U.S. DEPARTMENT OF ENERGY
Fossil Energy and Carbon Management

# FINDING UNKOWN ORPHAN WELLS

## DOE Fossil Energy Carbon Management
## Undocumented Orphaned Wells R&D Program

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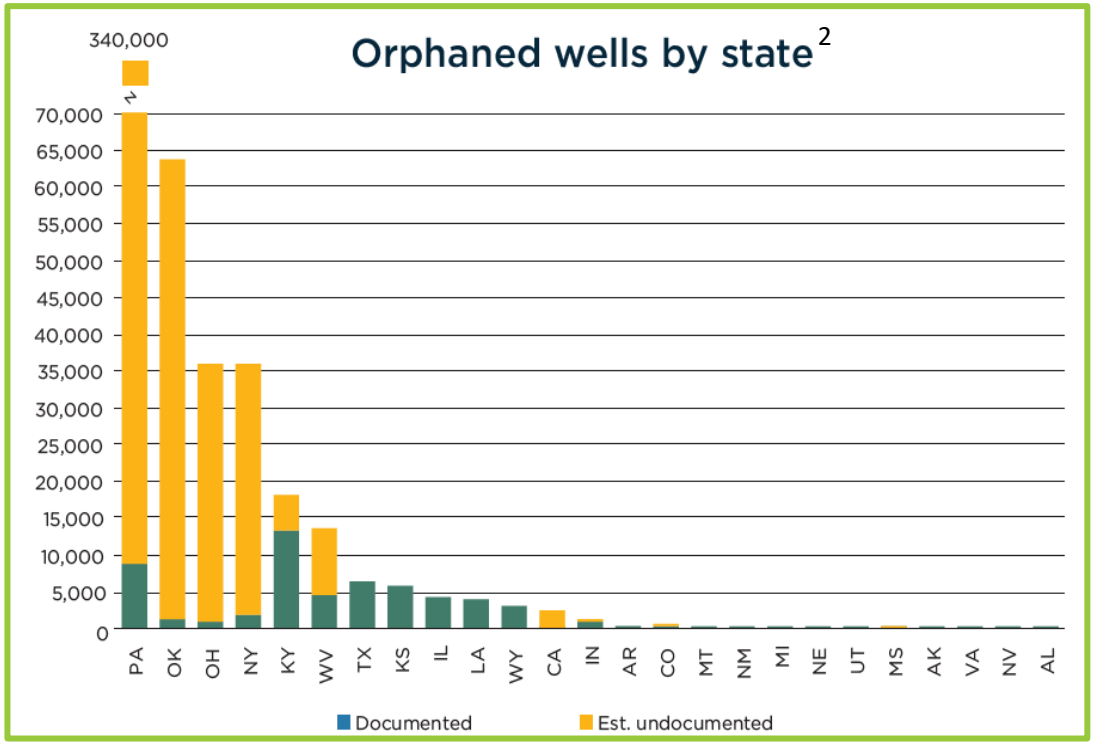
*Pictures Source: PADEP*

# Motivation for Undocumented Orphaned Well R&D

- It is estimated that there are hundreds of thousands of undocumented orphaned wells leaking methane in the U.S. that need to be located.[1]
  - The total estimated number of undocumented orphaned wells reported by the states is between 310,000 and 800,000.[2]
  - Per the EPA, there are 2M unplugged and abandoned wells in the U.S. (which includes orphaned wells).[3]
- **$4,700M Available to DOI/BLM/States/Tribes**
  - **$2,350 - $23,500 BIL funding per well**
  - **21,000 – 200,000 wells/year over 10-year timeline**
    - **100's to >10,000 wells/year, depending on state**
- **Current State of practice: <50 well/year (NM), ~500ish wells/week nationwide.**



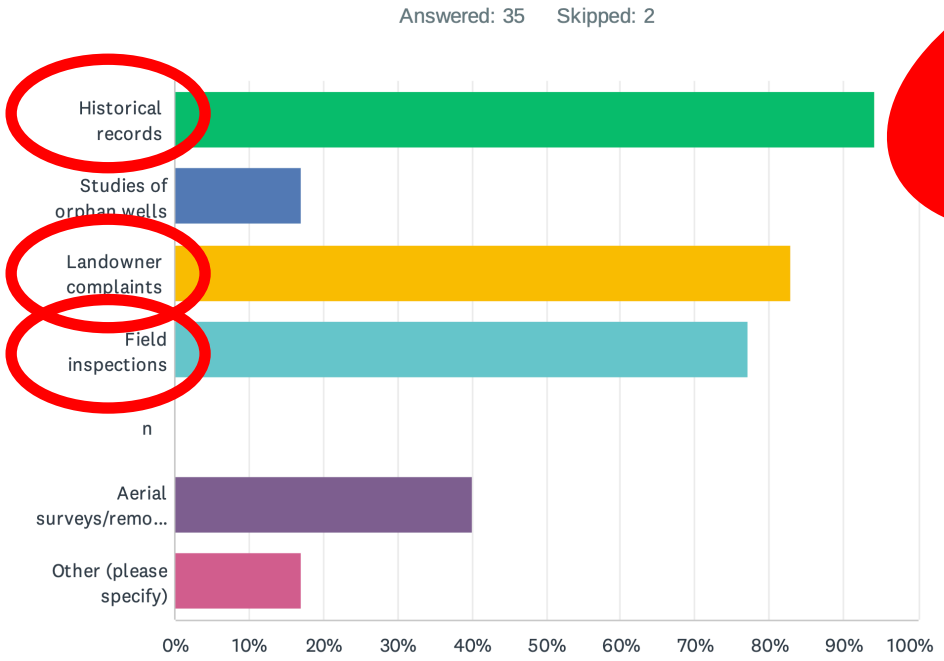

**DOE Products/Framework need to upscale current decisioning by factor of 40-400x to fully meet expected needs.**

[1] Management of Abandoned and Orphaned Oil and Gas Wells, The American Association for the Advancement of Science; [2] IDLE AND ORPHAN OIL AND GAS WELLS: STATE AND PROVINCIAL REGULATORY STRATEGIES 2021, IOGCC, December 2021, https://iogcc.ok.gov/idle-and-orphan-oil-and-gas-wells-2021; [3] Wright, B., Hide and Seek: The Orphan Well Problem in America, Journal of Petroleum Technology, August 2021

# IOGCC Survey Responses

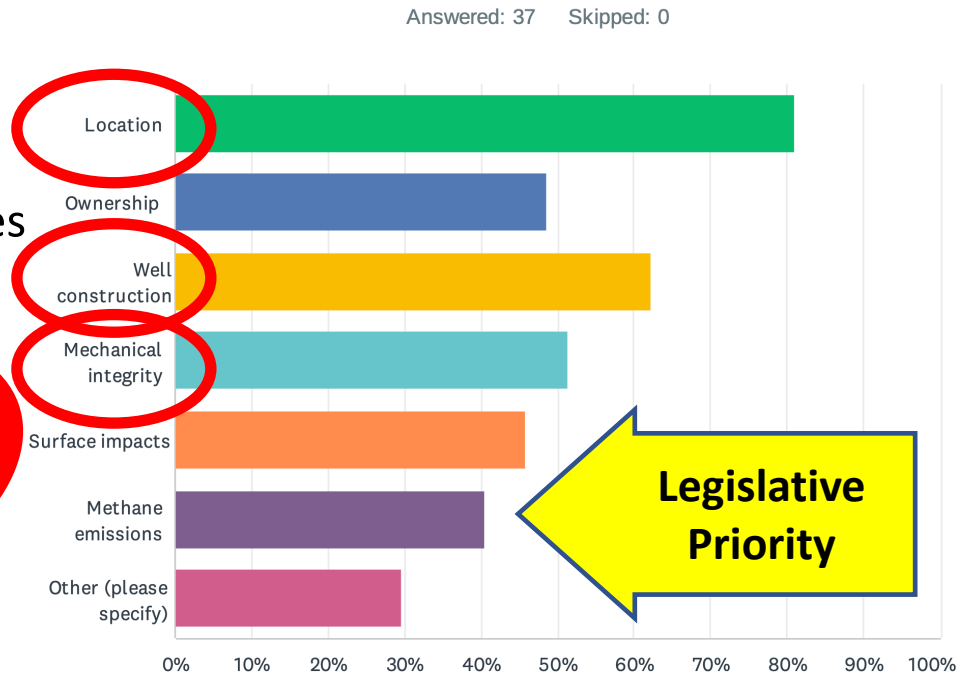
- 37 respondents representing 30 states
- 70% indicated “moderate” or “low” priority -> constrained resources

Q5 What approach/methods has your state been using or contemplated using to identify undocumented orphan wells?




Top Three Responses

Q4 What are your state's biggest data needs/gaps relative to undocumented orphan wells?




Legislative Priority

**State of Practice**

- Labor intensive, largely non-technical
- Where is it? What’s the state of health?
- Varying local constraints on inspection (e.g. Idaho’s no-drone laws)

# Challenges of Identifying & Characterizing UOWs

## Hurdles to Identification & Characterization

- Location and/or ownership records could be a complete unknown.
- Casing could have been removed (WWII efforts).
- Surface equipment could be overgrown.
- Surface equipment could be removed with subsurface equipment still in place.
- Modern structures could be concealing location.
- Wellbore integrity could be compromised.

Images courtesy of Range Resources Corp.

## Methods for Identification & Characterization

- Review of historic production and documents
  - Georeferencing and digitizing
- Desktop studies that include:
  - Soil and Bedrock Geology
  - Anthropogenic Features
  - Surface Cover
  - Water Table & Water Well History
- Ground-based and aerial surveys
  - Electromagnetic Induction
  - Ground penetrating radar
  - Resistivity Tomography
  - Seismic Refraction Tomography
  - Excavations
- Aerial surveys
  - Magnetometer
  - Gravimetry

# DOE Undocumented Orphaned Wells Program Priorities

- Methane Detection and Quantification
- Well Identification
- Sensor Fusion and Data Integration with Machine Learning
- Well Characterization
- Integration and Best Practices


**Consortium Advancing Technology for Assessment of Lost Oil & Gas Wells.**

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# Methane Detection and Quantification Activities

- Quantitative measurement of UOW methane emissions
- Backpack-based and drone measurements
- Used before and after P&A data
- Validates effective P&A
- Provides DOI with important metric of impact of program
- Applies to both undocumented and documented P&A programs

**Need: states and other stakeholders currently lack a rapid method for measuring methane emissions and robust methods for pinpointing leaking undocumented orphan wells**

Backpack Gas analyzer used to locate methane point sources (credit: Sebastien Biraud, LBNL)

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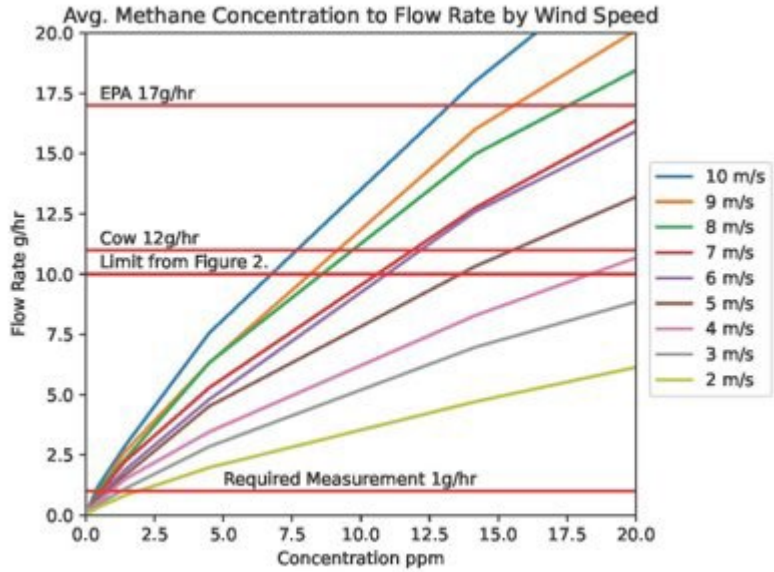
# Methane Detection and Quantification Activities

White Paper: **How to estimate O&G well leak rates from near field concentration and wind observations?**

- Use direct/fast CH4 and wind measurements downwind with compact sensors to infer mass flow rate.
- Gaussian plume dispersion models was used to derive fluxes from concentrations and wind speeds and identified challenges at small scales (< 10m).
- We are coordinating controlled experiments/simulations doe UQ and develop Machine Learning inverse methods




**Need: Using plume modeling, compact gas detector and anemometer, one can make reasonable cost-effective methane emission rate measurements to prioritize well plugging .**

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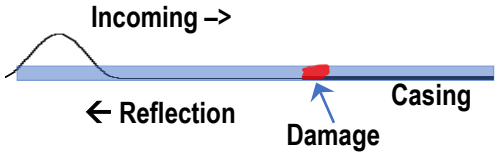
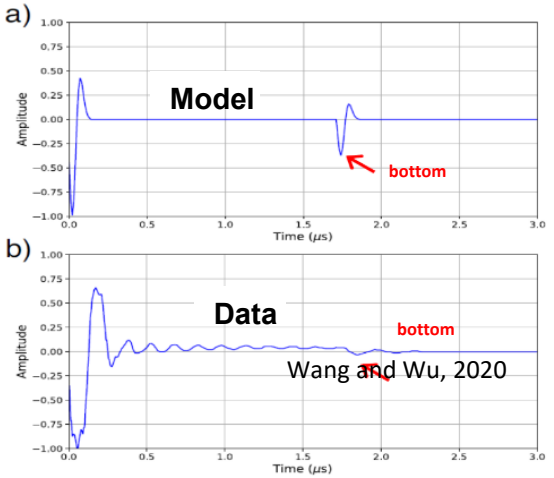
# Well Identification Activities: Electromagnetics (EM)

- Electromagnetic—time domain reflectometry
- Guided EM wave traveling along steel casing. Reflections are generated when features (e.g., wells) are encountered.
- Methods to differentiate between orphan wells, active wells and other metal features


Oil and gas well in California Central Valley




$$\Gamma = \frac{V_{reflected}}{V_{incident}} = \frac{Z_d - Z_0}{Z_d + Z_0}$$




Wang and Wu, 2020

**Need: Detect wells with drones, surface measurements and aerial surveys**

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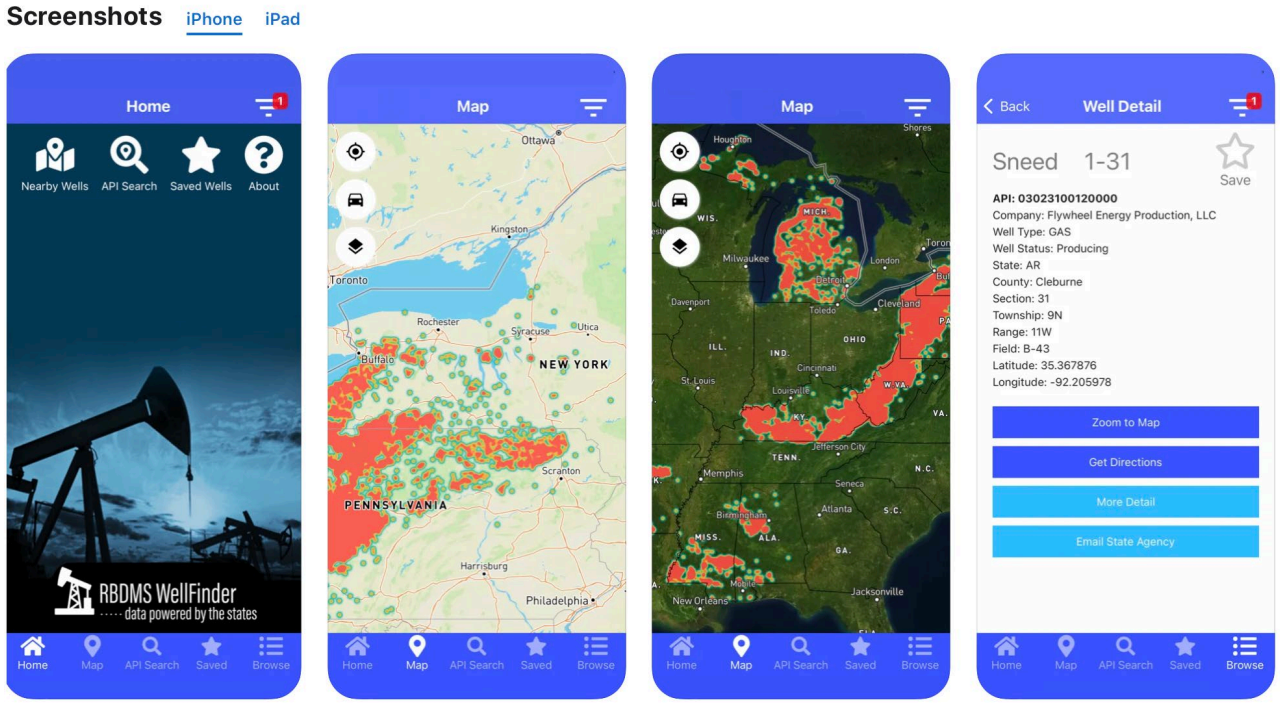
# Well Identification Activities: Well Finder App

- Well finder App
- Prior DOE  investment/experience with geo-location
- Add to this preliminary geophysical reconnaissance
- magnetometry
- Lidar
- Expands the workforce
- Public engagement/outreach/education




**Need: Smartphone data collects to log undocumented orphan wells**

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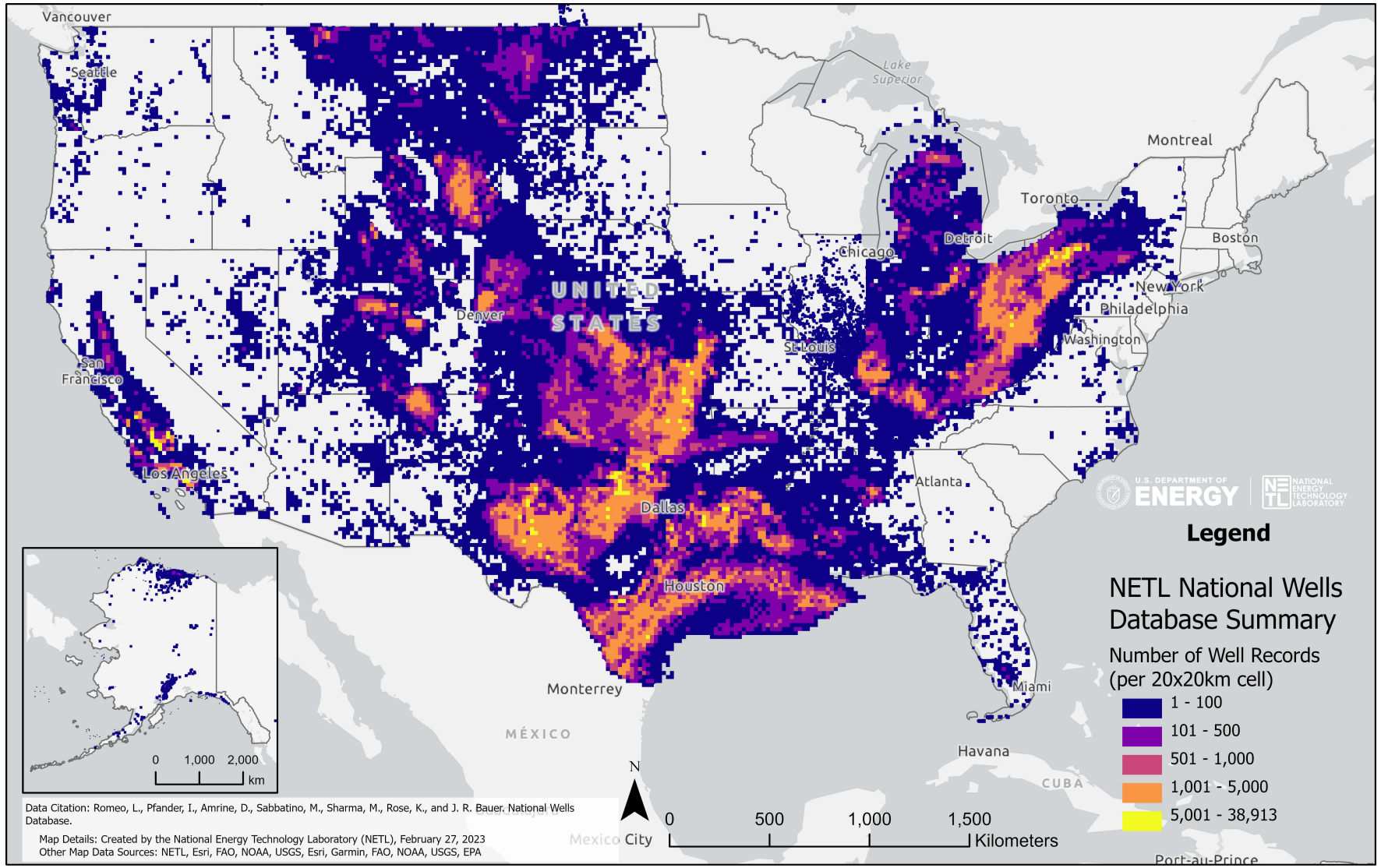
# National Wells Database




## Sources

- States
- Tribes
- Private
- DOI
- GWPC
  - Well Finder App
- NGOs

## Attributes

- Comparison and ranking via sources etc.
- Evergreen
- Tag back to managing agency.
- Framework for additional well data

# Sensor Fusion and Data Integration with ML

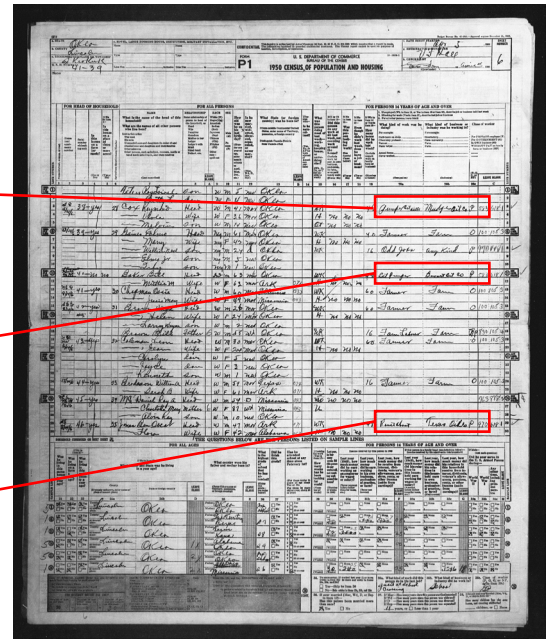
- Automate georeferencing of maps and photographs.
  - Aerial photos 1930s to 1980s
- Utilize advances in ML (ChatGPT, etc.) to extract usable data from documents.
  - Mapping petroleum-related occupations to census township.

**Need: Automatically extract data in tabular and georeferenced form.**

Oil field pumper for Mudge Oil Co.

Oil field pumper for Bavart Oil Co.

{illegible occupation} for Texas Oil Co.



1950s census. PDF of handwritten records

1937

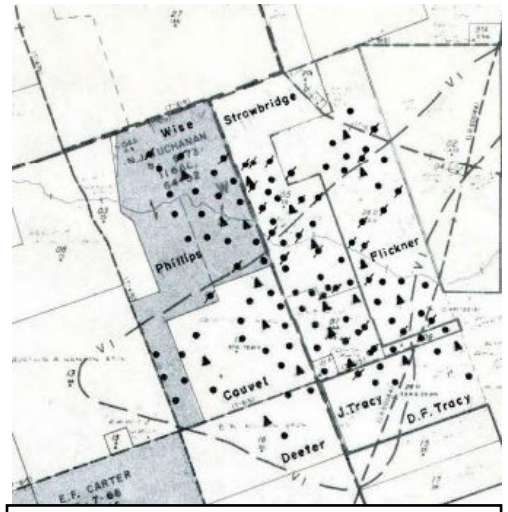
1954

1961


Aerial photos organized by township and range

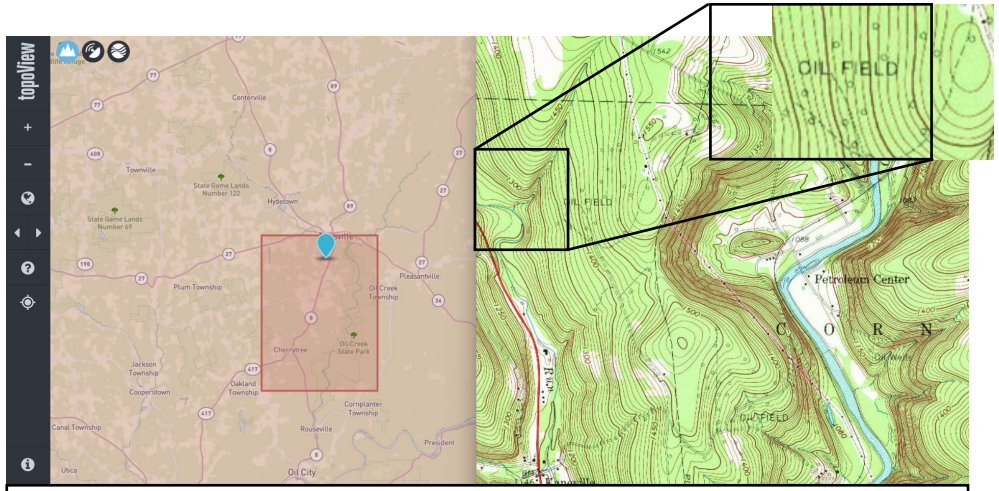
# Sensor Fusion and Data Integration with ML

- Utilize ML to extract wells and well associated signals.
  - Multi-modal signals from different mappable features.
  - Provides a basis for collecting additional data in the field (magnetometer etc.).

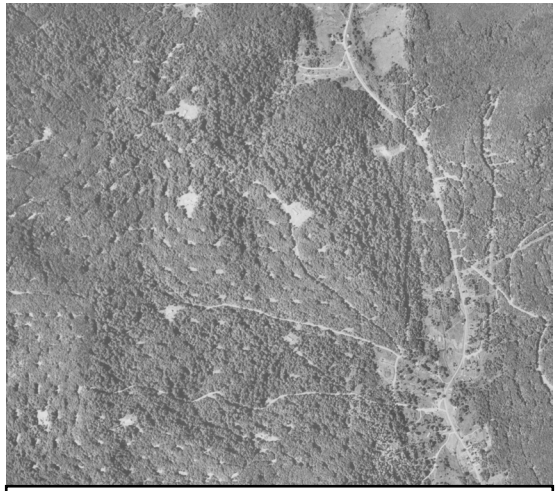



Farm Line Maps

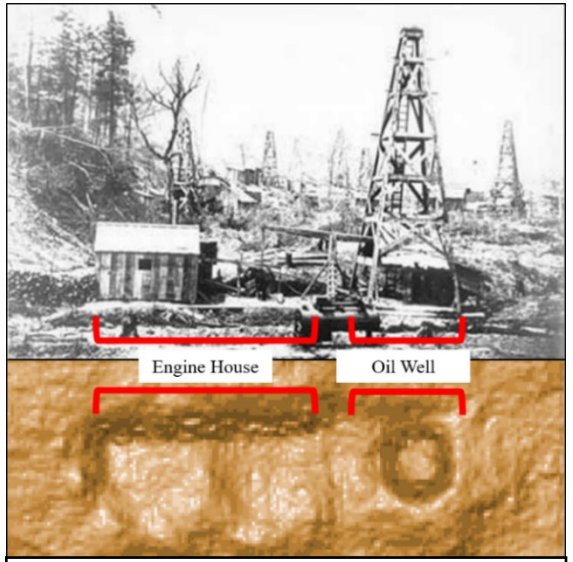
**Need: extract useful information out of layers of noisy data.**




USGS Quadrangle Maps



Aerial Photography




LiDAR Data

# Integration and Best Practices Activities: Data Integration

- Develop tools and techniques to standardize data and records for integration into a common framework
- Develop methodology for extracting information from records
- Provide a portal for uploading records


Lewis Evans map, 1755, http://hdl.loc.gov/loc.gmd/g3710.ar071000

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# Integration and Best Practices Activities: Field Demonstration

- Establishment of multiple test sites
  - Evaluating and demonstrating geophysical well location methods
  - Evaluating and demonstrating methane emissions measurement techniques
  - Training of Stakeholders in well finding and characterization approaches
  - Certifying competency of well location operators
- National labs focus on broad geographical coverage


**Need: Looking for areas to test new/refined approaches for well finding, characterization, and emissions measurements need to be tested and verified in the field at a range of orphaned well types and geologies.**

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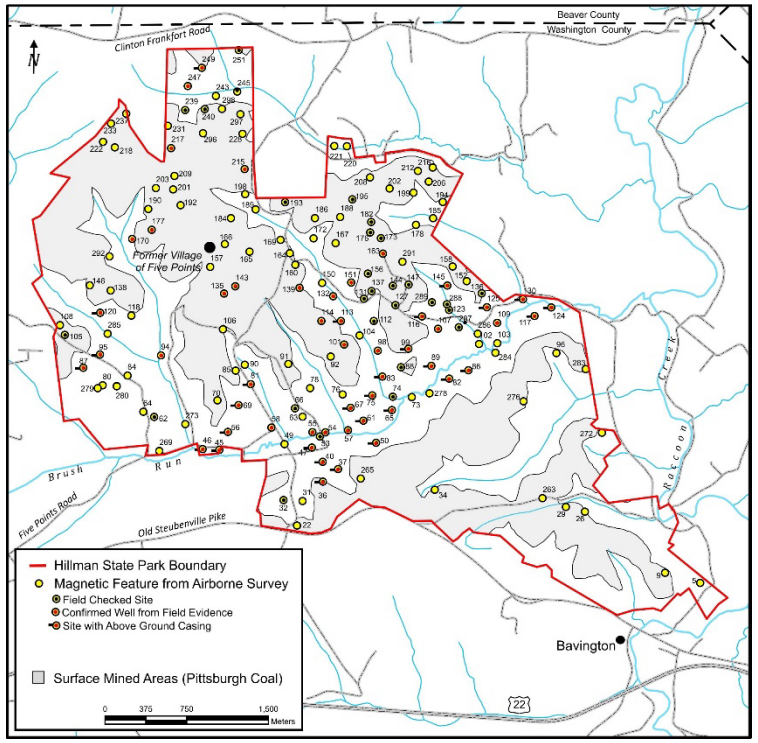
# Integration and Best Practices Activities: Field Demonstration

- First field demonstration site:  Hillman State Park, PA
  - 3,600–acre public lands with ~190 wells, most undocumented
  - NETL and partners have conducted aerial magnetic surveys at the park starting in 2014 (manned helicopter and drone)
  - Methane emissions measured from 31 wells
    - High flow sampling, optical gas imaging, flux chambers, continuous monitoring
  - Variety of well types: buried, open hole, open casing cut off at grade, intact well head, etc.
  - Suitable for ground-based or terrain-draped drone geophysical surveys




**Need: Previously characterized field demonstration site allows testing and demonstration of new/refined technologies against proven methods.**

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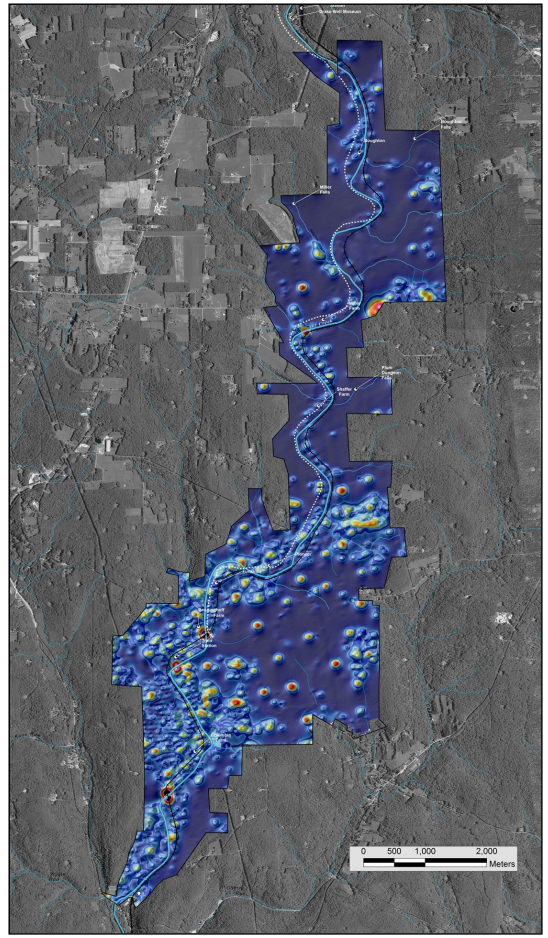
# Integration and Best Practices Activities: Magnetic Surveying

- Technology transfer - Sharing recommendations and guidelines based on a decade+ of magnetic surveying experience
- Provide a best practices guidance document for use of magnetic surveying to find UOWs
  - Ground-based and drone-based
  - Survey design parameters
    - Grid design and spacing
    - Height above ground
    - Magnetometers
    - Speed of drone
  - Relative to well density, terrain, expected success rate




**Need: Stakeholders need effective mitigation strategies.**

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# Questions

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