

HEI STATEMENT

Synopsis of Research Report 243

Potential Groundwater Vulnerability to Spills Associated with Unconventional Oil and Gas Development Across the Marcellus Region

BACKGROUND

Over the past two decades, unconventional oil and gas development (UOGD)* has allowed for a significant increase in oil and gas development across the United States.

UOGD-related releases to groundwater and surface water may occur under accidental conditions (e.g., spills). Thus, their potential for groundwater contamination has garnered much public concern, especially in the Marcellus region where there is considerable UOGD alongside populations that rely heavily on private wells for domestic water. However, understanding remains limited regarding how UOGD releases to groundwater and surface water could lead to population exposures through contaminated water.

Dr. James E. Saiers at the Yale School of the Environment and colleagues — Drs. Mario Soriano Jr., Joshua Warren, and Reed Maxwell — developed a groundwater modeling approach to improve our understanding of the potential for documented UOGD spills in the Marcellus region to adversely affect water quality that may lead to population exposures. Their study was funded through HEI Energy's Request for Qualifications [RFQ E23-2: Regional Groundwater Modeling to Understand Community Exposures Associated with Oil and Gas Development](#).

APPROACH

Saiers and colleagues developed a modeling approach to evaluate the vulnerability of groundwater wells to potential contamination from spills associated with UOGD well pads in the Marcellus region states of Ohio, Pennsylvania, and West Virginia. They also sought to evaluate potential associations between their estimates of well water vulnerability and UOGD-related chemical fingerprints, indicating potential contamination from UOGD.

What This Study Adds

- This study provides a modeling approach to estimate groundwater vulnerability of well water to potential contamination from spills associated with UOGD in the Marcellus region.
- The team found that up to 122,000 people who rely on domestic water wells live in locations where groundwater is vulnerable to such contamination.
- The team collected data on documented UOGD spills in the region and well water chemistry. They evaluated associations between their estimates of vulnerability of well water and the occurrence of chemical fingerprints resembling UOGD-produced waters in groundwater-supplied well water samples.
- The team found higher odds of detecting chemical fingerprints of UOGD in well water samples in areas that were classified as vulnerable to documented spills from well pads. This finding suggests that domestic water wells might be vulnerable to potential chemical contamination from UOGD.
- This study provides an important contribution to our knowledge of the locations of groundwater-supplied wells most vulnerable to UOGD spills. The modeling framework and datasets can inform decision-making related to water quality and UOGD, including potential setback distances from drinking water sources and spill investigation.

For the modeling approach, the investigators combined a two-dimensional physics-based groundwater flow model with a particle-tracking algorithm to simulate the transport trajectories of contaminants through groundwater in the region following their release from a UOGD well pad. They performed multiple model simulations and integrated the results to generate estimates of well water vulnerability

This Statement, prepared by HEI Energy, summarizes a research project funded by HEI Energy and conducted by James E. Saiers at the Yale School of the Environment and his colleagues. Research Report 243 contains the detailed Investigators' Report and a Commentary on the study prepared by the HEI Energy Review Committee.

*A list of abbreviations and other terms appears at the end of this report.

throughout Ohio, Pennsylvania, and West Virginia. The estimates consisted of the probability that a potential contaminant associated with a UOGD spill would reach a groundwater-supplied domestic well across model simulations. The investigators defined “high vulnerability” as a vulnerability estimate greater than 0.5 (the level of agreement among the model simulations that the area lies in the path of contaminants released from a UOGD well pad).

Well water vulnerability estimates were computed to evaluate two scenarios: (1) all UOGD well pads in the region ($N = 25,617$), and (2) a subset of UOGD well pads in the region with documented spills ($N = 1,761$), using data collected from state repositories. Subsequently, the investigators calculated the potentially vulnerable land area and population for both scenarios. They also aggregated their estimates to various geographic scales to explore potential spatial clustering in the region.

Next, Saiers and colleagues used publicly available water quality data and statistical models to evaluate associations between chemical fingerprints of UOGD spills and their groundwater vulnerability estimates. They collected information on over 27,000 groundwater-supplied well water samples across the three states, of which over 16,000 could be included in their statistical models. They adjusted their models to control other factors potentially associated with UOGD-like chemical fingerprints, such as geologic features (e.g., folds, faults), topography, and the presence of nearby conventional oil and gas well pads.

KEY RESULTS

Saiers and colleagues found that the average distance of a potential contaminant’s trajectory from a well pad was 671 m, and that most estimated travel distances were not greater than 2 km. Nonetheless, estimated distances generally exceeded regulatory setback distances between UOGD and wells supplying drinking water in Pennsylvania, Ohio, and West Virginia.

They estimated that the total land area vulnerable to potential contamination from spills from all UOGD well pads (scenario 1) in the region was around 3,600 km². The investigators were able to find and compile 3,853 documented spills from UOGD wells across the three states; however, due to missing information, only 1,761 spills were included in the analysis (scenario 2). For this second scenario, the estimated total land area vulnerable to groundwater contamination was approximately 600 km².

The investigators found that as many as 122,000 people who rely on groundwater wells for domestic water live in locations that are potentially vulnerable to contamination under scenario 1, which considers all

UOGD well pads. This estimate amounts to about 3% of the 3.9 million people who use domestic wells within the Marcellus region. For areas with documented UOGD spills, 22,000 people live in locations that were estimated to be highly vulnerable to contamination of their water wells. When aggregated to areas of about 30 km, the investigators observed spatial clusters of high vulnerability to groundwater contamination throughout Northeastern Pennsylvania, Southern West Virginia, and the area where those two states meet with Ohio (**Statement Figure**).

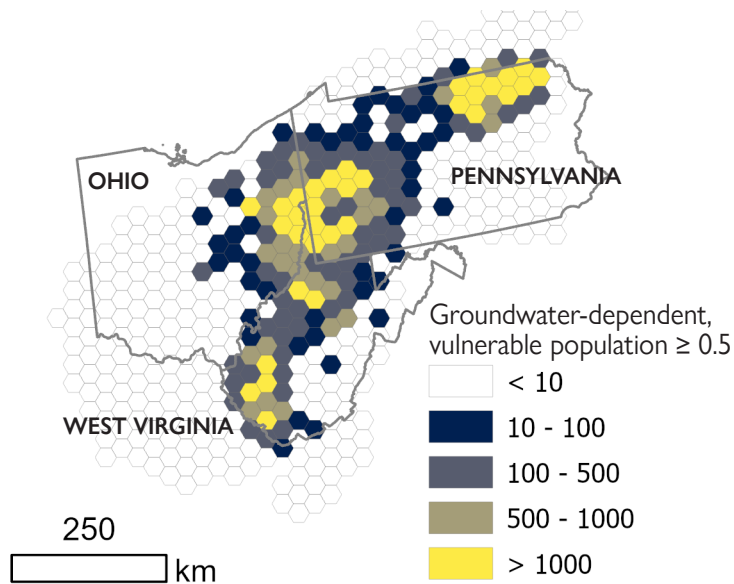
In areas with documented UOGD spills, Saiers and colleagues found positive associations between estimated well water vulnerability and the odds of detecting a UOGD-related chemical fingerprint in the groundwater samples. For example, the likelihood of detecting UOGD chemical fingerprints in water samples increased 13% (odds ratio 1.13) for every 0.1 increase in well water vulnerability. When modeled as a binary variable for high well water vulnerability, high vulnerability was associated with a 224% increase in the likelihood of detecting UOGD chemical fingerprints in water samples.

INTERPRETATION AND CONCLUSIONS

Saiers and colleagues developed a modeling approach to estimate groundwater vulnerability to potential contamination from UOGD spills in the Marcellus region states of Ohio, Pennsylvania, and West Virginia, and explored potential associations between estimated well water vulnerability and chemical fingerprints of UOGD in water samples.

In its independent review of the study, the HEI Energy Review Committee concluded that this study provided an effective modeling approach for examining groundwater vulnerability to potential contamination from UOGD spills that may be useful to inform decision-making. It also appreciated that this approach could be extended to other regions in the United States.

The Committee noted that the study was unavoidably limited by missing information for a large fraction of documented spills that could not be included in the analysis. This missing information may have resulted in an underestimation of well water vulnerability in areas with documented spills. They also noted some uncertainties associated with some simplifying assumptions used in the groundwater modeling (such as a two-dimensional rather than three-dimensional representation). Nonetheless, the Committee appreciated that the study’s findings, and its limitations, were thoughtfully and prudently presented. Moreover, they found that these limitations did not meaningfully change their conclusions about the utility of the modeling framework.



Statement Figure. Estimated number of people who depend on private wells and live in locations estimated to be highly vulnerable to potential groundwater contamination from UOGD spills in the Marcellus region. Source: Adapted from Investigators' Report Figure 7.

Overall, this study found that up to 120,000 people who rely on groundwater-supplied domestic water wells in the Marcellus region live in areas with “high vulnerability” to potential groundwater contamination associated with UOGD spills. Well waters determined to be vulnerable to documented spills from UOGD well pads were more likely to exhibit chemical fingerprints of UOGD produced water, although these fingerprints are not equivalent to exceedances of either health-based or aesthetics-based standards. The study provides a strong modeling framework and valuable datasets that can be used to inform decision-making by helping to predict the location of drinking water wells that are most vulnerable to UOGD spills.