# Engaging Angler Scientists in Methane Research: A Collaborative Approach

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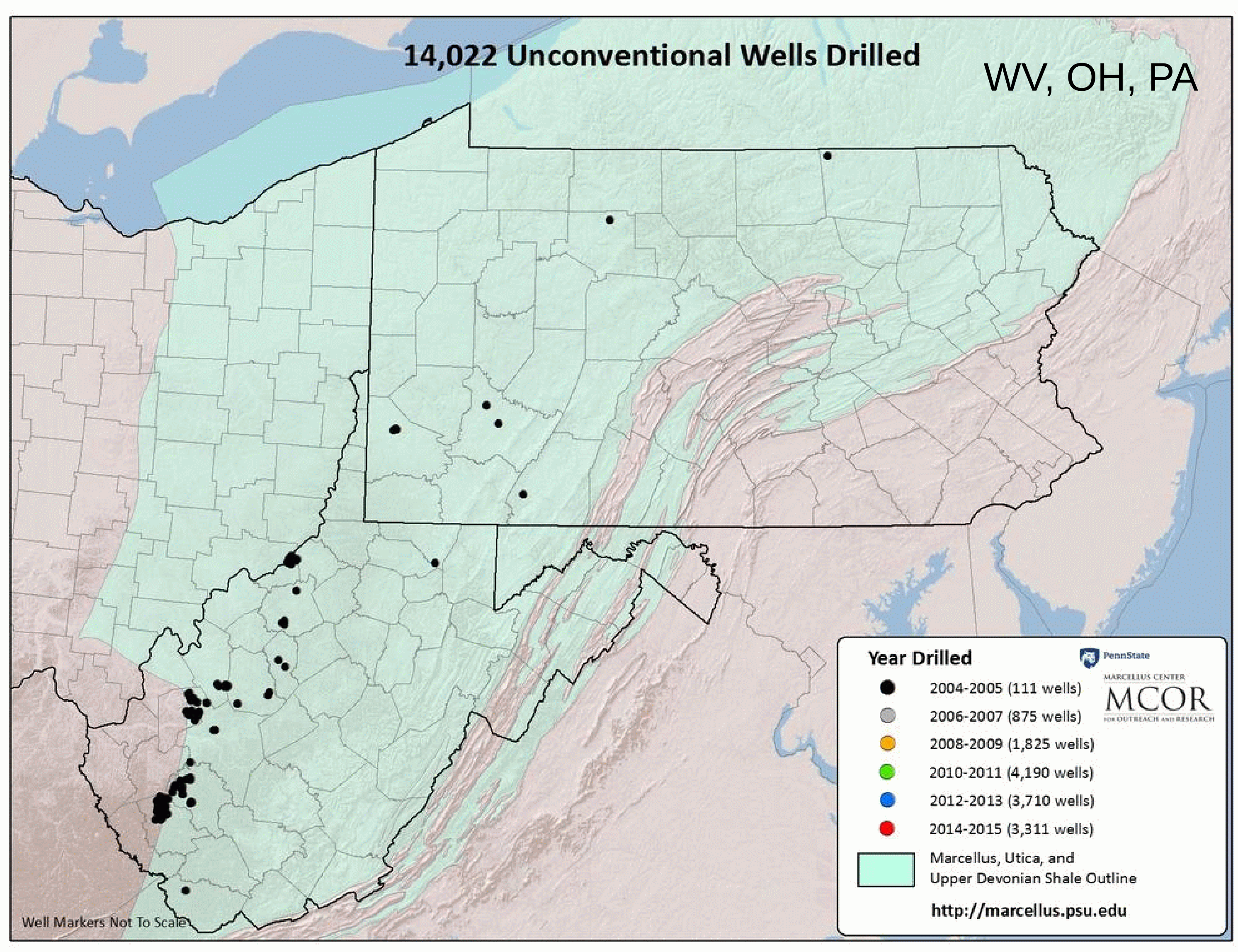
# Shale gas wells drilled in WV, OH, PA



# Gas: the most prevalently cited problem attributed to oil/gas development that has impacted water resources in PA

Photo of groundwater in Dimock PA, from StateImpact PA

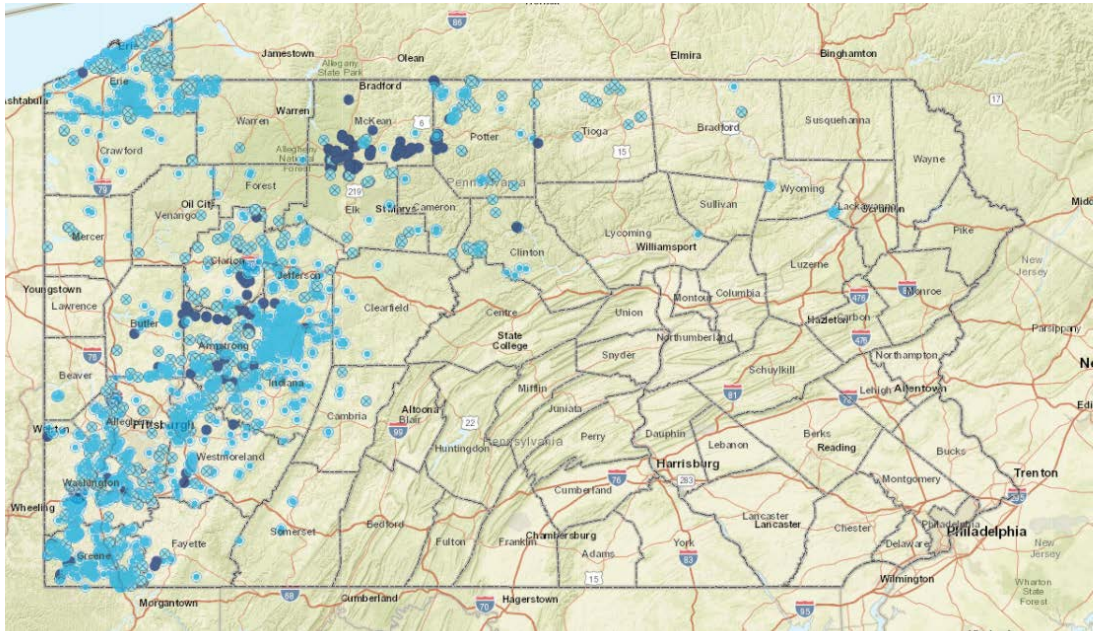

Photo of methane and groundwater spouting up in Tioga County after a shale gas well intersected a well abandoned in 1930s

# Why do we care about stray methane?

- Methane = main constituent of natural gas
- When released to atmosphere, $CH_4$ is a greenhouse gas
  - 26-38 times stronger then $CO_2$ when considered on a 100 year timescale
- $CH_4$ is an explosion hazard at high dissolved concentrations (>10 mg/L)
- $CH_4$ can change redox environments in natural systems, mobilizing metals (e.g. Fe, Mn, As) into groundwater

# Potential Methane Sources: Abandoned and Plugged gas wells

- Could be as many as 500,000 abandoned oil + gas wells in Pennsylvania
- May be improperly cemented, cased, or sealed.
- **Other Potential Sources of methane:**
  1. Biogenic
  2. Natural thermogenic
  3. Anthropogenic (shale gas development)

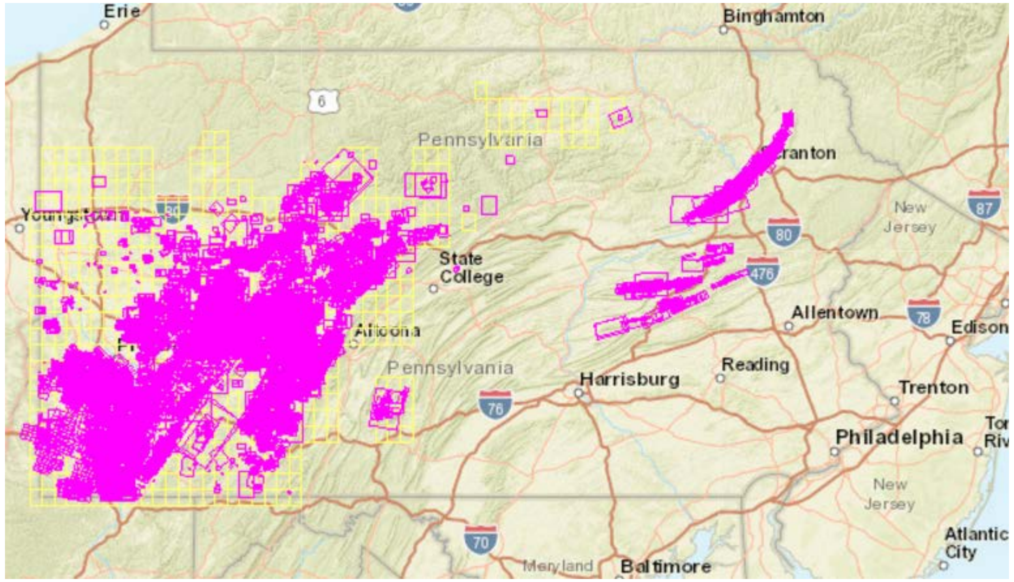



PA oil & gas mapping tool (Pa DEP)

# Potential Methane Sources: Abandoned Coal Mines

- 100,000 abandoned coal mine maps for Pennsylvania (**Patrick Jaquay- Pa DEP**)
- Estimated that 40-50% of these are flooded or partially flooded
- Flooded mines can discharge from natural seeps, mine tunnels, boreholes, etc.
- EPA assumes that **flooded** abandoned mines cease to emit methane after 15 years.

Acid mine drainage in Washington county, PA




PA Mine Map Atlas

# Trout Unlimited & Volunteer sampling

**PSU working with Trout Unlimited to monitor PA streams and engage citizens**

**Goals:**

1. Creation of inventory of background dissolved methane concentrations in streams statewide
2. Determination of whether stream methane concentrations can be used as indicators for sources of contamination
   - Emphasis on exploring if methane in streams can be a useful method for finding leaking unconventional gas wells
3. Engagement with citizen scientists on issues of water health and safety associated with this sampling technique
4. Understanding the effects of methane emissions into streams
5. Calculation of methane fluxes

TROUT UNLIMITED

# Trout Unlimited

TU's work to **protect**, reconnect, restore and sustain North America's coldwater fisheries and their watersheds.

48 chapters and 13,000 members in PA

400 chapters and 150,000 members nationwide

# TU Angler Science

Anglers gathering scientific information about the fish and the places they love

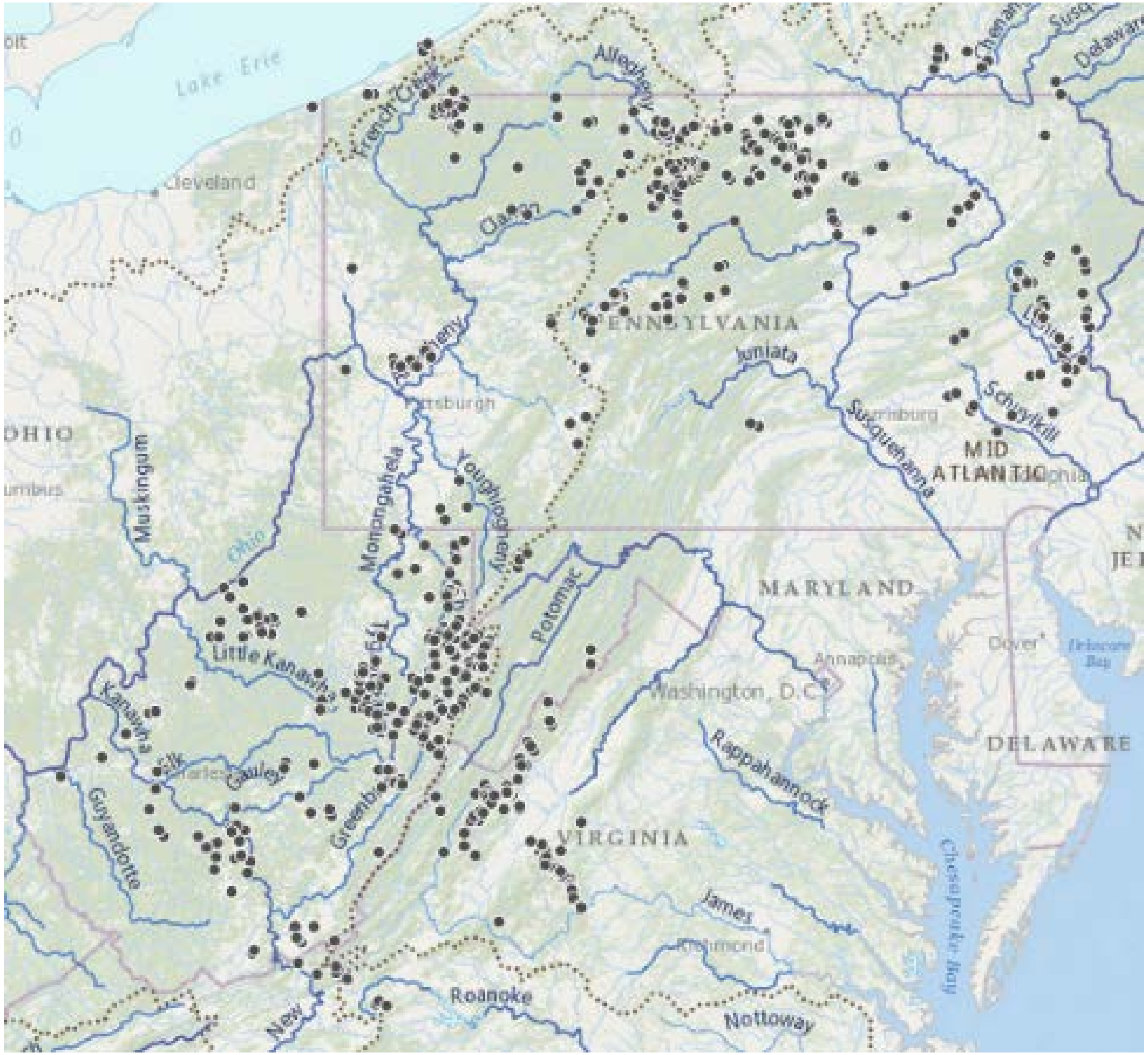

- Water temp and flow monitoring
- Water quality monitoring
- Tracking the spread of invasive species
- Tracking climate change impacts (water temperature, phenology)
- Documenting species presence (photographic and eDNA)
- Tracking development impacts
- Measuring restoration effectiveness
- Biological monitoring

# TU Eastern Shale Gas Monitoring Program

**Role of Volunteers:**

Collect **baseline data** in advance of construction.

Serve as eyes and ears on the ground, **identifying pollution events** if they occur and reporting them to the proper authorities.



# Volunteer Sampling Design

1. Individual volunteer engagement for single monitoring event or seasonal monitoring.
2. Chapter or watershed group engagement for regional monitoring effort.
3. Staff coordinated “watershed snapshot days”.

In the case of elevated methane concentration:

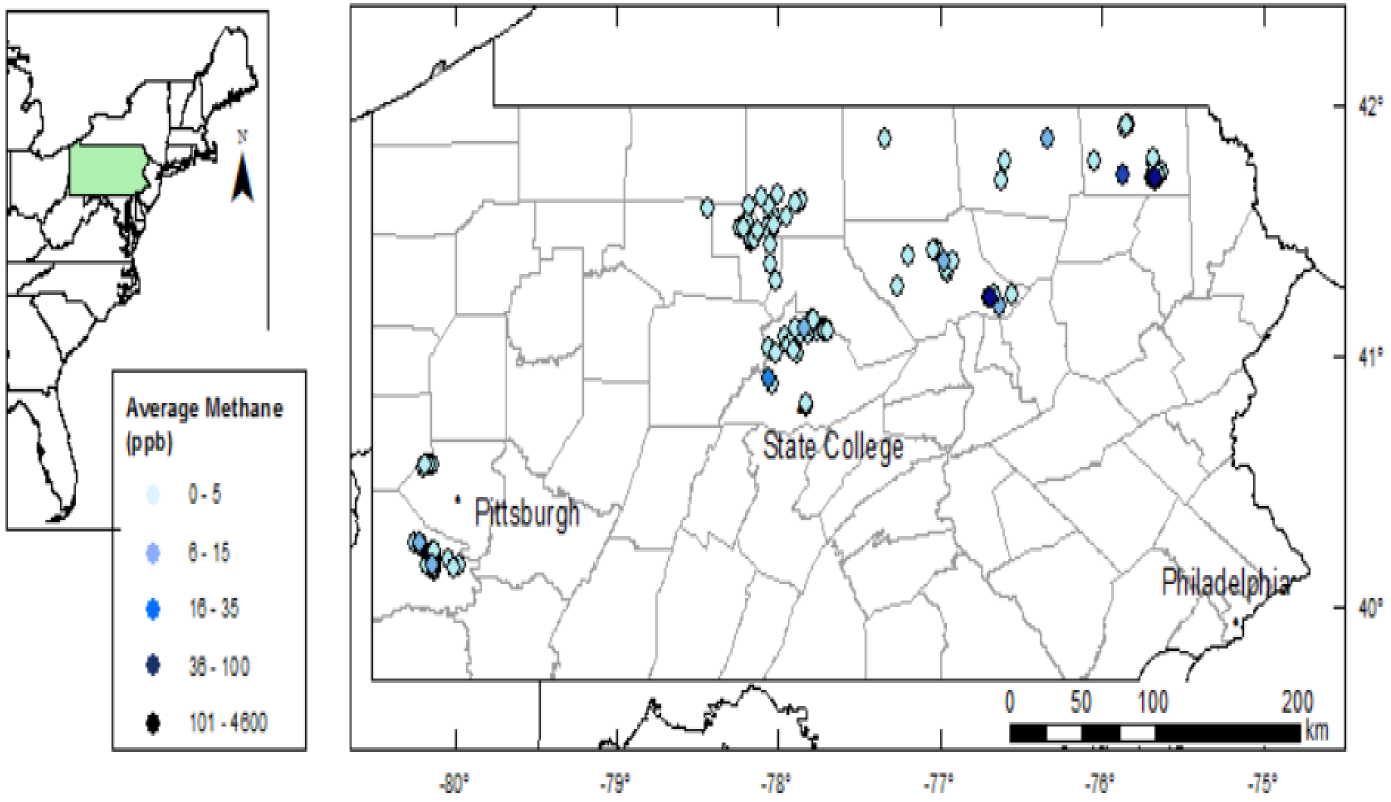
Repeat sampling with PSU Scientists and local volunteers to determine source of elevated $CH_4$

**Current sampling regions:**

1. Washington County
2. Moshannon State Forest
3. Erie County
4. Lycoming County
5. Monongahela National Forest

Snapshot day in West Virginia

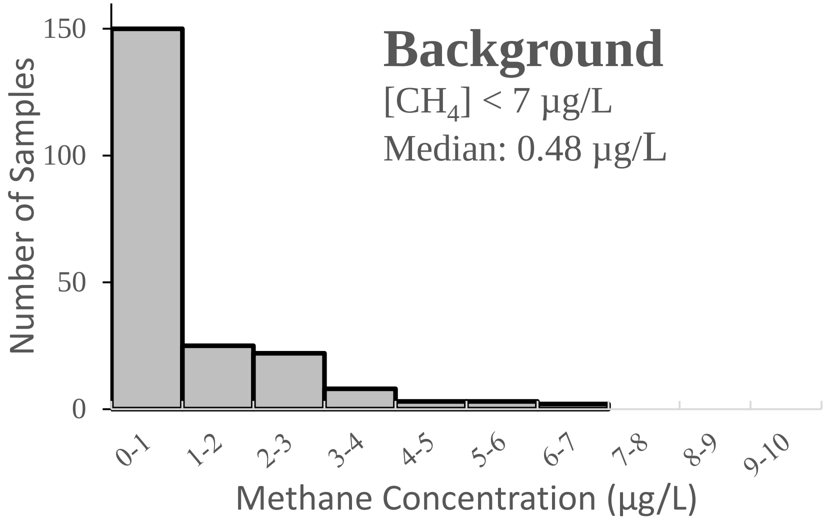
# Results: Initial Work (2015-2016)

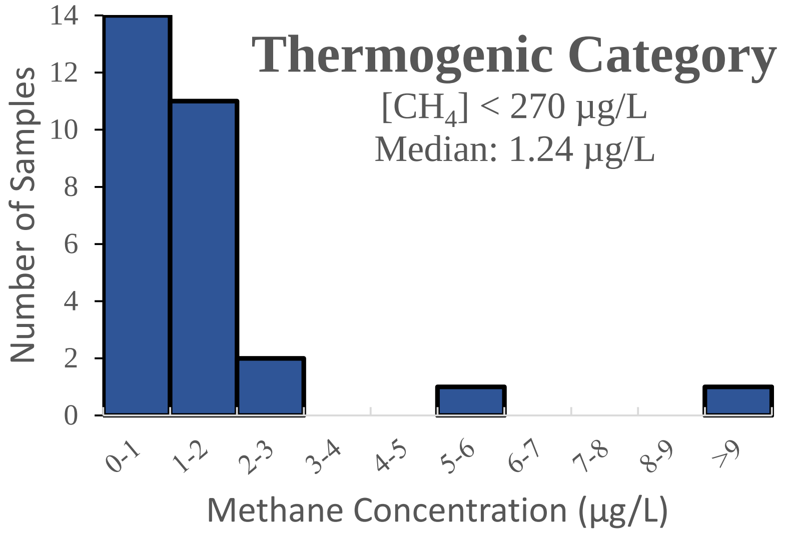


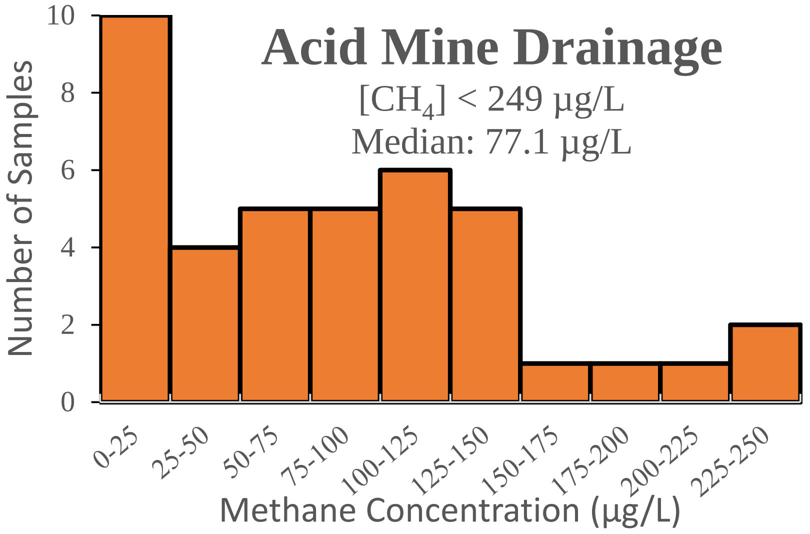

(Wendt et al., 2016, in Prep)

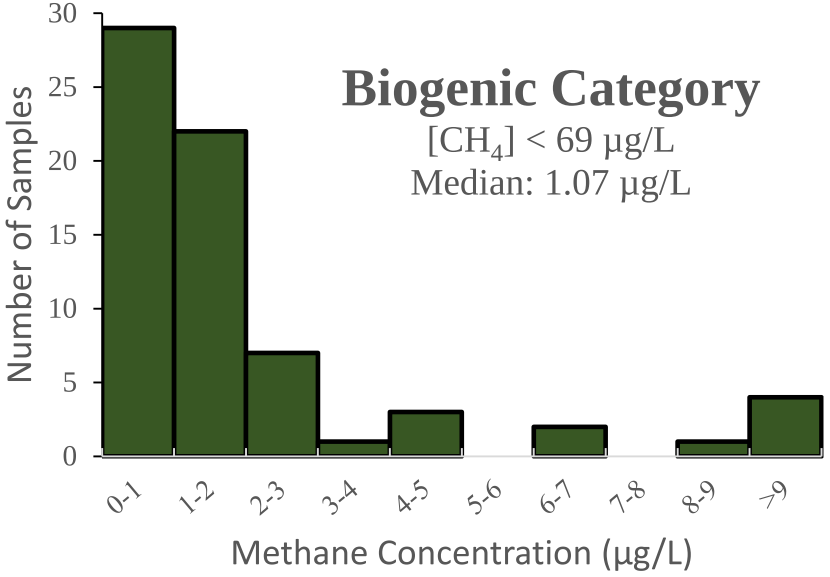
- Number of samples: 263
  - 155 Stream Sites
  - 40% of samples collected by volunteers
- Binned into four categories:
  1. **Biogenic:** (<30m from wetland)
  2. **Thermogenic:** (known fault/lineament and $\delta^{13}C$ in methane)
  3. **Anthropogenic:** (Possible leaking gas well)
  4. **Background**
- Median surface water $CH_4$ concentration is around **1 µg/L (ppb)**
- The maximum $[CH_4]$ in streams without known wetland, AMD or shale gas inputs **= 7 µg/L**

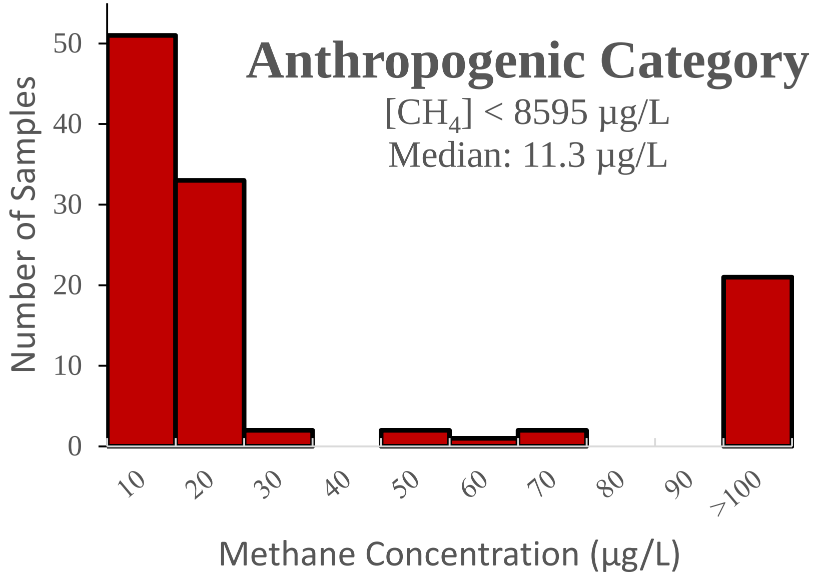
# Results: Stream Background Concentrations (2015-2017)




- Addition of 193 samples
- 59% collected by/with volunteers
- One snapshot day (West Virginia)
- New category (Acid Mine Drainage)

# Cases of elevated methane concentration

- **Case one:** Volunteer (Fred Zelt) in Pittsburgh collected samples with elevated methane concentrations (19.62 µg/L)
  - We sent him back to the site and his exploration lead him to *Acid Mine Drainage (AMD)* seeps coming into riverbed
- **Case two:** Volunteer in Moshannon state forest collected multiple samples with elevated methane concentrations from different locations (30-100 µg/L)
- In both cases Penn State researchers re-visted sites to determine source of elevated methane concentration

# Case one: AMD flux measurements and assumptions

- Assume all methane is lost to atmosphere (most likely some is consumed)

C *D= Flux

- C= Methane Concentration (dissolved)
- D = Discharge
- Flux= Flux to atmosphere (Kg/year)

# Presto-Sygan Seep (Washington County, PA)

- Methane Concentration: 227 (µg/L)
- Approx. Discharge: 420 GPM
- Flux: 189 kg/ year
- Cows: 2.1

# Gladding Seep (Washington County, PA)

- Methane Concentration: 115 (μg/L)
- Approx. Discharge: 1410 GPM
- Flux: 329 kg/ year
- Cows: 3.6

# Honey Pot Outfall (Near Wilkes Barre, Pa)

- Methane Concentration: 163 (μg/L)
- Approx. Discharge: 6,181 GPM
- Flux: 2,014 kg/ year – 2.2 tons/ year
- Cows: 22

# Old Forge (High Emitter) (near Scranton, Pa)

- Methane Concentration: 115 (μg/L)
- Approx. Discharge: 50,000 GPM
- Flux: 11,440 kg/ year – 12 tons/ year
- Cows: 127

Old Forge discharge into Lackawanna River

# Flux's from AMD seepages compared to Kang et al. (2014, 2016)

**Acid Mine Drainage**

**Number:** 10

**Mean:** 1,625 kg/ year

**Median:** 303 kg/year

**Max:** 11,440 kg/ year

**Abandoned gas wells (Kang)**

**Number:** 42

**Mean:** 98.55 kg/year

**Median:** 0.47 kg/year

**Max:** 3,066 kg/year

Total Pennsylvania anthropogenic methane emissions per year = 0.04–0.07 Mt ($10^{12}$ grams)

# Case Two: Follow up trip (1st find)

- Volunteer: David Matta (TU)
- Follow up trip led to venting plugged gas well and metal rich seeps

David Matta with Trout Unlimited: Picture of a “venting pipe” discharging water and methane into stream. Methane concentration of **discharge: 789 µg/L**

David Matta with Trout Unlimited standing next to “plugged” gas well

# Case Two: Methane & metal rich seeps (2nd find)

- Source of metal rich seeps remains unclear. Chemical analysis for inorganic anions and cations are not consistent with AMD
  - Low dissolved sulfate/nitrate and elevated dissolved Mn/Fe
  - **Gas well seepage?**

Metal rich seep along Laurel Run in Moshannon State Forest, PA (Dissolved methane concentration **= 337.55 μg/L)**

# Conclusion: What has been learned from stream sampling?

- Technique has helped characterize background methane concentrations in Pennsylvania streams
  - The maximum [$CH_4$] in streams without known wetland, AMD or shale gas inputs **= 7 μg/L**
- Technique was successful in finding one site of likely methane leakage from a shale gas well (Sugar Run)
  - Since then, no new leakages from unconventional gas wells have been identified
    - Methane oxidation, degassing, and dilution may mask thermogenic methane quickly
    - For best results: small, first order, easily accessible streams are optimal
- Technique successfully identifies “coal mine seepage” sites with high methane
  - Acid mine drainage site may be emitting significant quantities of methane to atmosphere
  - **Gas well seepage?**

# Future Plans

- Snapshot days in Pine Creek Watershed and Allegheny National Forest
  - Areas of new and old development for both oil and gas resources
- Encourage TU volunteers to keep an eye out for metal seepages
  - Trout Unlimited will conduct outreach through member newsletters and email.
- Continue sampling AMD discharges to try and understand methane concentration changes spatially and temporally from these discharge points

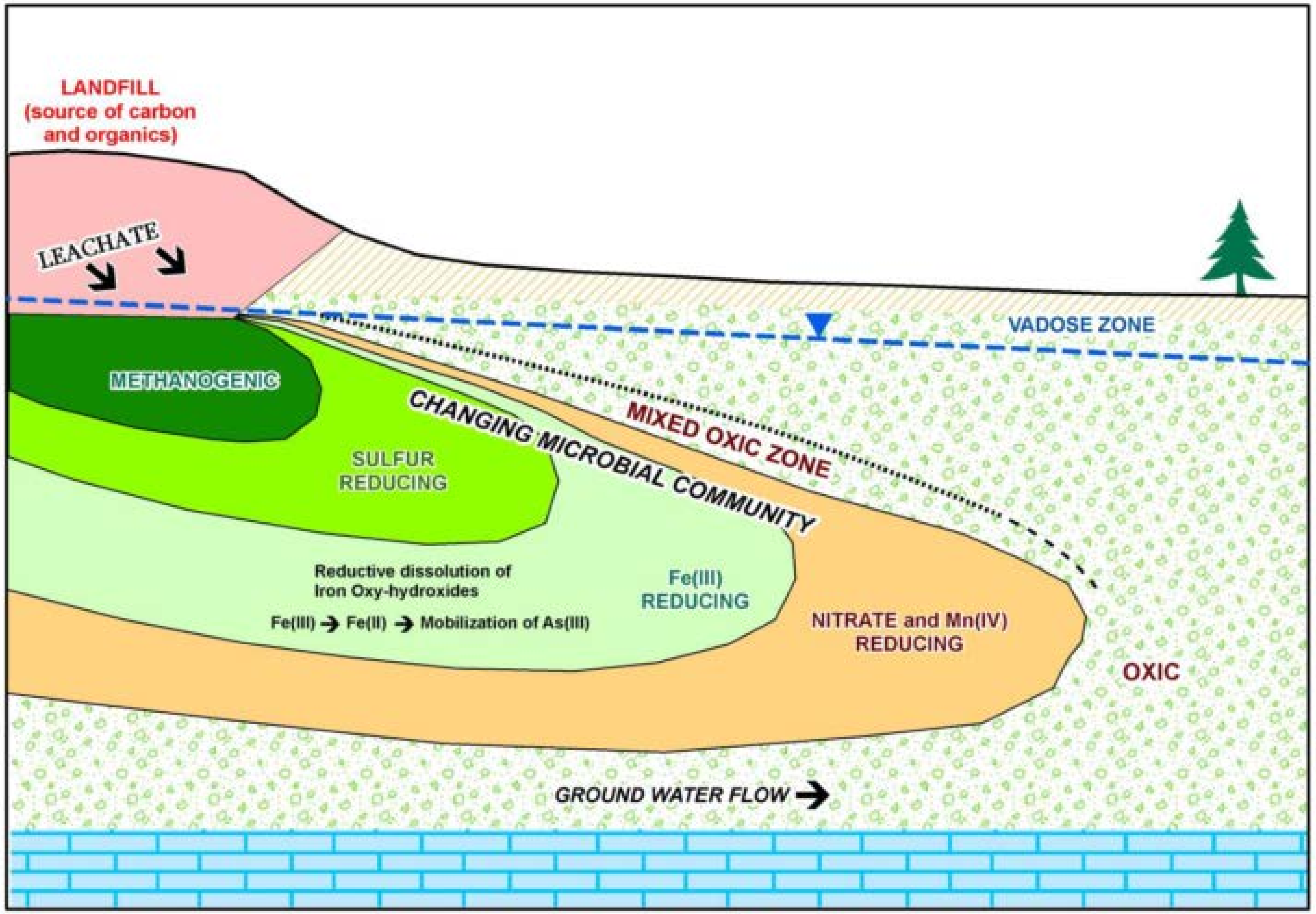
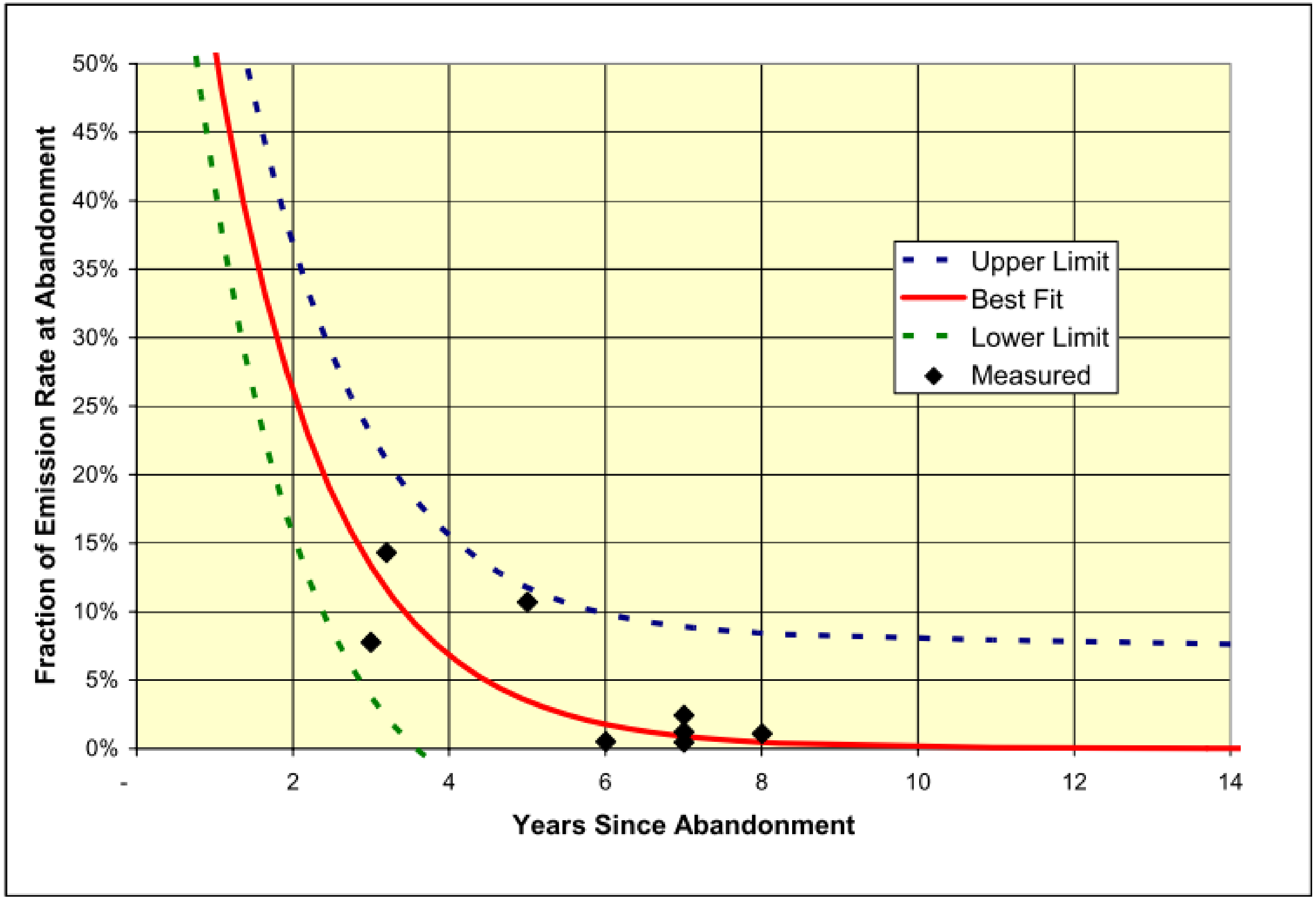


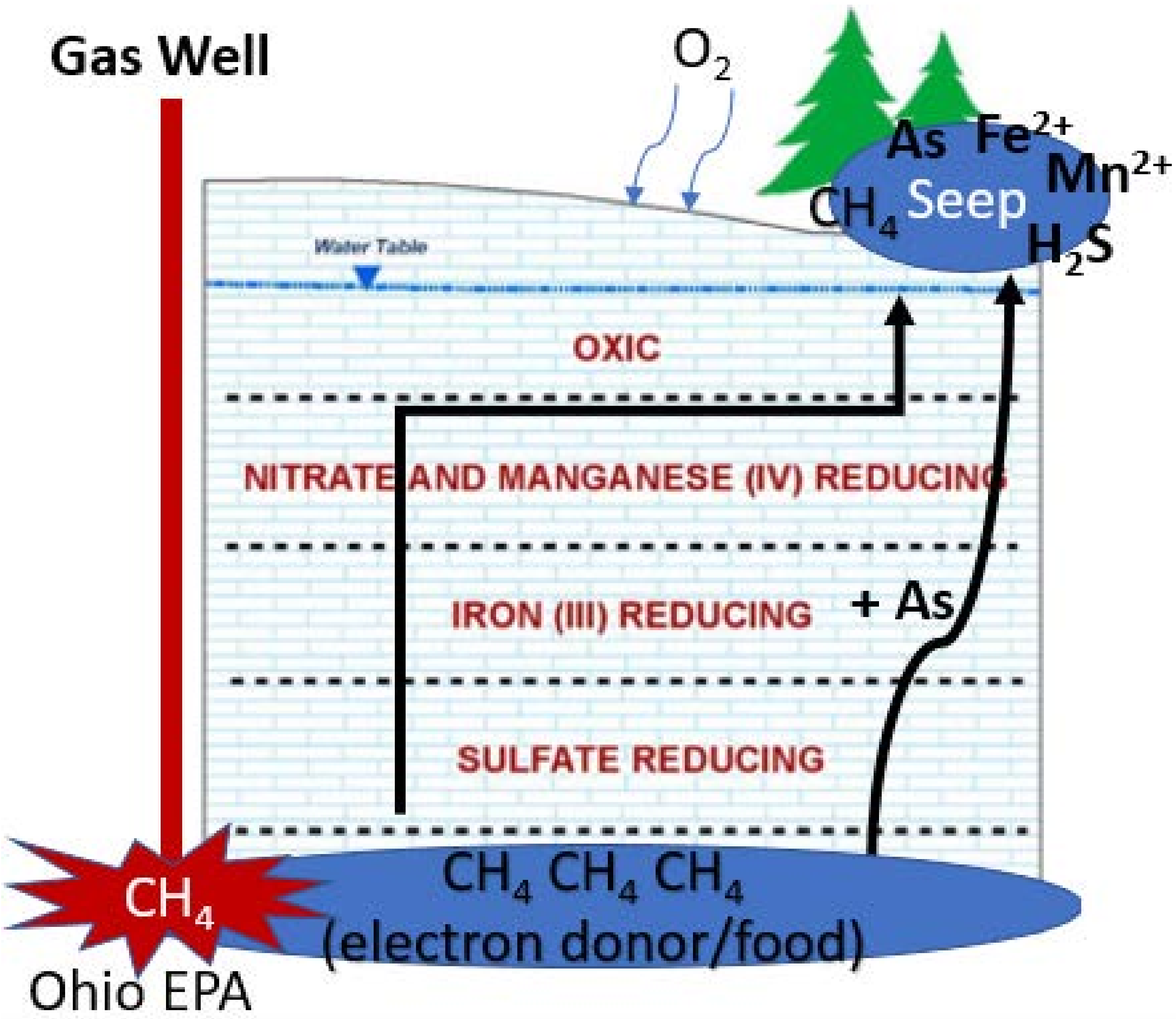

Figure 8. Redox zonation resulting from leachate input to local ground water from an unlined landfill cell.

Ohio EPA

**Figure 10. Emission model for abandoned flooding mines**




EPA, 2004


Gas Well
$O_2$
As $Fe^{2+}$
$Mn^{2+}$
$CH_4$ Seep
$H_2S$
Water Table
OXIC
NITRATE AND MANGANESE (IV) REDUCING
IRON (III) REDUCING
+ As
SULFATE REDUCING
$CH_4$
$CH_4$ $CH_4$ $CH_4$
(electron donor/food)
Ohio EPA