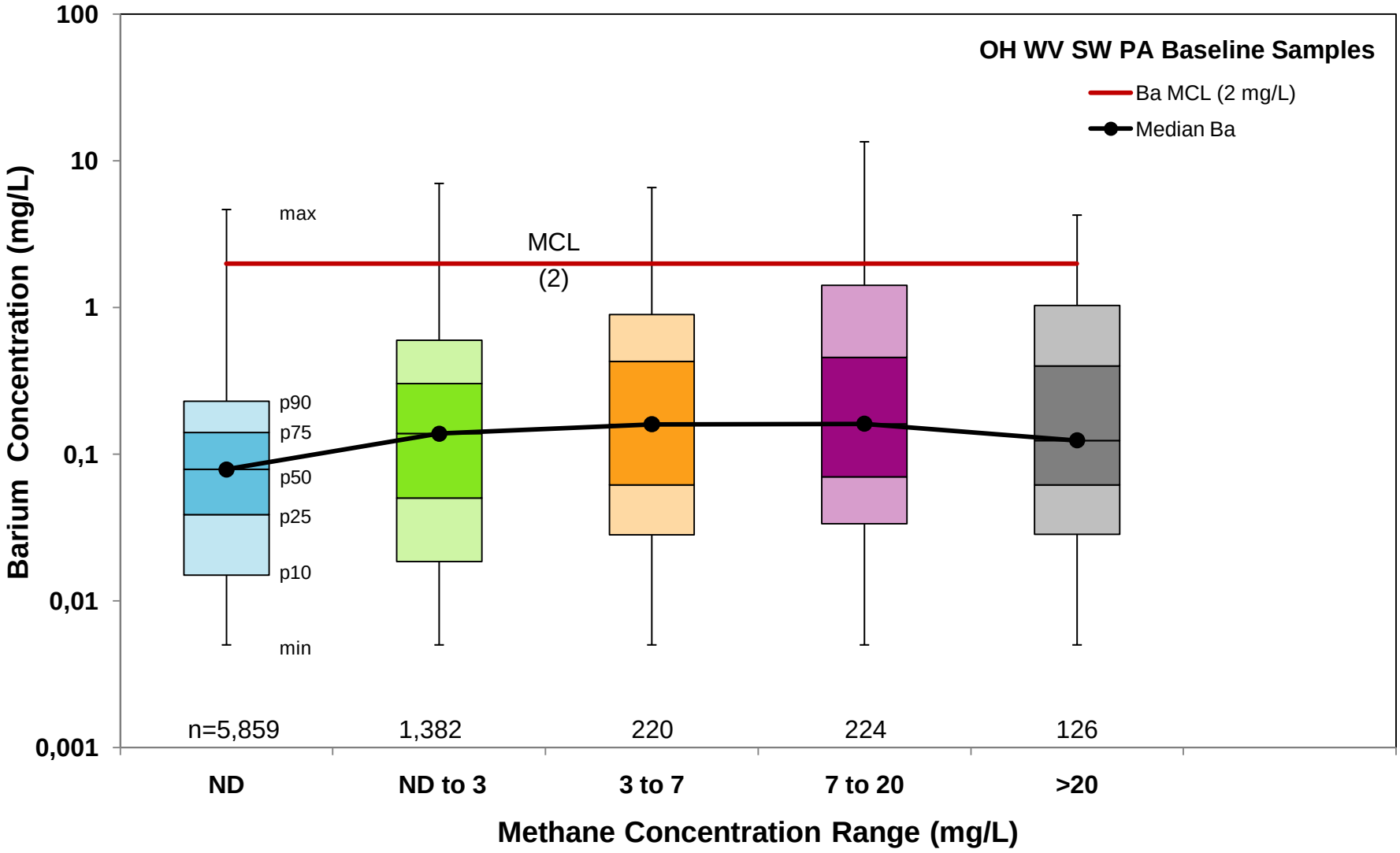
Methane and TDS

Ohio – West Virginia – Southwestern PA



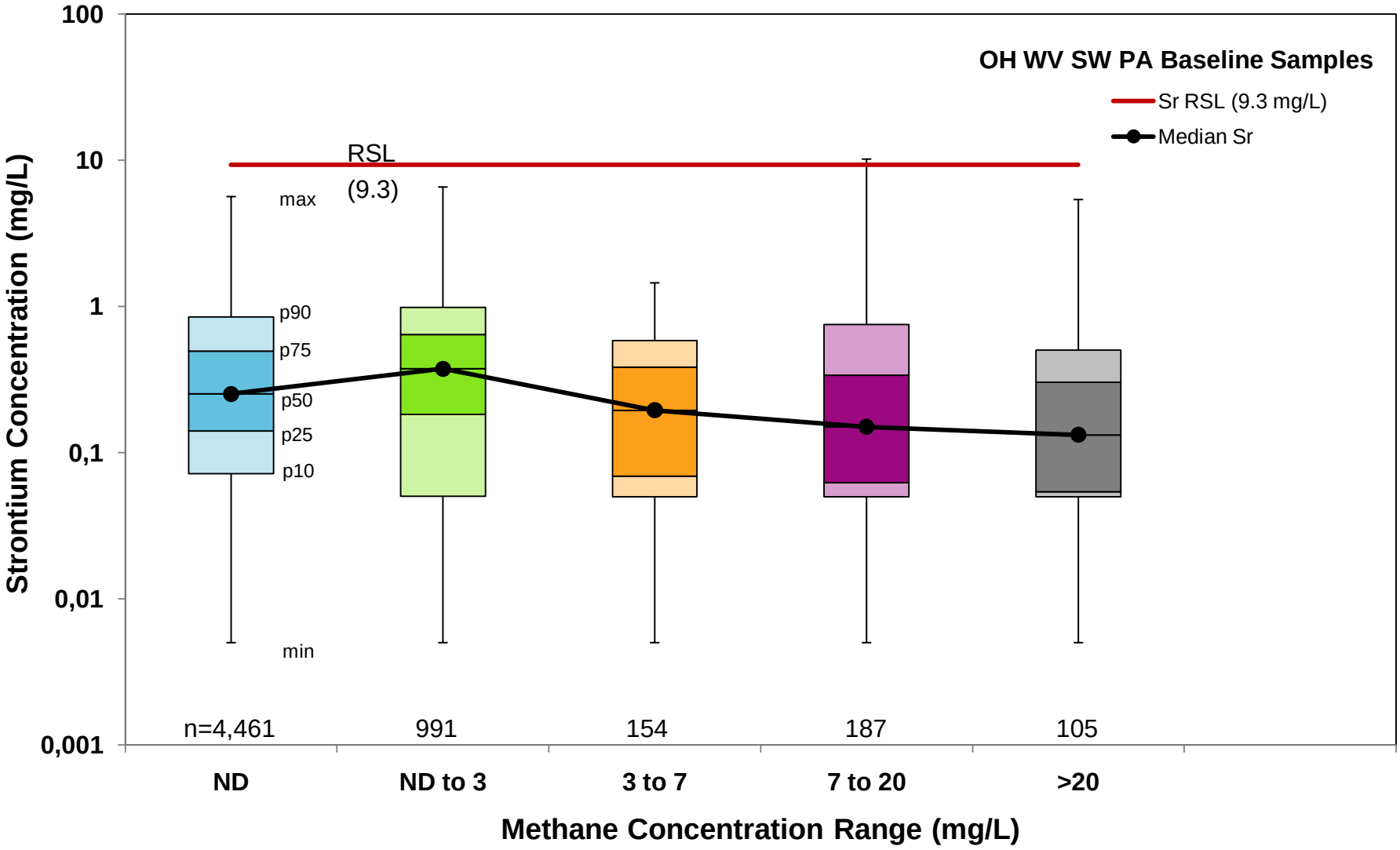
Methane and Barium

Ohio – West Virginia – Southwestern PA



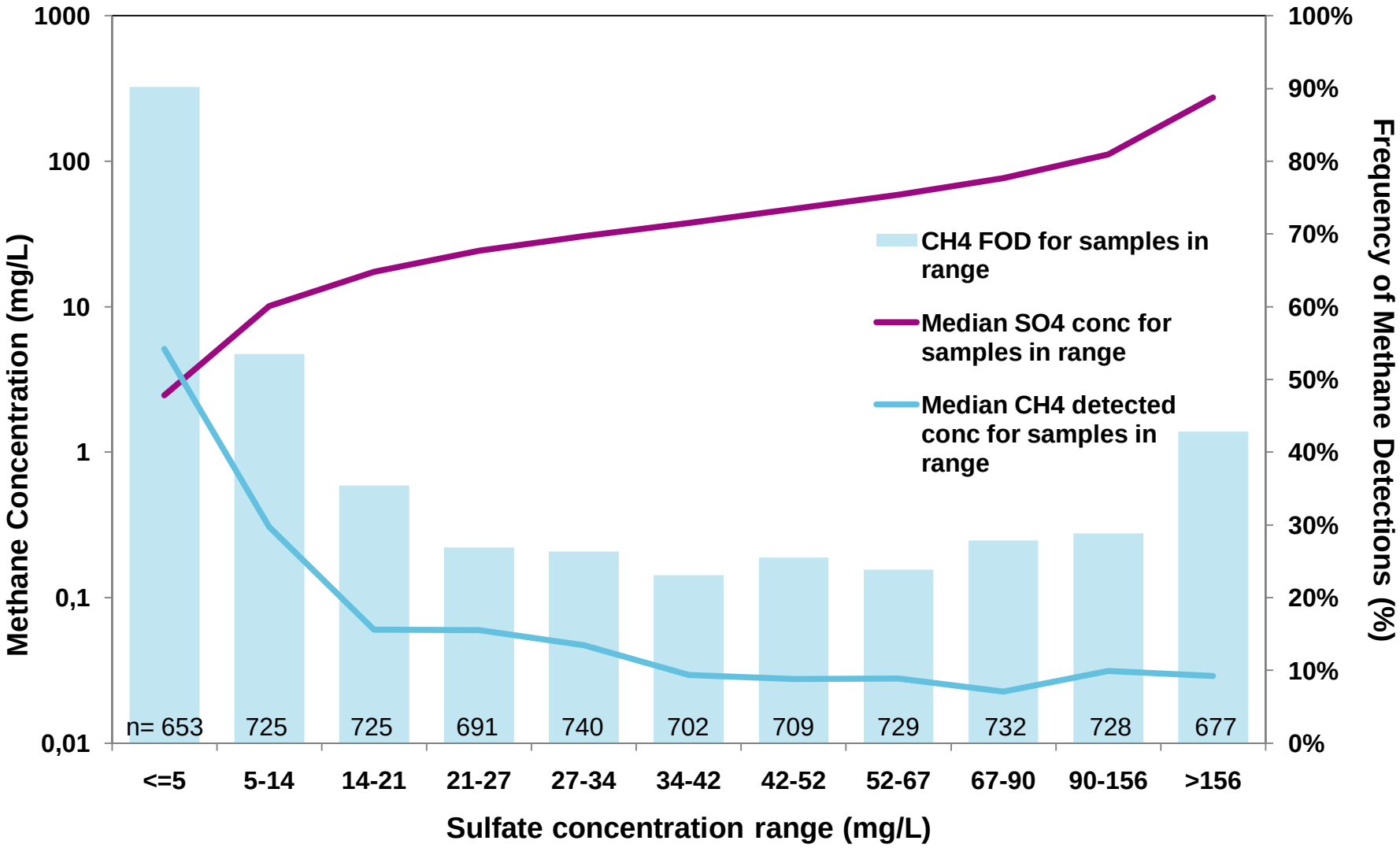
Methane and Strontium

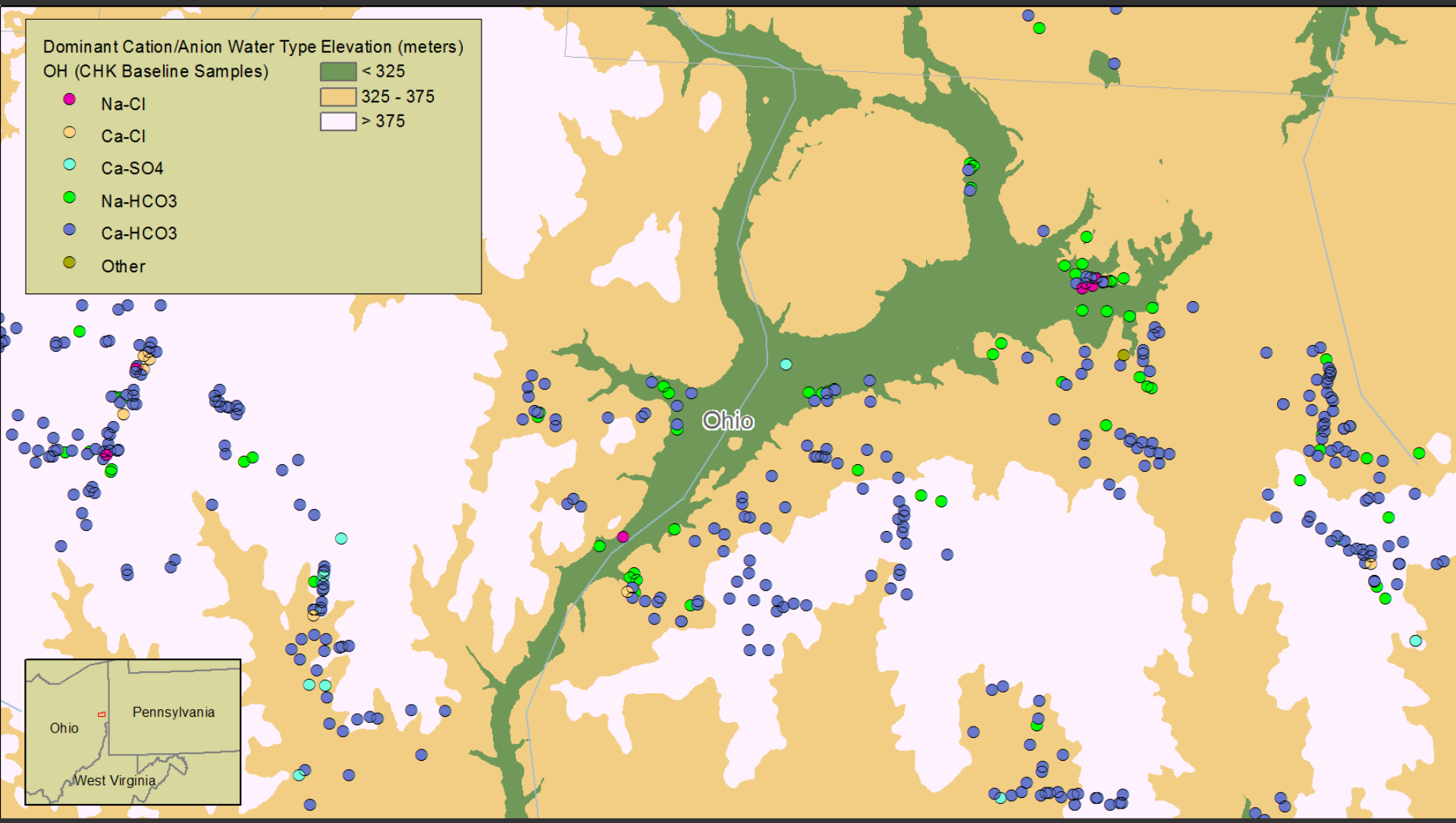
Ohio – West Virginia – Southwestern PA



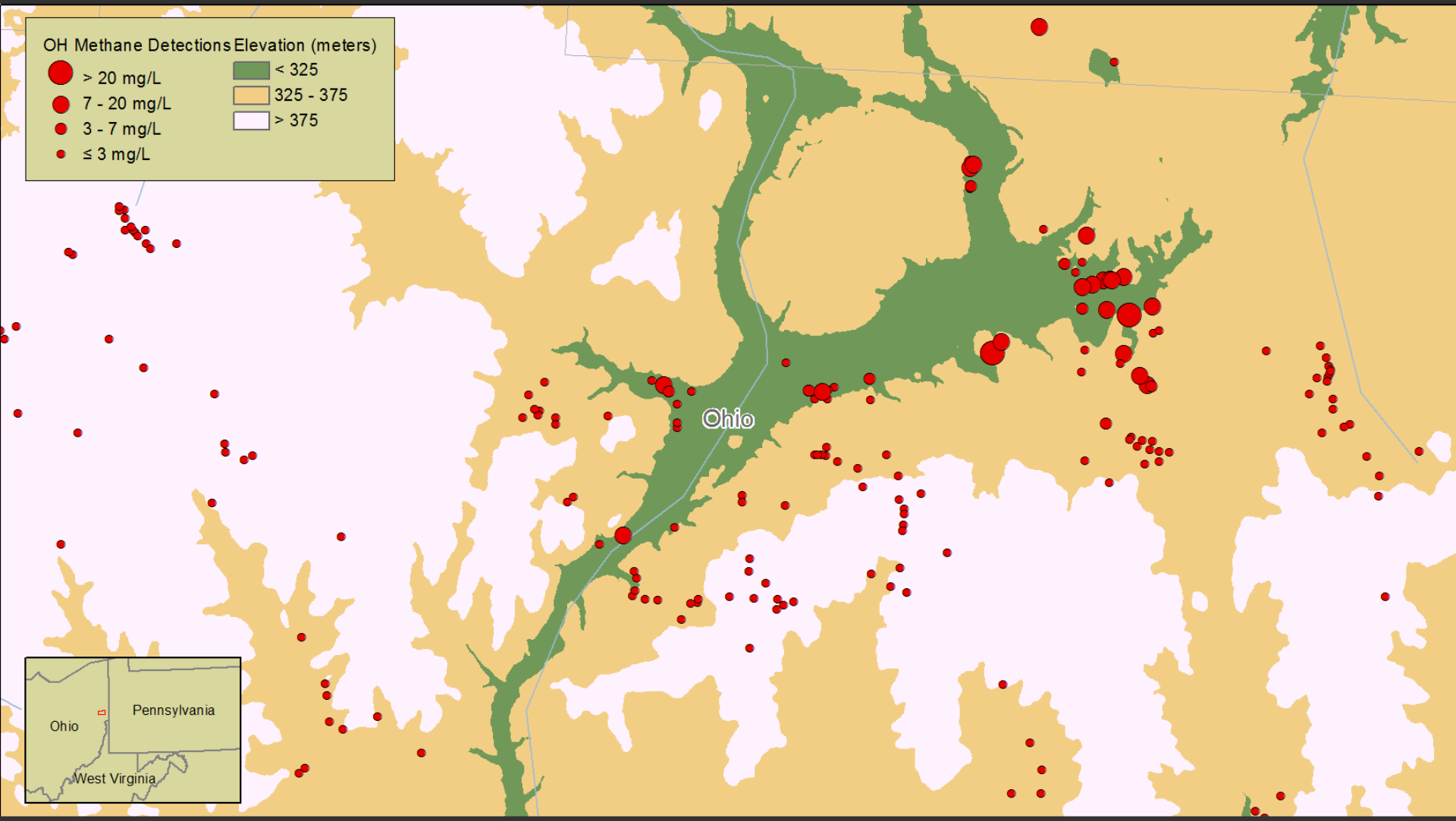
Methane Occurrence Inversely Related to Sulfate

Ohio – West Virginia – Southwestern PA

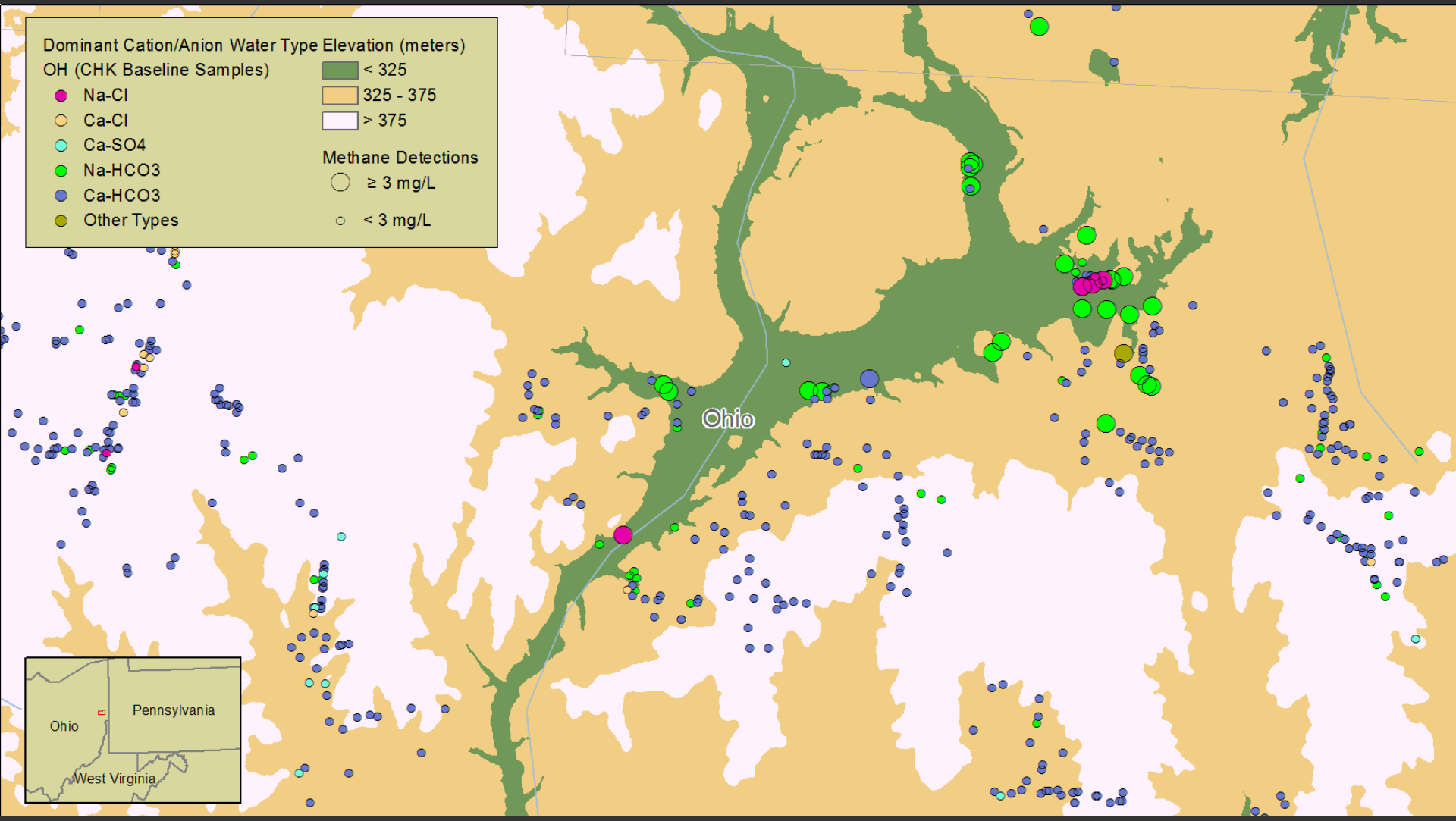




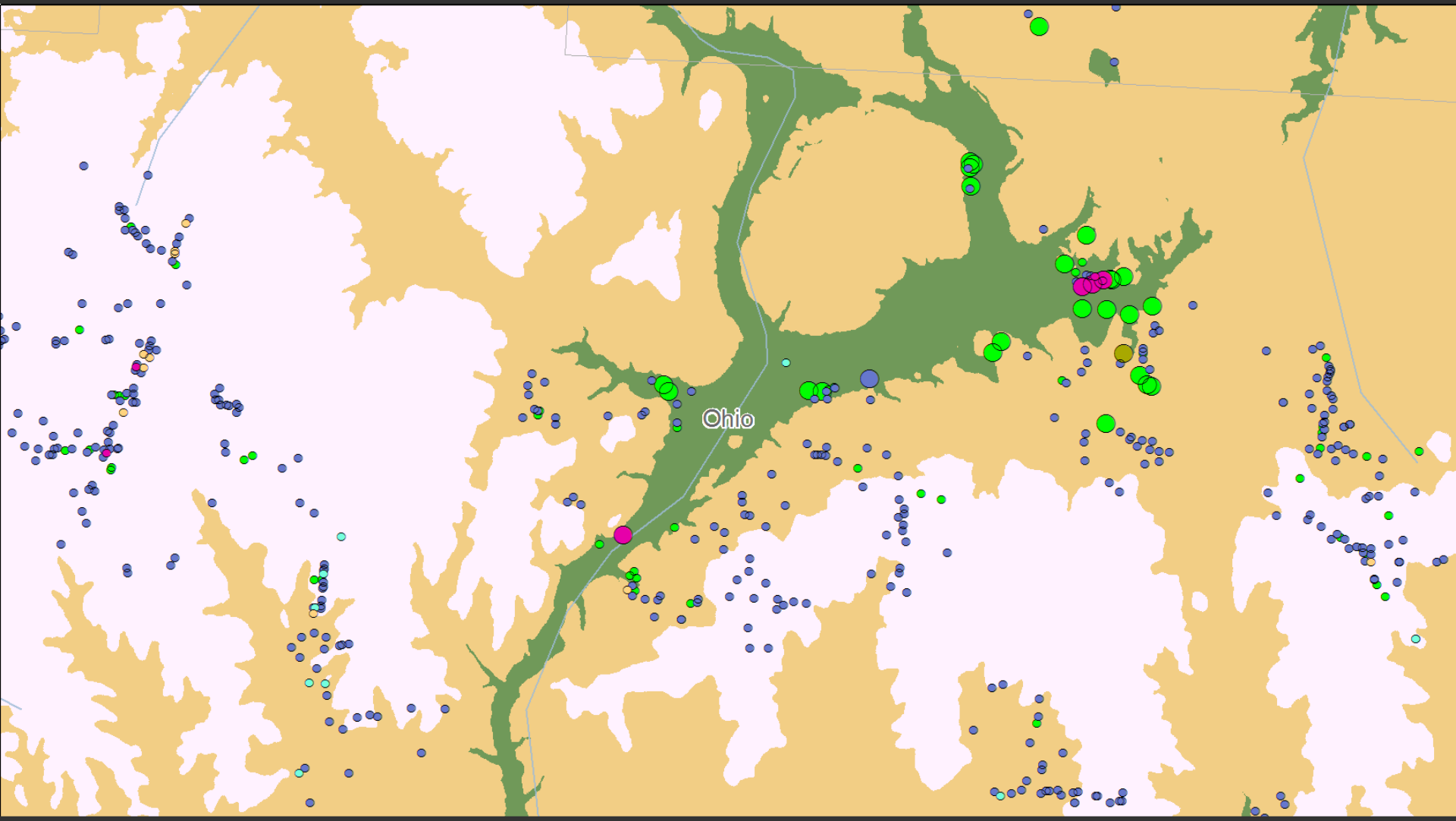
Water Types vs. Elevation
CHK BASELINE DATA (2009-2012)



Methane Distribution vs. Elevation
CHK BASELINE DATA (2009-2012)



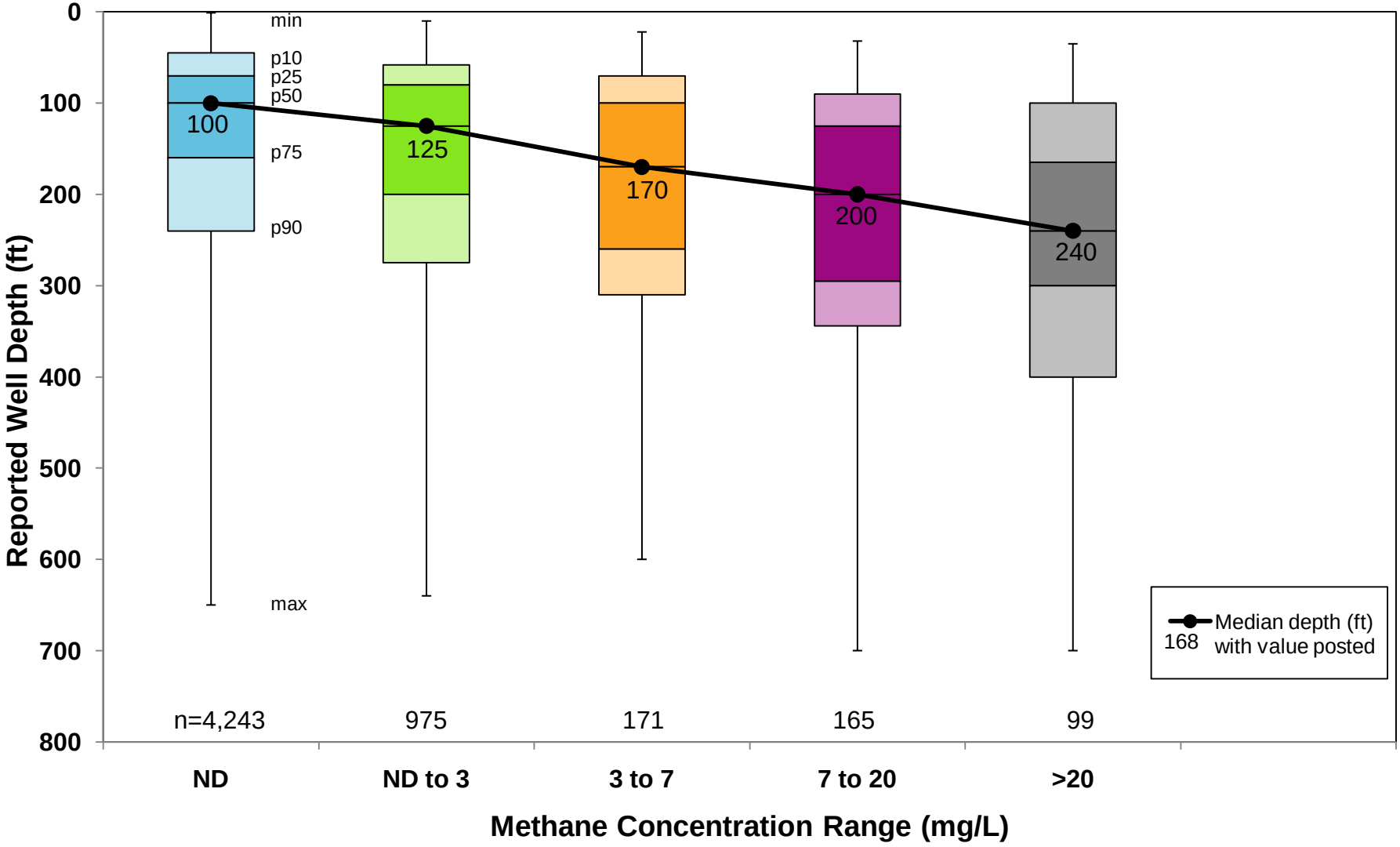
Water Types and Methane Distribution vs. Elevation
CHK BASELINE DATA (2009-2012)



Water Types and Methane Distribution vs. Elevation
CHK BASELINE DATA (2009-2012)

Methane and Well Depth

Ohio – West Virginia – Southwestern PA



Summary of Preliminary Findings

- Pre-drill sampling associated with unconventional shale-gas development provides regional information about natural occurrence and distribution of methane in groundwater
- Presence of methane in groundwater is not unusual
  - Detected in 29.1% of Baseline samples
  - In PA, 3.9% of samples exceed PA Action Level of 7 mg/L
  - In OH, 4.1% of samples exceed OH Action Level of 10 mg/L
- Occurrence of methane appears associated with:
  - Topographic position
  - Depleted sulfate (i.e., redox conditions)
  - Water type (esp. Na-HCO_3 and Na-Cl)
  - Higher concentrations of TDS, Na, Cl, Ba, Sr (regional variations)
  - Well depth (esp. OH-WV-SWPA)

Thank you!

Understanding Methane in Shallow Groundwater from Extensive Pre-Drill Sampling- AAPG 2013 Annual Convention and Exhibition, Pittsburgh, PA, May 19-22, 2013

John Boulanger, PG - AECOM
A. Elizabeth Perry, PG - AECOM
Bert Smith, PG - Chesapeake
Mark Hollingsworth - Chesapeake