A Review of Hydro "Fracking" and its Potential Effects on Real Estate

Ron Throupe
University of Denver

Robert A. Simons
Cleveland State University

Xue Mao
University of Denver

Abstract
In this paper we review the phenomena of hydro ''fracking'' operations for oil and gas in the United States. We provide background information on fracking, a summary of federal and state fracking disclosure and management regulations, and an evaluation of the potential surface and subsurface effects. We then examine case studies of claims of contamination from several shale-heavy states. Lastly, we report the results of survey research related to proximity to fracking operations in Texas and Florida. Our contingent valuation surveys show a 5%–15% reduction in bid value for homes located proximate to fracking scenarios, depending on the petroleum-friendliness of the venue and proximity to the drilling site.

As the international thirst for hydrocarbons continues unabated, domestic exploration in the United States has turned away from oil and natural gas in underground and offshore pockets to other alternatives. In the 1980s, we had an abortive quest to exploit oil shale in Colorado. The Canadian tar sands process was initiated at about the same time, and is just now gathering momentum where its products can be delivered to the U.S. and other markets by a controversial pipeline though the northern Midwest. For the past few years, a relatively ''new'' exploration procedure, ''fracking'' or ''hydro-fracking,'' has been developed to extract natural gas trapped in dense shale deposits. Tens of thousands of shale extraction leases have already been signed, keeping many landmen busy, but very little is known about the effects of the fracking process on the local environment and on proximate real estate markets. There is almost no real estate sales data on this issue, indicating a need for alternative methods such as contingent evaluation analysis. Yet, there is tremendous urgency to move forward with exploration, for many viable reasons.

The speed of this exploration will likely be driven by the price of natural gas [currently $4.04 per million British Thermal Units (BTUs)][1] compared with the price of extracting the gas from the ground. In general, based on hydrocarbon BTUs, shale gas is much cheaper to extract than oil, and is much less polluting than coal, thus better for greenhouse gas emissions. Within the shale deposit options, some like the Marcellus and Utica shale deposits in Ohio, Pennsylvania, and New York cost less than $2 per metric cubic feet (MCF) to extract, while shale in other locales are only profitable above $3 per million BTU's of energy.[2] Further, there's a political controversy if hydro-fracking is an alternative energy. Since it's a hydrocarbon, some say it's not, especially compared with renewable sources like solar or wind. However, the big energy company players involved, plus some others, argue that hydro-fracking is a new source of energy. In a down economy, economic development (especially the gold standard: job creation) from shale exploration and production potential is quite large. In manufacturing-heavy Ohio, for example, the unemployment rate shrank from above the national average in most years, to a point below the national average in August, 2012 (7.2% vs. 8.3%).[3]

The oil and gas industry continues to claim that there has never been a case of fracking fluid in ''direct'' contamination to drinking water. They promote fracking as safe, but the number of documented spills, blowouts, leaks, trucking accidents, and pollution from normal drilling activities appears to contradict these benign claims. The focus has been clearly on the well and casing maintenance, not on other effects or conditions. One main concern is the potential for fracking to invade historic groundwater drinking wells near drilling areas, or old oil and gas wells, where the new operations could blow out their seals or create a vertical conduit to upward aquifers or the surface. The oil and gas industry continues to say the mixture is mostly water and sand and a little bit of chemicals on a percentage basis. However, when even very small amounts of chemical exposure are hazardous (e.g., benzene toxicity, which is measured in parts per billion), this is a potential concern. The actual amounts of chemicals are tens of thousands of gallons per well.

The oil and gas industry in the U.S. is an economic driver, and has evolved over the last 20 years from a public focus on offshore drilling and traditional exploration to a more diversified set of activities. Technological advances in drilling have created the ability to extract oil and gas deposits that were not economically feasible a decade ago. Hydraulic fracturing is frequently used in the completion of gas wells, particularly those involved in what's called ''unconventional production,'' such as production from so-called ''tight shale'' reservoirs. The process has been used on over 1 million producing wells. As the technology continues to develop and improve, operators now fracture as many as 35,000 wells of all types (vertical and horizontal, oil and natural gas) each year.[4] This circumstance and an exemption from monitoring of drilling operations have led to a boom in drilling operations and in particular the ability to ''frack'' a new or existing well to create a producing well when previously not economically feasible.

This paper introduces the concept of hydraulic fracking as a new lexicon for oil and gas drilling. Fracking is now associated with drilling of all types, whether a well is actually fracked or not. Although the fracking (injecting a mixture of water, sand, and chemicals into the groundwater to facilitate hydrocarbon recovery) process has been used since at least the late 1970s in the Rangely Oil Field of northwestern Colorado, to facilitate secondary or tertiary recovery of oil and gas, its focus was never as a primary technique. What's new is a primary recovery of shale gas, and vastly upgraded horizontal drilling techniques. Thus, due to the maturity of the on-shore, hydrocarbon extraction business in the U.S., it's expected that a majority of wells drilled in the near future will be fracked multiple times over their production life.

The organization of the paper is as follows: We first provide background information on fracking, including the concept, history, locations of deposits, and chemical concerns. We continue with a summary of federal and state fracking disclosure and management regulations. This is followed by existing peer-reviewed literature on petroleum damages to residential property and evaluation of the potential surface and subsurface effects. We then examine case studies of claims of contamination from several shale-heavy states. Next, we discuss the results of survey research related to proximity to "fracking" operations in Texas and Florida. We close with policy recommendations and calls for future research.

Background on Fracking

Hydraulic fracturing is not a "drilling process" but a process used after the drilled hole is completed. Hydraulic fracturing or "fracking" is the propagating of fractures in a rock layer caused by the presence of a pressurized fluid creating small cracks, or fractures, in deep, underground geological formations to liberate oil or natural gas. This process is used to release petroleum, natural gas (including shale gas, tight gas, and coal seam gas), or other substances for extraction, via a technique called induced hydraulic fracturing. "Protecting groundwater contained in intervening aquifers are important steps to take during the fracking process. In this process, chemical-and-sand-laden watery fluid will be pumped down into the well and the watery oil or gas will eventually be collected. Therefore, in order to prevent the fluid from entering the water supply, steel surface or intermediate casing need to be inserted into the well. Normally the depths of the insertions are between 1,000 and 4,000 feet. Also, cement needs to be filled into the annulus, the space between the casing strings and the drilled hole. Once the cement has set, then the drilling continues from the bottom of the surface or intermediate cemented steel casing to the next depth. This process is repeated, using smaller steel casing each time, until the oil and gas-bearing reservoir is reached (generally 6,000 to 10,000 feet)."[5]

To fracture the formation, fracturing fluids—water and sand, and proprietary chemical mixes—are injected down the well bore into the formation. The fluid, injected under pressure, causes the rock to fracture along weak areas. The fluids that create the initial fractures are then mixed with thicker fluids that include sand and gelatin. These thicker fluids lengthen the openings in the rock. When the fractures are complete, and pressure is relieved, a portion of the fluids flows back up the well where it is captured and stored for later treatment or disposal. As the fluids flow back up, sand remains in the fractures and props the rock open, maintaining an open pathway to the well. This allows the oil and gas to seep from the rock into the pathway, up the well and to the surface for collection. A distinction can be made between low-volume hydraulic fracturing used to stimulate high-permeability reservoirs, which may consume typically 20,000 to 80,000 gallons of fluid per well, with high-volume hydraulic fracturing, used in the completion of tight gas and shale gas wells; enormous amounts of water, up to 5 million gallons of water for a single well. After the fracturing procedure is complete, 15% to 80% of the fluid returns to the surface as waste water, often contaminated by fracturing chemicals and subsurface contaminants including toxic organic compounds, heavy metals, and naturally occurring radioactive materials. Left untreated or not adequately secured, this wastewater can have detrimental environmental and health effects. Exhibit 1 is an overview of the fracking process.

HISTORY OF FRACKING IN THE U.S.

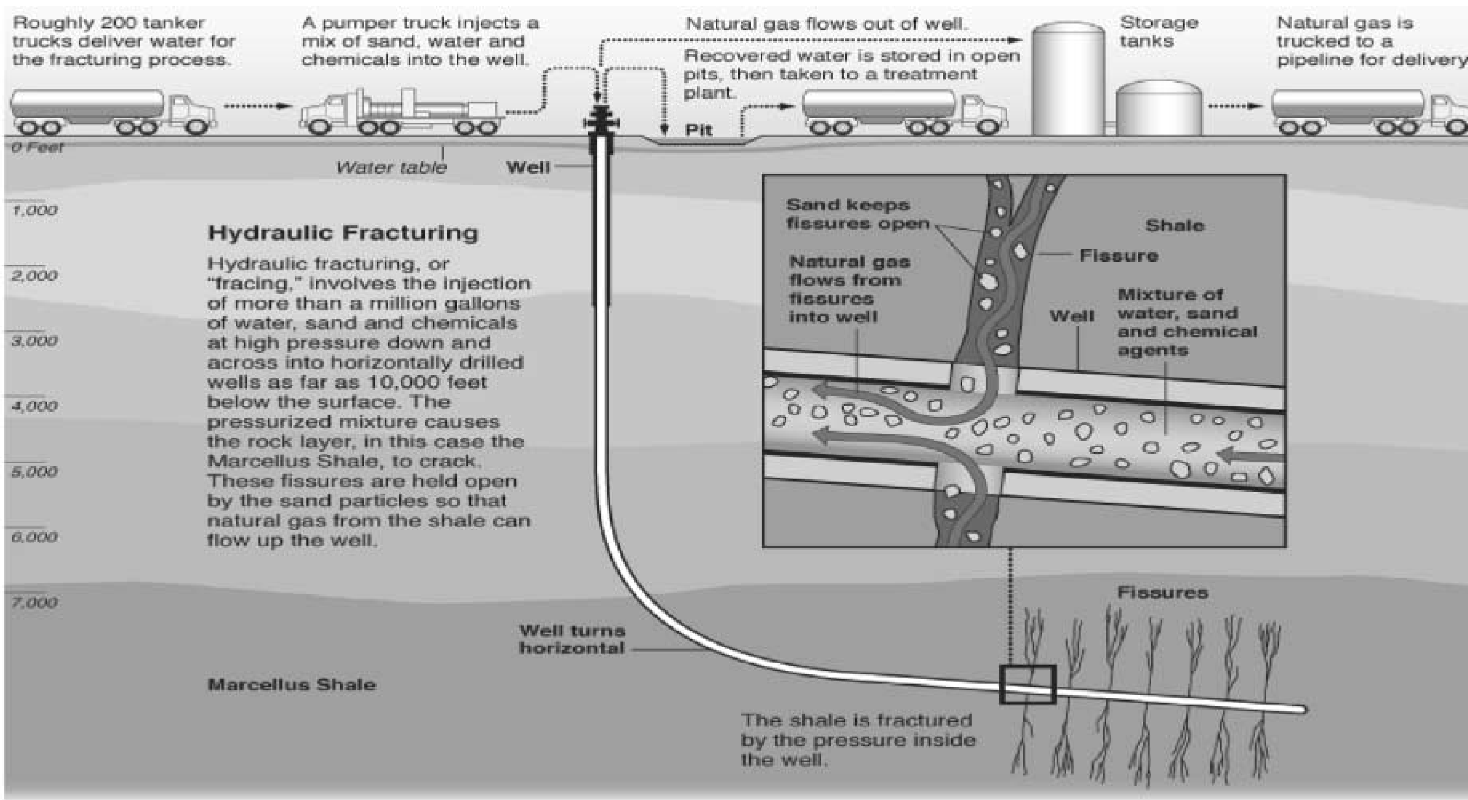
The first fracking operation in the U.S. was performed in 1947 in the Hugoton Kansas gas fields by Halliburton. However, hydraulic fracking did not become economical for commercial use for several decades. Significant R&D was necessary before hydraulic fracturing could be commercially applied to shale gas deposits, due to shale's high porosity and low permeability. In the 1970s, the federal government initiated both the Eastern Gas Shale Project and the Gas Research Institute. The Eastern Shale Project was a dozen public-private hydro-fracturing pilot demonstration projects. The Gas Research Institute was established as a gas industry research consortium receiving approval for research and funding from the Federal Energy Regulatory Commission. During that time, Sandia National Laboratories was conducting research into microseismic imaging for use in coal beds. Sandia contributed its geologic micro-mapping software, which proved to be crucial for the commercial recovery of natural gas from shale. In the late 1970s, the Department of Energy (DOE) pioneered massive hydraulic fracturing, a drilling technique, later improved upon for the economic recovery of shale gas. In 1986, a joint DOE-private venture completed the first successful multi-fracture horizontal well in shale. The DOE later subsidized Mitchell Energy's first successful horizontal drilling in the north-Texas Barnett Shale in 1991. Mitchell Energy engineers developed the hydraulic fracturing technique known as ''slickwater fracturing,'' the addition of chemicals to water to increase fluid flow. This innovation was implemented in 1996, and started the modern shale gas boom.

ADVANCES IN DRILLING: GOING HORIZONTAL

Technological drilling advances allow drillers to deviate from vertical drilling, and steer the drilling equipment to a location that is not directly underneath the point of entry. This is in contrast to 'slant drilling' where the well is drilled at an angle instead of directly vertical. New technology is allowing for the drilling of tightly curved well holes where 90-degree turns can be accomplished within several feet underground. Traditional directional drilling takes several thousand feet to turn 90 degrees.[6] These new technologies are aided by borehole telemetry to gain real time information from steerable drilling motors.

Conventional vertical wellbore suffers from a lack of exposure to the shale formation in comparison to horizontal wellbores. Horizontal drilling is particularly useful in shale formations that do not have sufficient permeability to produce economically; therefore, it is becoming more and more pervasive, especially in North America (Seale, 2007). In the U.S., tight reservoirs such as the Bakken (ND and Montana), Montney, Barnett, and Haynesville (Texas/Oklahoma) Shale and most recently Marcellus Shale (NY, Pennsylvania, and Ohio) are drilled, completed, and fractured using this method.

Exhibit 1
The Fracking Process



Source: ProPublica: Graphic by Al Granberg and Krista Kjellman Schmidt.

HARVESTING GAS AFTER DRILLING

After the drilling rig is moved off site, water tanks and water-hauling trucks arrive at the site. The day the operation is to begin, the sand haulers, pump truck, blender, and control van arrive. The equipment will all be connected together and then connected to the well head with high pressure hoses. After testing the equipment, the actual fracture stimulation will begin. The operation may take several hours to several days depending on the number of fracture zones. The equipment noise and truck traffic is the most noticeable occurrence during the operations.[7]

FRACKING HOT SPOTS IN THE U.S.

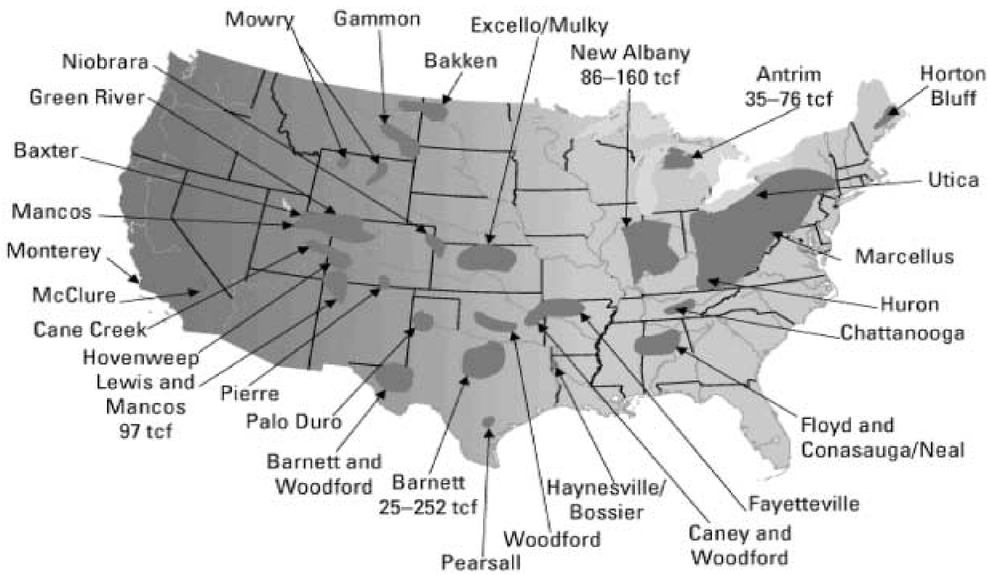
While the locations of gas-bearing shale have been known for some time, the confluence of advanced technology and market demand for clean-burning fuel has made development of these resources more urgent. Exhibit 2 shows U.S. locations where oil and gas reserves are being fracked, or where extraction is likely. About 20 states can expect to feel the effects of fracking exploration. The densest deposits are the Marcellus and Utica shale belts stretching from New York through Pennsylvania, Ohio, and Indiana into Illinois. Some states, like Texas, Oklahoma, Colorado, and Wyoming, are also experiencing resource extraction near populations. Others, like North Dakota and Montana, are largely rural.

FRACKING MIX OF CHEMICALS

Many of the communities in these locations face a choice of potential economic booms, along with potential exposures, accidents, congestion, and a loss of quiet enjoyment of property.

Water is the largest component of fracking fluids. Over its lifetime, an average well can require five million gallons of water for the initial hydraulic fracturing operation and possible restimulation. The large volumes of water required have raised concerns about fracking in water shortage areas such as Texas, which has been in a multiple-year drought. Chemical additives used in fracturing fluids typically make up less than 2% by weight of the total fluid. Nonetheless, over the life of a typical well, this may amount to 100,000 gallons of chemical additives.[8] These additives include some that are known carcinogens, some are toxic, and some are neurotoxins. These include benzene, lead, ethylene glycol, methanol, boric acid, and 2-butoxyethanol. High levels of iodine-131 (a radioactive tracer used in hydraulic fracturing) are the major contributor to the generally elevated radiation levels found near hydraulic fracturing sites. However, it is not listed among the chemicals to be monitored in the U.S. Environmental Protection Agency's Hydraulic Fracturing Draft Study Plan. The 2011 U.S. House of Representatives investigative report on hydraulic fracturing chemicals showed that there are 750 compounds in hydraulic fracturing products. "More than 650 of these compounds contained chemicals that are either known or possible human carcinogens, regulated under the Safe Drinking Water Act, or listed as hazardous air pollutants."[9] This report also showed that between 2005 and 2009, many components were listed as "proprietary" or "trade secret" on their Occupational Safety and Health Administration (OSHA) required Material Safety Data Sheets (MSDSs).

Exhibit 2
Fracking Locations



Source: www.ehelpfultips.com.

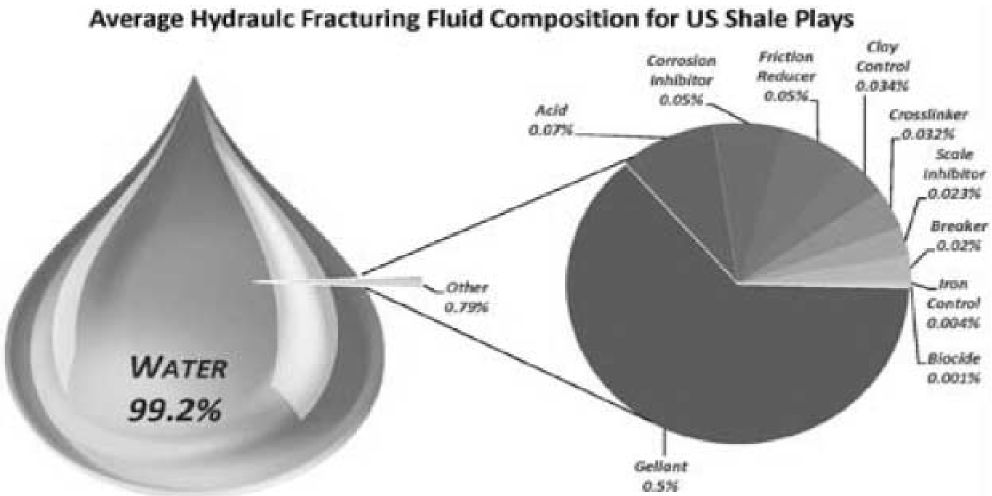
When asked to reveal the proprietary chemical components, most companies participating in the investigation did not do so. This non-disclosure prevents government regulators from monitoring and documenting the changes in the components, thereby making it impossible to prove that hydraulic fracturing is contaminating the environment (Fitz Patrick, 2011). Without knowing the identity of the proprietary components, regulators cannot pass measures requiring testing for their presence.

In his 2012 State of the Union, Barack Obama stated his intention to force fracking companies to disclose the chemicals they use, but proposed guidelines were criticized for failing to specify disclosure of the chemicals used. This and other prior intentions are known as part of the proposed Fracturing Responsibility and Awareness of Chemicals Act (FRAC Act).[10] Exhibit 3 shows the categories of chemicals that are potentially part of a fracking fluid mix.

VOLATILE ORGANIC COMPOUNDS

One group of emissions associated with natural gas development and production are those associated with combustion. They include particulate matter, nitrogen oxides, sulfur oxide, carbon dioxide, and carbon monoxide. Another group of emissions that are routinely vented into the atmosphere are those linked with natural gas itself, which is composed of methane, ethane, liquid condensate, and volatile organic compounds (VOCs). The VOCs that are especially impactful on health are benzene, toluene, ethyl

Exhibit 3
Fracking Fluid Composite



Source: FracFocus.com.

benzene, and xylene (BTEX). The health effects of exposure to these chemicals include neurological problems, birth defects, and cancer.

VOCs, including BTEX, mixed with nitrogen oxides from combustion and combined with sunlight can lead to ozone formation. Ozone has been shown to impact lung function, increase respiratory illnesses, and is particularly dangerous to lung development in children.[11] In 2008, measured ambient concentrations in rural Sublette County, Wyoming, where ranching and natural gas are the main industries, were frequently above the National Ambient Air Quality Standards (NAAQS) of 75 parts per billion (ppb) and have been recorded as high as 125 ppb (Urbigkit, 2011). A 2011 study for the city of Fort Worth, Texas that examined air quality around natural gas sites "did not reveal any significant health threats." The Fort Worth *Star-Telegram* characterized that report as "the most comprehensive study of urban gas drilling to date."[12]

GOVERNMENT REGULATIONS ON FRACKING

A number of federal laws and regulations, including the Federal Oil Pollution Control Act, address petroleum extraction. Further, the Environmental Protection Agency (EPA) may also regulate the chemicals that oil and gas companies use. A detailed accounting of this is beyond this research, but we do address three pertinent topics: the 2005 Energy Policy Act, the ongoing EPA study of fracking, and regulations pertaining to obtaining permission to drill wells on federal lands.

2005 ENERGY POLICY ACT

''The oil and gas industry received a helping hand from the federal government during the Bush Administration. Although fracking was never regulated by the federal government when it was a less prevalently used technique, it was granted explicit exemptions, despite dissent within the EPA, from the Safe Drinking Water Act, the Clean Air Act, and the Clean Water Act by the Energy Policy Act of 2005, the wide-ranging energy bill crafted by Dick Cheney in closed-door meetings with oil-and-gas executives and what has become known as the ''Halliburton Loophole.'' Thus, drilling firms do not need to disclose to the public their practices. Congressional hearings held by the House Energy and Commerce Committee have been taking place since 2009, but proposed legislation to eliminate the Halliburton Loophole has made little progress'' (Bateman, 2010).

''Claiming that the information is proprietary, drilling companies have not fully disclosed the components of their fracking fluids; however, activists and researchers have been able to identify some of the chemicals.[13] According to Theo Colborn, a noted expert on water issues and endocrine disruptors, at least half of the chemicals known to be present in fracking fluid are toxic; many of them are carcinogens, neurotoxins, endocrine disruptors, and/or mutagens. Colborn has estimated that a third of the chemicals in fracking fluid remain unknown to the public'' (Bateman, 2010).

ENVIRONMENTAL PROTECTION AGENCY

The major role and competency of the EPA is protecting human health and safeguarding the environment. In terms of oil and gas extraction, the EPA is responsible for researching and assessing the air and water contamination that is harmful to the public health and safety, along with evaluating the detrimental physical, chemical, and biological changes to the environment. To be more specific, the EPA has an obligation associated to four aspects: (1) improving understanding of hydraulic fracturing; (2) providing regulatory clarity and protections against known risks; (3) assuring regulatory compliance; and (4) promoting transparency and conducting outreach.

The House of Representatives Appropriation Conference Committee identified the necessity of a study on hydraulic fracturing in its 2010 fiscal year. On behalf of the Congress, the EPA fracking study is aimed at studying if there is a relationship between hydraulic fracturing and the ground water and drinking water by conducting research and monitoring the water use in hydraulic fracturing. This study, after many delays, is expected to be completed in 2014.[14]

According to the final plan of the study, the EPA is expected to implement different approaches including analysis of existing data, case studies, scenario evaluation, laboratory studies, and toxicity assessments. On one hand, the data analysis focuses on the existing data regarding well location and construction, chemicals, operating procedures, spills, and wastewater disposal. Furthermore, the EPA sent a letter to nine randomly chosen oil and gas companies to request additional information to support the study, in August 2011. The requested information includes quantity and quality of well cement, extent of integrity testing, identity of products or chemicals used, drinking water resources near the well or through which the well passes, and extent of baseline water quality monitoring. In order to assess the impact of hydraulic fracturing on the drinking water resources, seven cases were identified that include five retrospective cases (Killdeer, Dunn County, ND; Wise County, TX; Bradford & Susquehanna Counties, PA; Washington County, PA; Animas & Huerfano Counties, CO) and two prospective cases (DeSoto Parish, LA; Washington County, PA). As shown in the February 2012 progress update of the EPA study, verification of potential issues in the five retrospective cases is finished. The final study plan was amended based on a peer review from the EPA's Science Advisory Board, which is an independent, external federal advisory committee and comments from the stakeholders including individual citizens, communities, tribes, state and federal partners, industry, trade associations, and environmental organizations.

FEDERAL LAND PROCESS

The process for obtaining drilling permits on federal land is separate from individual state procedures. State laws for drilling are now developing and are addressed in the next section. The Federal land process for drilling is as follows. A copy of ''a notice of intention to drill'' must be given to the surface owner, but surface owner permission is not required prior to entry. The exploration period begins 30 days after notice is given and lasts 60 days. During exploration, the ''entry'' onto the surface owner's land does not allow for use of mechanized equipment, the construction of roads, drill pads, or the use of hazardous materials, and may not cause more than ''a minimal disturbance of surface resources.''

Failure to reach agreement requires the operator to post two bonds with the Bureau of Land Management (BLM). The surface use bond must cover damages to crops, permanent improvements, and your land's grazing value. The bond must exceed $1,000 and be provided to the landowner, along with a description of their right to appeal the bond. A second copy must be submitted to the BLM. If the bond is insufficient, the landowner may challenge it with the BLM within 30 days. If the BLM decides the bond is sufficient, you may appeal again. The reclamation bond must cover the cost of plugging wells and reclaiming and restoring land and surface waters. Standard bond amounts per company are: $10,000 per lease, $25,000 for all leases in a state, or $150,000 for all leases nationwide. If a landowner determines the total reclamation costs will exceed the bond, they can ask the BLM to increase the bond.

Before mineral operators can begin an oil and gas operation they must submit an Application Permit to Drill (APD) and a drilling plan. Once the APD is filed, the BLM must consult with other federal agencies and other appropriate interested parties. Surface owners have 30 days to comment. The drilling plan details the location of proposed roads, well pads, and other facilities, along with methods for handling waste such as garbage, sewage, and produced wastewater, and reclamation plans and other requirements. One can contact the BLM field office for a copy of the drilling plan.

Within 15 days of receiving a complete APD, the BLM must conduct an on-site inspection. Surface use and reclamation stipulations are developed during the inspection. By participating, the surface owner can press for tough reclamation requirements and responsible siting of roads and other infrastructure. The BLM will decide whether to incorporate the surface owner's suggestions.

STATE LAW INITIATIVES

A growing number of states have passed their own set of disclosure regulations. Wyoming was the first state, in September 2010, followed by Arkansas, Pennsylvania, and Michigan. In June 2011, Texas became the first state to pass a law requiring companies to disclose what chemicals are being injected into the ground at each well. Several other states, including North Dakota and Colorado, have recently enacted disclosure regulations. Colorado was the first to require disclosure of the chemicals used for fracking (family of chemical).

In December 2011, Colorado regulators approved new disclosure rules that are associated with the disclosure of hydraulic fracturing chemicals used during the fracking process. The chemical disclosure registry, by definition, means the chemical registry website known as fracfocus.org developed by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. If the website becomes permanently inoperable, then chemical disclosure registry shall mean another publicly accessible information website designated by the Commission.[15]

Texas was the first state to pass a law requiring companies to disclose the concentration of hydraulic fracturing chemicals by listing the chemicals on a national registry. Similar to the law in Texas, Colorado's disclosure rules require a company to disclose the concentration of all chemicals used in hydraulic fracturing, along with the chemical family of the ingredients; however, the exact chemicals are very often considered a trade secret. The companies are required to disclose the secret ingredients in emergencies. The Colorado rules took effect on April 1, 2012.

Even though some state disclosure regulations only require the companies to disclose the concentration of hydraulic fracturing chemicals or the ingredient's chemical family, physicians and other medical professionals may request specific information of certain chemicals and gases for diagnosis or treatment purposes. However, the legislations can forbid them from disclosing the information for any purpose other than those two stated above.

In Ohio, the medical gag rule, introduced in the amendment of SB 315 that passed on May 15, 2012, requires a medical professional who receives information about trade secret chemicals to keep the information confidential. In Pennsylvania, Act 13, which was approved in early February 2012, allows the companies to not provide trade secret or proprietary information to physicians and others who work with citizen health issues. Also, the regulation forbids health care professionals from telling their patients, specialists, or the community.

Severance taxes are excise taxes on non-renewable natural resources that are extracted from the earth. They historically have been a significant revenue generator in energy-rich states. Currently, at least 36 states have some form of severance tax; 31 of which are especially on oil and gas extraction; at least 11 states are considering either imposing new or amending existing ones. However, Pennsylvania, the largest natural gas-producing state, has no such tax. Some states impose impact fees rather than taxes. In Pennsylvania, H.B. 1950 was enacted in early February 2012 to impose an impact fee based on the average natural gas price in the following year, with a cap at $355,000 per well within 15 years.

Due to different geological factors, different states have various ways of addressing fracking waste management and monitoring. These include addressing transportation, the use of open pits, and testing for fracking waste. Some states are taking steps in reducing risks related to the transportation of fracking disposal waste. In Pennsylvania, the pending H.B. 1741 would require placards to be posted on the outside of the vehicles if they are carrying hydraulic fracking wastewater. Drilling companies are experimenting with recycling frack fluid, reducing the amount of transport.

Some oil and gas companies evaporate fracking wastewater in large retention ponds for disposing purposes. Using retention ponds is dangerous because chemical oxidation and airborne toxins can potentially affect ‘‘downwind’’ areas. States, such as North Dakota, are regulating and attempting to reduce the number of open pits for frack fluid storage. If a new pit is the only alternative, it is required to have liners to attempt to prevent ground water contamination.

Fracking locations are required to be tested for waste in recent law enactments. A Statewide Groundwater Baseline Sampling and Monitoring rule, being the first rule for groundwater testing both before and after drilling, was approved by Colorado regulators on January 7, 2013. It requires four water samples from aquifers to be collected. In New York, several pending bills require wastes to be tested for radioactive contaminants and samples to be gathered to identify contaminants of concern.

Moratoriums are established in some states by law in order to delay or ban hydraulic fracking operations until the effects are better known. In New York, a moratorium of 120 days is established by pending A.B. 5547 after the EPA issues its reports on the effects of fracking treatment. A.B. 300, another pending bill, establishes a moratorium of 120 days on disposal of fluid after the EPA's report is released.

Several states are considering well setback regulations. In New York, pending A.B. 4237 prohibits drilling within 10 miles of the city water supply infrastructure. Fracking near a watershed is also prohibited by pending SB 1234. In Colorado, a hearing is required when oil and gas companies want to operate within 1,000 feet of a school or a hospital, under a newly proposed regulation. Also, in Texas, a bill was filed in 2011 to prohibit drilling within 1,200 feet of public schools; however, the bill did not pass due to industry opposition.

PEER-REVIEWED LITERATURE ON PETROLEUM CONTAMINATION

Since there is no peer-reviewed literature on fracking, the next closest body of research addresses petroleum groundwater contamination, primarily from leaking underground storage tanks. Four recent studies have addressed the effect of groundwater contaminated with benzene on residential property values (Simons, Bowen, and Sementelli, 1997, 1999; Simons, 1999a; and Simons and Winson-Geideman, 2005).

Simons, Bowen, and Sementelli (1997, 1999) focused on housing using municipal drinking water in Cuyahoga County, Ohio (Cleveland). Using regression analysis countywide, the observed losses ranged from 13% to 16% of property value. One case study of a higher priced suburban residential subdivision showed 16% losses. The houses were on municipal drinking water, and the contamination plume extended about one-quarter of a mile, and several dozen homes were involved.

A case study near Akron, Ohio in a rural subdivision on well water had losses of 25%, resulting from benzene contamination from a pipeline release (Simons, 1999a). These losses were about 10% higher than for homes on municipal drinking water. Simons and Winson-Geideman (2005) used contingent valuation analysis to gauge stated preference losses due to contaminated groundwater in several states, with losses in the 11%–27% range, depending on the severity of the scenario and location. To summarize, the residential leaking underground storage tank (LUST) literature indicates a loss of between 13% and 25% under various circumstances.

In similar fashion to this article, Wilde, Loos, and Williamson (2012) review the effect of pipelines on property values. Their review included the effect of proximity to pipelines, as well as from releases and ruptures. They conclude that research is limited and that results based on survey research in comparison to actual sales data requires further scrutiny to determine if the finding of their survey match the actual pricing effects for properties over time.

SUMMARY OF LITERATURE: POTENTIAL ISSUES

There is some concern that drilling leases may be problematic in relation to mortgage financing, lender's insurance, and homeowners insurance. In particular, mortgages typically stipulate that an owner is not to allow damage, destruction or substantial change to collateral including the use, disposal, storage or release of hazardous materials. In addition, the signing of a gas or drilling lease may require permission of the underlying lender. This result could give either of the federally-run companies (Fannie Mae and Freddie Mac) the right to demand immediate payment of the full loan.

Airborne chemicals (VOCs) and contaminated groundwater are types of toxic trespasses related to fracking, spills, and storage mishaps (Anderson, 2010).[16] The concept of an underground trespass and subsequent rent due for storage was developed by Krause, Throupe, Kilpatrick, and Speiss (2012). The concept being that chemical stored on the land of another constitutes a tenant status with rent due. The renter in this case would be the drilling firm who was aware of the chemicals used and left within the well during the fracking process. There are others who claim that a trespass per say is not due compensation unless there is damage to the surface rights (Anderson, 2010). For fracking where it is known that chemicals have been used, although not exactly which chemicals, residual effects to the surface from oil and gas drilling may be linked.

This type of easement is usually considered a temporary easement subject to paying rent. These easements typically last for a time period of less than a year. For natural gas operations, one could split the time into the period for when the well is initially drilled and then fracked versus a length of time that the well is in operation. During operation, there is a potential for visual degradation, traffic, and odor.

The development of a drilling site can create a loss of quiet enjoyment to adjacent property owners. Many times there is a need to create roads for access; and the transport to and from the site creates unwanted traffic and noise. Adjacent neighbors to drilling sites can also experience interruption from noise, lighting, and odor from releases of gases. For the local community, the discovery and extraction of natural gas or oil can create increased truck traffic, congestion, and noise effecting the quite enjoyment of the community.

The result of actual or perceived risk is based on various levels of knowledge (Mundy 1992a,b). The publicity and the lack of clarity from industry participants lead to a level of unknown risk to potential buyers. The result can be a discount for housing in proximity to drilling operations.

An onerous feature of gas drilling in New York is that the land owners by default will get stuck with the comprehensive liability for environmental clean-up, while the gas companies who leased the mineral rights have a more limited liability, like renters. Some leases protect land owners better than others, so there is some variety in how this issue is resolved.

Case Studies

The following examples from Pennsylvania, Ohio, Colorado, and Wyoming illustrate issues related to fracking.

PENNSYLVANIA

The town of Dimock, Pennsylvania, population 1,400, exemplifies the dangers posed by hydraulic fracturing. Dimock residents began noticing ill-smelling, brown, well water in 2008 after Houston-based Cabot Oil & Gas began fracking. Both the Pennsylvania Department of Environmental Protection (DEP) and the EPA found that at least 18 residential water wells were fouled by stray methane gas from Cabot's drilling operation. The town was later featured in the documentary ''Gasland'' by Josh Fox.

Residents claim that ''landmen'' from Cabot Oil & Gas, a midsize player in the energy-exploration industry, came knocking on doors to inquire about leasing the mineral rights to their land. Some residents claim the landmen told them that their neighbors had already signed leases and that the drilling would have no impact whatsoever on their land. ''Others in Dimock claim they were told that if they refused to sign a lease, gas would be taken out from under their land anyway, since under Pennsylvania law a well drilled on a leased piece of property can capture gas from neighboring, unleased properties’’ (Bateman, 2010).

Cabot’s drilling operations in Pennsylvania commenced in August 2008. Clearing and ground leveling were performed to make way for a four-acre drilling site less than 1,000 feet away from property owners. Residents claimed they could feel the earth beneath their home shake whenever fracking was initiated. A month later, their well water had turned brown and corrosive. They complained to Cabot, which eventually installed water-filtration systems in some homes. The problem appeared to be resolved, until additional DEP testing indicated high levels of methane.

Several incidents occurred after Cabot came to town. A truck turned over and caused an 800-gallon diesel fuel spill in April 2009. Also, in September 2009, up to 8,000 gallons of Halliburton-manufactured fracking fluid leaked from faulty supply pipes, with some seeping into surrounding wetlands and a stream, killing fish. By October 2009, the DEP had taken all the water wells in affected neighborhood offline. A major contamination was acknowledged with dangerously high levels of iron and aluminum, in addition to the methane found in the water. The residents relied on water delivery every week by Cabot. Some claim the value of their land was damaged. Others wanted to move but could not afford to buy a new house while carrying their current mortgage.

Residents are suing the company for diminution in value, negligence, breach of contract, and fraudulent misrepresentation, among other charges. Cabot declines to comment on the lawsuit but said that its operations are ‘‘in full compliance with environmental and oil and gas drilling regulations’’ and ‘‘the accidental release of materials has occasionally occurred’’ during its operations (Bateman, 2010).

In 2010, Cabot was banned by the DEP from drilling additional wells around the village of Dimock and required to take legal responsibility for the methane found in the wells, including constructing a pipeline to bring in clean water. Cabot contends that water wells in the area were tainted with the gas long before the company arrived. The company also says it met a state deadline to restore or replace Dimock’s water supply. On November 30, 2011, Cabot won permission from state regulators to halt daily water deliveries. The environmental group ‘‘The Sierra Club’’ then arranged for trucks to continue to deliver water.

Confusion remains regarding whether the water in Dimock is safe to drink. On December 2, 2011, the EPA sent an email to several Dimock residents indicating that their well water presented no immediate health threat. However, on January 19, 2012, the EPA reversed its position, and asked that the agency’s hazardous site cleanup division take immediate action to protect public health and safety (Gardner, 2012). Meanwhile, the Agency for Toxic Substances and Disease Regulation (ATSDR) continues to investigate the long-term effects of exposure to Dimock’s water. This case illustrates: (1) the case illustrates the struggle of a lack of coordination, disruption to people’s lives; (2) landmen ultimatums; (3) a debate of whether Cabot should continue supplying clean water and doing more tests relating to water quality; and (4) ongoing debate among the residents, DEP, the EPA, ATSDR, and Cabot.

OHIO

The eastern and central parts of Ohio and western Pennsylvania are imbued with the Marcellus Shale layer, a gas-rich rock formation. The Utica Shale formation (characterized as more liquid rich) is also in Ohio.[17] The shale formation has attracted the attention of many oil and gas landmen scrambling to obtain mineral rights to the deep (about 7,000 feet) shale formation under contract. In Northeast Ohio, Chesapeake Energy has been one of the more active firms in acquiring leases. This energy focus has started to ignite an economic mini-boom, and Ohio's unemployment rate has dropped below the national average for the first time in five years.[18] The battle for minds and influence has taken sides, with Cleveland State's Levin College of Urban Affairs conducting an economic impact analysis on behalf of the state addressing the positive side of the equation,[19] and the No Frack Ohio Coalition[20] taking the contrarian view, for both Pennsylvania and Ohio. Some assert that the potential employment from shale exploitation in these hard-hit areas is at least 10,000 jobs, and potentially as high as 40,000 jobs. Just on the Pennsylvania side, the estimate is over 23,000 jobs.[21] However, only a modest portion of these would be specific to the drilling locations. For example, a case study of Susquehanna County, Pennsylvania showed direct impacts of only a few hundred jobs and under $10 million in overall economic impact for 2010.[22]

On the downside, residents are concerned about increased truck traffic, the influx of new workers, and taxing local infrastructure, especially water. Although property value impacts have been mentioned on the No Frack Ohio website, no data are presented to back up claims.[23]

The other issue peculiar to Ohio is the incidence of modest seismic activity near Youngstown, Ohio in early 2012. Research shows fracking-related activity, notably water injections, have eluded control and ''slipped into a previously unknown fault line.'' The location has been linked to earthquakes in the area where there are over 150 horizontal fracking injection wells. A 4.0 magnitude earthquake near one of the deep disposal injection wells is likely linked to a disposal well for injecting wastewater used in the hydraulic fracturing process, according to seismologists at Columbia University. Consequently, Ohio has since tightened its rules regarding the wells, increased fees, and is considering a moratorium on the practice. The Youngstown area, thus, is at the epicenter of the Marcellus Shale exploration, incurring both the negative environmental effects of earthquakes and potential degradation of water quality, and the positive economic boom of having its moribund steel industry revived.

This case illustrates the tradeoffs of economic stimulus versus disruption of lives.

COLORADO

The process of hydraulic fracturing has been used for decades in Colorado, dating back to the 1970s. Hydraulic fracturing continues to be refined and improved and is now standard for virtually all oil and gas wells in the state, and across much of the country. But in Colorado, 206 chemical spills were linked to 48 cases of water contamination in 2008 alone. In Parachutte, Colorado, 1.6 million gallons of fracking fluid leaked and were transported by groundwater. According to state records, it seeped out the side of a cliff, forming a frozen waterfall 200 feet high. It was later melted into a tributary of the Colorado River.[24]

Reports of environmental degradation have come out of many places where natural gas drilling and fracking are occurring. The full extent of the problem is difficult to determine because much of the evidence is anecdotal because drilling companies are accused of buying people off when things go wrong. ‘‘In Silt, Colorado, a woman no longer talks about the adrenal gland tumor and other health complications she developed after her water was contaminated by a gas well drilled less than 1,000 feet from her home. (A state investigation into the matter concluded that a drilling failure had likely led to intermingling between the gas and water strata in the ground.) She signed a non-disclosure agreement as part of an agreement to sell her tainted land to EnCana, the large Canadian gas company that drilled the well. But perusing newspapers from towns where fracking was going on revealed how the issue refused to die, with headlines like ‘‘Fears of Tainted Water Well Up in Colorado,’’ ‘‘Collateral Damage: Residents Fear Murky Effects of Energy Boom,’’ and ‘‘Worker Believes Cancer Caused by Fracking Fluids’’ appeared regularly’’ (Bateman, 2010).

In Garfield County, Colorado, the location of the documentary ‘‘The Split Estate,’’[25] another area with a high concentration of drilling rigs, VOC emissions increased 30% between 2004 and 2006; during the same period there was a rash of health complaints from local residents. Epidemiological studies that might confirm or rule out any connection between these complaints and fracking are virtually non-existent (Brown, 2007). The health effects of VOCs are largely unquantified, so any causal relationship is difficult to ascertain; however, some of these chemicals are suspected carcinogens and neurotoxins.

‘‘Clusters of unusual health problems have popped up in some of these Colorado drilling hot spots. Kendall Gerdes, a physician in Colorado Springs, has told how he and other doctors in the area saw a striking number of patients come to them with chronic dizziness, headaches, and neurological problems after drilling began near their homes. One of Dr. Gerdes’s patients developed idiopathic hemorrhaging, or spontaneous bleeding, as well as neuropathy, a pituitary gland tumor, and a rare neurological speech impediment after alleged frequent exposure to noxious fumes from drilling. Although her health improved after she moved to another part of Colorado, she claims to continue to have trouble speaking and walking’’ (Bateman, 2010). In addition, the Colorado School of Public Health performed a study in 2011 regarding potential adverse health effects, concluding that residents near gas wells may suffer a series of ailments. This study was never published, after disagreements between drilling company and community members over the study’s methods.[26]

This case illustrates: (1) buy out of problems with gag orders; (2) long-term degradation of a community; and (3) oil and gas company ability to potentially thwart information.

WYOMING

Sublette County, Wyoming was the first site of groundwater contamination to be documented by a federal agency, the U.S. Bureau of Land Management, in 2008. Water from more than 88 drinking wells were contaminated and found to contain benzene, a chemical that causes leukemia, at concentrations up to 1,500 times a safe level. Researchers returned to take more samples, but were unable to open the water wells. Monitors showed they contained so much flammable gas that they were likely to explode (Lustgarten, 2008).

The industry pointed out the uniqueness of the location as the reason. Industry representatives say the gas wells in Wyoming were drilled under circumstances not found in most other fracking sites, with shallower wells, closer to water sources. Some of the fracking wells were drilled at around 1,200 feet, while most other shale drilling sites were between 4,000 and 14,000 feet, well below water sources. There were comments that the elevated levels of methane, benzene, and other petrochemical compounds found in EPA monitoring wells are naturally occurring because the wells were drilled ''into hydrocarbon-bearing zones.'' Thus, it is claimed to not be from fracking operations.

Another incident involving water was reported by residents near a gas field in Pavillion, Wyoming prompting the EPA to conduct a groundwater investigation. Pavillion is a town in Fremont County, Wyoming, with a population of 165 as of the 2000 census. Residents near the drilling sites in Pavillion asked the EPA in 2009 to investigate possible contamination after water from their wells started tasting and looking off. Canada's largest natural gas producer, Calgary-based Encana Corp. (ECA), owns about 150 wells in Pavillion. In 2010, the EPA opened an investigation into the possible contamination of groundwater approximately five miles east-northeast of Pavillion. Also in 2010, the Department of Health and Human Services recommended that Pavillion residents use alternate sources of water for drinking and cooking. While testing detected petroleum hydrocarbons in wells and in groundwater, the agency at the time said it could not pinpoint the source of the contamination. Meanwhile, Encana started providing drinking water to about 21 families in Pavillion in August 2010. A few days later the EPA released draft findings of contamination by hydraulic fracturing drilling operations in Wyoming. The industry's reaction was to attempt to find holes in the EPA's findings.

In December 2011, the EPA concluded that chemicals used in extracting natural gas through hydraulic fracturing were found in a drinking water aquifer in west-central Wyoming. The report also commented on contaminants in wells near pits, indicating that (frack) pits are a source of shallow ground water contamination. Two deep monitoring wells were dug by the EPA. They identified ''compounds likely associated with gas-production practices, including hydraulic fracturing.'' These chemicals in the deep wells were ''well above'' acceptable standards under the Safe Drinking Water Act. The EPA also found that the reports companies filed detailing jobs, listed chemicals as a class or as ''proprietary,'' ''rendering identification of constituents impossible.''

The draft EPA report also stated: "Alternative explanations were carefully considered to explain individual sets of data. However, when considered together with other lines of evidence, the data indicates likely impact to ground water that can be explained by hydraulic fracturing" (Phillips, 2011). The EPA also said that the type of contamination found is "typically infeasible or too expensive to remediate or restore." Industry figures rejected the EPA's findings. The location is now part of the EPA study on hydraulic fracking.

This case illustrates: (1) Sublette, Wyoming as the first time an agency has documented groundwater contamination; (2) Pavillion, Wyoming as the first time the EPA confirmed drinking water contamination; and (3) an inability to determine exact chemical identification.

Residential Buyer Market Survey

SETBACK LEGISLATION

Recent proposed legislation by multiple states has included setback requirements for fracking operations. As previously mentioned, these proposals address proximity to schools, residential property, and hospitals. A residential buyer survey was constructed to further study the potential impacts of fracking. This survey was designed to study proximity and general population sensitivity to fracking operations. Documented market transactions of properties are difficult to find and verify. Thus, a contingent valuation (CV) survey is used to investigate further. CV is a peer-reviewed procedure that can utilizes telephone calls to potential buyers, in this case homeowners in nearby counties, who are asked a series of questions about buying property, including acquisition of contaminated property.[27]

A professional survey firm (NSØN, Inc. of Salt Lake City, Utah) conducted telephone surveys under the direction of a researcher. The calls were made to a random sample of homeowners in ZIP Codes 77015, 77017, 77502, 77503, 77506, 77520, 77521, 77536, and 77587 in Metropolitan Houston, Texas, and ZIP Codes 32404, 32405, 32409, 36608, 36609, 36618, and 36619 along the Florida/Alabama Gulf Coast. Because Texas is a "petroleum friendly" location, we expected some differences in homeowner preferences, so we present the results separately.

The survey firm called names at random, until they reached a homeowner who was willing to participate in the brief 8-to-10-minute survey. Two different survey forms were used for this research (frack "heavy" and frack "light"); one case (frack "heavy" only) was presented to both Texas and Florida respondents. Two hundred surveys of each type were collected for a total of 570 respondents. This number of responses generates statistically significant results with an approximate 90% level of confidence. The survey instruments contained a baseline case to establish value, and four scenarios with potential environmental or nuisance-related disamenities. Each survey was presented with a business park (harmless, meant to calibrate the survey form to show zero losses) with a leaking gas station scenario (meant to benchmark to the peer reviewed literature), and one of two fracking scenarios. Finally, one scenario in each survey subgroup relates to litigation, and these results are not presented here. With respect to the disamenities, the respondent is asked if they would make a bid on the property and, if so, how much. The instrument is quite detailed, and avoids key problems described in Mundy and McLean (1998a,b) and later expanded upon in Lipscomb (2011) and Lipscomb et al. (2011). These survey problems were originally debated as part of the Natural Resource Damages Assessment document (Federal Registrar 1996) produced by the National Oceanic and Atmospheric Administration. These include hypothetical bias with inflated responses because of the hypothetical nature of the questionnaire; and a self-interest bias based on respondents' motives; additional bias based on the survey instrument structure can be reviewed in Mitchell and Carson (1989).

We use an identical methodology to that used in peer-reviewed literature (Simons, 2002; Simons and Throupe, 2005; Simons and Winson-Geideman, 2005).[28] The instrument also did not specifically guide the respondent to a fracking scenario, but "nests" the issue in a broader context.

Each survey instrument was successfully pretested with 30 respondents (for each of the three groups) before beginning survey protocol. The pretests revealed no issues regarding survey design or respondent understanding.

INTERPRETING THE SURVEY RESULTS

There are two factors of major importance in evaluating survey results. The first is the portion of respondents that would bid on a scenario, which indicates any reduction in market demand. This is measured by the ratio of "no bid" to total responses. The second factor addresses potential value loss where there are bids. Of those that did bid, the ratio of maximum bid to baseline case reflects the percentage respondents state that they would pay. One minus this percentage reflects the discount. For example, if the person's baseline house price is $100,000, and the maximum they would bid on a particular scenario was $85,000, then that bid would reflect a 15% discount. The first part of the survey was a "warm up" and lets the respondent become comfortable with the bidding scale. It also determined a baseline property price in the context of a job move. In addition to the litigation and fracking scenarios, each respondent was asked about two other scenarios: a house near a business park and a house near a leaking underground storage tank ("LUST"). These scenarios were presented for benchmarking purposes and to familiarize respondents with the evaluation and bidding process. Bid percentages for these three comparative scenarios are presented in the data table, but are only discussed relative to methodology issues.[29] As mentioned above, two variations of the fracking situation were presented. Fracking "heavy" includes potential effects on groundwater, and was closer to the drilling site, which was visible from the house. About 200 Texas homeowners near Houston, Texas and a similar number of people in the Florida panhandle were asked about this scenario. In the fracking "light" scenario, the home was a mile away from the drilling site, and it was not visible from the home. Only Florida area homeowners were asked about this scenario. Thus, the difference could be attributable to a visual and possibly an auditory nuisance.

THE FIRST FRACKING SCENARIO (HEAVY)

Respondents to the group of surveys were asked to consider the following scenario:

The property is located at the edge of town. Last year, an energy company bought the rights to inject a pressurized mix of water, sand and chemicals into a lower groundwater aquifer to try to recover natural gas trapped under the property you are looking at buying. This is called hydraulic fracturing, or fracking. The drilling and injection equipment for this procedure is over one-quarter mile away, and is visible from the house. The house is on well water from a shallow aquifer, separate from the lower aquifer the natural gas is being recovered from. This process is expected to go on for five years. Except for this issue, the neighborhood is like yours, and the house is very similar to your house.

The bidding issue was determined by the following question: "Using the scale below, where −3 means you definitely would not bid and +3 means you would, how likely is it that you would make any offer on this home?"[30] Of the 194 Texas respondents to the fracking heavy scenario, only 26% expressed a willingness to offer any bid on this scenario. In other words, 74% of the respondents would not even consider living in the house described in this scenario. This latter percentage reflects the reduction in the market demand for this type of property. These results as well as all other fracking scenario findings are reported in Exhibit 4. Of those who bid, the following question was asked: "What is the most you would be willing to pay for the home?" Of the 66 Texas bids on this fracking heavy scenario (within ¼ mile, drilling site visible, possible groundwater contamination), the prices offered were discounted by amounts between 0% (that is, no discount, or full price) and 99.9%. The average bid discount (i.e., value loss) for the property affected by fracking was 34% (median bid 32%). However, not all these bids necessarily would be in the market. Due to search costs, and the smaller number of bidders, the chances are reduced that any of the potential bidders would find a suitable home and place a bid that would be accepted by a seller. On the other hand, hugely discounted "bottom fishing" (very low) bids would have little value in the market, because it is the bids with the smallest discounts that would get the attention of likely sellers and culminate in a sale.[31] For this case, due to the reduced percentage of potential buyers (34% willing to make any offer), we considered market-clearing bids in the top half of the market (average loss of 14%) and the top quarter of the market (average loss of 6%). In other words, for this first fracking scenario offered to Texans, the average discount of the top half of potential bidders is 20% where information about the refinery's recent history of airborne chemical releases is known. Moving to the same fracking heavy scenario offered to 177 Gulf Coast Floridians, 36% offered any bid, a higher percentage than for Texas respondents; however, the discounts were deeper: 50% was the average bid, with 29% as the average of the top half bid, and 15% as the average of the top quarter bid. Thus, petroleum-friendly Texans had smaller discounts of about 10% with respect to the fracking heavy scenario (e.g., 6% for top quarter vs. 15% for top quarter bids for Floridians), than did those from places where petroleum exploitation is less commonly accepted.

Exhibit 4
Residential Contingent Valuation Survey

BUSINESS PARK: Several stores 3 blocks away. No unpleasant or unattractive uses.

	% Bidding Scenario	Average Bid	Top Half Discount	Top Qtr. Discount
Texas (N = 194)	83%	15%	−1%	−3%
Florida (N = 360)	78%	20%	2%	−4%

LUST: Closed gasoline service station with leaking underground storage tanks (LUST); gasoline components including MTBE in groundwater, on subject property; house on municipal drinking water.

	% Bidding Scenario	Average Bid	Top Half Discount	Top Qtr. Discount
Texas (N = 194)	21%	47%	28%	16%
Florida (N = 360)	20%	59%	37%	24%

FRACKING: Hydraulic fracturing injection site ¼ mile away; house on well water, drill site visible.

	% Bidding Scenario	Average Bid	Top Half Discount	Top Qtr. Discount
Texas (N = 194)	26%	34%	14%	6%
Florida (N = 177)	36%	50%	29%	15%

FRACKING: Hydraulic fracturing injection site one mile away; house on well water, no mention of drill site.

	% Bidding Scenario	Average Bid	Top Half Discount	Top Qtr. Discount
Florida (N = 183)	37%	41%	17%	6%

Source: Authors' surveys.

THE SECOND FRACKING SCENARIO (LIGHT)

Floridian respondents (183 people) to the second fracking scenario were asked about the following situation:

The property is located at the edge of town. Last year, an energy company bought the rights to inject a pressurized mix of water, sand, and chemicals into a lower groundwater aquifer to try to recover natural gas trapped under the property you are looking at buying. This is called hydraulic fracturing, or fracking. The drilling and injection equipment for this process is a mile away, but is not visible from the house. The house is on well water from a shallow aquifer, separate from the lower aquifer the natural gas is being recovered from. This process is expected to go on for five years. Except for this issue, the neighborhood is like yours, and the house is very similar to your house.

Results based on 183 responses indicate that 68 respondents (about 37%) bid on the property described in this scenario, meaning that the corresponding reduction in market demand would be 63%. Of the 68 bids (home 1 mile from the drilling site out of view), the prices offered were discounted by amounts between 0% (that is, no discount, or full price) and nearly 100%. The average bid discount (i.e., value loss) for the property was 41%. The market-clearing bids in the top half of the market were an average loss of 17%, and in the top quarter of the market it was a 6% discount. Thus, for this fracking light scenario, for Floridians, the reported discounts were about ten percentage points lower than for the fracking heavy scenario, ¾ mile closer, and in view of the drilling site. Exhibit 4 shows the results of the residential survey.

ANALYSIS OF THE RESIDENTIAL CV SURVEY

The results demonstrate the relative undesirability of residences in fracking areas. Based on the contingent valuation survey results, only 26%–37% of prospective buyers with the information stated in the fact paragraph would bid to buy a home situated similarly to those in the fracking scenarios, and many of those that do bid would discount their offers so much that many sellers would probably refuse them, at least within a normal, reasonable marketing period. And perhaps permanently, in light of the stated reduction in market demand revealed in this survey. The expected loss on this example residential property near fracking sites would be 5% to 15% in a robust real estate market. If the market is weaker (fewer sales, mortgage foreclosure issues, etc.), losses could increase by another 10%. Texan homebuyers are less risk averse than Floridians (also by about 10%) and being within close proximity and view of the drilling site would likewise indicate a 10% greater discount than further away. This reduction in bid value is a way to measure the reduction in housing services, the flow of enjoyment from owner-occupied housing. It also typically assumes more complete information than is often the case among actual buyers and sellers of homes.

Conclusion

The oil and gas industry has accelerated efforts to extract because of improved technology. This field as an area of study is very new and the ability to confirm information and data is difficult with non-standardized industry practices. Case studies show a lack of coordination and disclosure of potential effects to the quite enjoyment of property. The short- and long-term effects are contested as interests aligned with economic benefits in contrast to health and property concerns. There is a need for impartial and uninfluenced review and input, which is hard to come by.

Survey results for markets in Texas and Florida evaluating the effects of fracking on residential property values show single-digit discounts in strong markets of what is perceived as petroleum-friendly places. In contrast, low double-digit discounts in places unfamiliar with petroleum extraction, illustrate the effect of a potential stigma and how the new lexicon "fracking" can influence public opinion.

There is an emerging focus on reducing the environmental impact of exploration for oil and gas. The questions for future research include the long-term implications of chemicals left underground, the air quality implications, the storage solution to flow-back materials such as toxic fracking fluids and radioactive materials, and health and safety concerns of nearby people.

There is a need to share best or improved practices in connection with fracking operations. These include site development or shrinkage, post reclamation, reuse and disposal practices for frack fluid, cutting the emissions from drilling operations, and the public review process. These reactions to the industry, policy changes, and effects on operations and real estate are for further study.

ENDNOTES

1. http://money.cnn.com/data/markets/. Last visited 5/3/13. Oil at the same date was $95.61 a barrel.
2. 1 million BTU's of energy is approximately 1 million cubic feet of gas.
3. http://www.bls.gov/news.release/pdf/laus.pdf. Last visited 8/18/12.
4. http://fracfocus.org/hydraulic-fracturing-how-it-works/history-hydraulic-fracturing.
5. http://fracfocus.org/hydraulic-fracturing-how-it-works/hydraulic-fracturing-process.
6. Directional and Horizontal Drilling, Natural Gas. http://www.naturalgas.org/naturalgas/extraction_directional.asp.
7. Information on Hydraulic Fracking, State of Colorado Oil and Gas Conservation Commission, Colorado Department of Natural Resources, http://cogcc.state.co.us/General/HydraulicFracturingInfoSheet.pdf.
8. Committee on Energy and Commerce, Chemicals used in hydraulic fracturing. Available at: http://democrats.energycommerce.house.gov/.
9. Chemicals Used in Hydraulic Fracturing (Report). Committee on Energy and Commerce U.S. House of Representatives. April 18, 2011. http://democrats.energycommerce.house.gov/sites/default/files/documents/Hydraulic%20Fracturing%20Report%204.18.11.pdf.
10. A legislative proposal in the U.S. Congress to define hydraulic fracturing as a federally regulated activity under the Safe Drinking Water Act.
11. EPA, Achievable Air Pollution Standards for Oil and Natural Gas/Half of fractured wells already deploy technologies in line with final standards, which slash harmful emissions while reducing cost of compliance, *EPA Issues Updated*, April 18, 2012.
12. Study: No 'significant health threats' from natural gas sites in Fort Worth. *Fort Worth Star-Telegram* July 15, 2011.
13. They include such substances as benzene, ethyl benzene, toluene, boric acid, monoethanolamine, xylene, diesel-range organics, methanol, formaldehyde, hydrochloric acid, ammonium bisulfite, 2-butoxyethanol, and 5-chloro-2-methyl-4-isothiazotin-3-one. Recently, in congressional testimony, drilling companies have confirmed the presence of many of these chemicals.
14. Http://www.epa.gov/hfstudy/.
15. Colorado Oil and Gas Conservation Commission Rules, Definitions (100 Series), as of April 1, 2012.
16. The bundle of rights also has a vertical spatial component. Surface rights are the most widely understood, and include the right to use the surface of the property subject to zoning,

building codes, covenants, and easements. The real estate bundle of rights is usually thought to apply most directly to the surface of the land. If someone deposits contamination on your soil without your permission, you have lost control of this part of your real estate rights. There are also subsurface rights which include the water, groundwater, and mineral rights under the property. In some rural areas mining and water rights are valuable. If someone allows hazardous material from their property to encroach on subsurface water or air pockets underneath your property, without your permission, it is toxic trespass. In some urban areas, this hazardous material may get into a basement and present a fire hazard. It would also be of concern to a lender, and make it less likely that a buyer could get a mortgage secured by the real estate. In rural areas, where property owners obtain their drinking water from private wells, the same issues apply, but the added risk of contamination of the drinking water means the health risk, through the drinking water pathway, is an issue. In addition the air rights above your land or building, extending at least up to the legal building limit or height, and in some cases beyond that. When someone allows hazardous substances or nuisance odors from their property to disperse into the air above your property, it is also a form of trespass. Where the airborne substances include hazardous or potentially noxious compounds, there is an associated health risk issue, through the breathing pathway. Where nuisance odors foul the air on your property, there is a loss in value related to the reduction in use and enjoyment of the property's outdoor features, and sometimes to the additional cost incurred to keep the nuisance odors from encroaching into the dwelling itself.

17. http://articles.marketwatch.com/2012-04-3/general/31335058_1_marcellus-shale-oil-rich-region-horizontal-drilling.
18. Ohio Department of Employment Services, 2012.
19. http://www.csuohio.edu/news/releases/2011/09/14931.html.
20. www.nofrackohio.com.
21. http://www.msetc.org/docs/EconomicImpactFINALAugust28.pdf.
22. http://extension.psu.edu/naturalgas/publications/economic-impact-study-in-5-counties/economic-impacts-of-marcellus-shale-in-susquehanna-county-employment-and-income-in-2010/view.
23. http://www.nofrackohio.com/quick-facts-on-fracking/.
24. ProPublica and *Vanity Fair*.
25. The Split Estate, Documentary film by Debra Anderson, 2009.
26. Study shows air emissions near fracking sites may have serious health impacts. @theForefront. Colorado School of Public Health. March 19, 2012. http://attheforefront.ucdenver.edu/?p=2546. Retrieved 25 April 2012.
27. As a research methodology, CV has well-documented limitations. If survey participants had a financial stake in the outcome of a specific case, they could bias their responses to questions to get money. Other survey participants could have issues with the polluter, and may give responses based on this instead of the facts presented to them. To avoid these threats, we did not name polluters, and there is no fracking litigation involved.

    Other respondents may be tempted to give certain answers to "please" the surveyors. This issue has been minimized by having the surveyors stick to a prearranged script. Also, some respondents may give answers that may not reflect their actions in real life because there are no consequences to providing responses to hypothetical questions (Rowe, d'Arge, and Brookshire 1980; and Mathews and Desvousges, 2002). This has been associated with a discrepancy between stated and revealed preferences (Jackson, in Kinnard, 2003).

Hypothetical bias is a validity threat that can include potential overbidding (resulting in smaller losses than might be expected), and potential underbidding, which could lead to bigger-than-expected losses. Some bidders facing this situation could overbid, and because of their lack of familiarity with environmental situations, trivialize the perceived risks, and artificial nature of the survey (compared to an actual transaction). This may underestimate the discount because an upper bid could in actuality pull out, whereas in a hypothetical situation they state that they would bid full value. The underbidding component is addressed by removing unreasonably low bids from the analysis, focusing instead on bids closer to full value, which would be more likely to be accepted by a seller. This top-of-the market approach employs marginal bids (as opposed to the average bid approach, which averages all bids). Two studies have compared revealed (actual sales) and stated preferences (surveys) for contaminated real estate. They found that stated (survey) techniques generate higher losses than actual sales outcomes, in the range of mid-single digits (Simons and Winson-Geideman, 2005; Simons and Saginor, 2006). This range gives an indication as to the potential order and magnitude of hypothetical bias. Therefore, while hypothetical bias is still a potential validity threat to CV research, we believe its effects are manageable.

28. The technique is also similar to that summarized in Simons (2006), and set forth in Simons, Saginor, Karam and Baloyi (2008), who used personal interviews but the same tabulation approach, and Simons and Saginor (2010), who applied the CV technique to commercial property.

29. For the business park scenario, 75%–82% of the respondents bid some amount, indicating only a modest reduction in market demand. The business park had little effect on the bid amount for the top quarter of bidders (those closest to full value), from a small premium of 2% to a slight loss of 3%. These results are used to calibrate the survey instrument to zero. For the gas station LUST scenario, the reduction in demand was substantial. Between 65% and 80% refused to offer a bid at all, with Florida respondents slightly less likely to bid. Among those that did bid on the LUST scenario, the extent of losses was between 15% and 25% for the top quarter of bidders, with Texas bidders closer to 15% and Florida bidders closer to a 25% discount. This is consistent with published survey results set forth in Simons and Winson-Geideman (2005), and is used to benchmark these survey results to the peer-reviewed literature. The detailed results are shown on Exhibit 4.

30. The bidding scale was designed to include negative values in part because the authors wanted respondents to consider the negative and positive aspects of housing characteristics. It was also used to separate those respondents who were paying attention and could also understand negative numbers in two initial ‘‘tripwire’’ (screening) questions. The authors are unaware of any potential behavioral biases that were induced by using this scale, which has been part of previous published literature of real estate damages.

31. While the number of participants may well decline, the intensity of the search may increase for bargain hunters, thus altering the dynamics of the marketplace and ultimately the equilibrium price and transactions volume levels.

REFERENCES

Anderson, O.L. Subsurface Trespass: A Man’s Subsurface is Not His Castle. *Washburn Law Journal*, 2010, 49:2, 247–81.

Bateman, C. A Colossal Fracking Mess. The Dirty Truth Behind the New Natural Gas. *Vanity Fair*, June 21, 2010. http://www.vanityfair.com/business/features/2010/06/fracking-in-pennsylvania-201006.

Brown, V.J. Industry Issues: Putting the Heat on Gas. *Environmental Health Perspectives*, 2007, 115:2, A76.

EPA. Achievable Air Pollution Standards for Oil and Natural Gas. Half of fractured wells already deploy technologies in line with final standards, which slash harmful emissions while reducing cost of compliance, *EPA Issues Updated,* April 18, 2012.

Fitz, Patrick, K. Ensuring Safe Drinking Water in the Age of Hydraulic Fracturing. November 17, 2011. http://sites.duke.edu/sjpp/2011/ensuring-safe-drinking-water-in-the-age-of-hydraulic-fracturing/.

Gardner, T. Water Safe in Town Made Famous by Fracking-EPA. *Reuters*. 5/11/2012. http://uk.reuters.com/article/2012/05/11/usa-fracking-dimock-idUKL1E8GBVGN20120511.

Krause, A., R. Throupe, J. Kilpatrick, and W. Speiss. Contamination, Trespass & Underground Rents. J*ournal of Property Investment and Finance*, 2011, 30:3, 304–20.

Lipscomb, Clifford, Max Kummerow, Will Spies, Sarah Kilpatrick, John Kilpatrick, Contingent Valuation and Real Estate Damage Estimation. *Journal of Real Estate Literature*, 2011 283–305.

Lipscomb, C. Using Contingent Valuation to Measure Property Value Impacts. *Journal of Property Investment and Finance*, 2011, 29:4/5, 448–59.

Lustgarten, A. Buried Secrets: Is Natural Gas Drilling Endangering U.S. Water Supplies? *ProPublica*, November 13, 2008.

Mathews, K. and W. Desvousges. The Truth The Partial Truth and Anything But The Truth: Survey Reliability and Property Valuation. Working paper by Triangle Economic Research Co., Presented at the Symposium on Environmental and Property Damages: Standards, Due Diligence, Valuation and Strategy, Toronto Canada, 2002.

Mitchell, R.C. and R.T. Carson. Using Surveys to Value Public Goods: The Contingent Valuation Method. Washington, DC: *Resources for the Future*, 1989.

Mundy, B. The Impact of Hazardous and Toxic Material on Property Value. *The Appraisal Journal*, 1992a, October, 463–71.

——. Stigma and Value. *The Appraisal Journal*, 1992b, 61:1, 7–13.

Mundy, B. and D.G. McLean. Adding Contingent Valuation and Conjoint Analysis to the Required Body of Knowledge for the Estimation of Environmental Damages to Real Property. *Journal of Real Estate Practice and Education*, 1998a, 1:1, 1–19.

——. Using the Contingent Value Approach for Natural Resource and Environmental Damage Applications. *The Appraisal Journal*, 1998b, 66:3, 290–97.

Phillips, S. EPA Blames Fracking for Wyoming Groundwater Contamination. *State Impact Pennsylvania*. WITF, WHYY & NPR. December 8, 2011. http://stateimpact.npr.org/pennsylvania/2011/12/08/epa-blames-fracking-for-wyoming-groundwater-contamination/.

Rowe, R.D., R.C. d'Arge, and D.S. Brookshire. An Experiment on the Economic Value of Visibility. *Journal of Environmental Economics and Management*, 1980, 7, 1–19.

Rubinkam, M. Associated Press, EPA: Dimock PA. Water Quality Initial Tests Results Revealed. March 15, 2012. http://www.huffingtonpost.com/2012/03/16/epa-dimock-pa_n_1350446.html.

Seale, R. Open Hole Completion Systems Enables Multi-stage Fracturing and Stimulation Along Horizontal Wellbores. *Drilling Contractor*, July/August 2007. http://drillingcontractor.org/dcpi/dc-julyaug07/DC_July07_PackersPlus.pdf.

Simons, R.A. Settlement of an Oil Pipeline Leak with Contaminated Residential Property: A Case Study. *Real Estate Issues*, 1999a, 24:2, 46–52.

——. The Effects of Oil Pipeline Ruptures on Non-Contaminated Easement-Holding Property. *The Appraisal Journal*, 1999b, 67:3, 255–63.

——. Estimating Proximate Property Damage from PCBs in a Rural Market: A Multiple Techniques Approach. *The Appraisal Journal*, 2002, 70:4, 388–400.

——. When Bad Things Happen to Good Property. Washington DC: Environmental Law Institute Press, 2006.

Simons, R.A., J. Saginor, A. Karam, and H. Baloyi. Use of Contingent Valuation Analysis in a Developing Country: Market Perceptions of Contamination on Johannesburg's Mine Dumps. *International Real Estate Review*, 2008, 11:2, 75–104.

Simons, R.A. and J. Saginor. Determining Offsite Damages to Non-residential Property from Leaking Underground Storage Tanks. *International Real Estate Review*, 2010, 13:2, 134–56.

Simons, R.A., W. Bowen, and A. Sementelli. The Effect of Underground Storage Tanks on Residential Property Values in Cuyahoga County, Ohio. *Journal of Real Estate Research*, 1997, 14:1/2, 29–42.

——. The Price and Liquidity Effects of UST Leaks from Gas Stations on Adjacent Contaminated Property. *The Appraisal Journal*, 1999, 67:2, 186–94.

Simons, R.A. and R. Throupe. An Exploratory Review of the Effects of Toxic Mold and Real Estate Values. *Appraisal Journal*, 2005, 73:2, 156–66.

Simons, R.A. and K. Winson-Geideman. Determining Market Perceptions on Contamination of Residential Property Buyers Using Contingent Valuation Surveys. *Journal of Real Estate Research*, 2005, 27:2, 193–220.

Urbigkit, C. Ozone Mitigation Efforts Continue in Sublette County, Wyoming. *Wyoming's Energy News*, March 10, 2011.

Wilde, L., C. Loos, and J. Williamson. Pipelines and Property Values: An Eclectic Review of the Literature. *Journal of Real Estate Literature*, 2012, 20:2, 245–59.

Ron Throupe, University of Denver, Denver CO 80208 or rthroupe@du.edu.

Robert A. Simons, Cleveland State University, Cleveland, OH 44122 or R.simons@csuhio.edu.

Xue Mao, University of Denver, Denver CO 80208 or mm.xuer@gmail.com.