ENVIRONMENTAL WORKING GROUP

Cracks in the Façade

25 Years Ago, EPA Linked "Fracking" to Water Contamination

Dusty Horwitt, Senior Counsel, Environmental Working Group

August 3, 2011

Contents

Background

Illustrations

Acknowledgments

EWG's Cracks in the Façade was made possible thanks to the generosity of the Park Foundation, Civil Society Institute and EWG's community of online supporters.

Our thanks to EWG's staff designer Aman Anderson for his work in layout and illustration, Tylan Yalniz for his work in designing the report's website and interns James Meinert and Justine Chow for their research.

The opinions expressed in this report are those of the authors and editors and do not necessarily reflect the views of our supporters. EWG is responsible for any errors of fact or interpretation contained in this report.

EXECUTIVE SUMMARY

25 Years Ago, EPA Linked "Fracking" to Water Contamination

In 2006, a Dallas-based company riding a nationwide natural gas boom drilled and hydraulically fractured a gas well in a sandstone and shale formation in Jackson County, W. Va. Just after EXCO Resources fractured the well, area residents said that two nearby water wells became polluted.[1]

"When the water actually went bad was after they fractured," says Paul Strohl, 69, a retired firefighter who lives in Jackson County.

"Even the consistency changed," said his wife Janet, 67. "It was slimy."

After the problems surfaced, Paul Strohl says, Tyler Mountain Water, a company based in Poca, W. Va., began delivering water to the affected residents. "After they fracked, this water truck started showing up delivering water. I don't think it takes more than a third-grade education to figure out what that means."[2]

The landowners whose water wells were involved in the incident have declined to comment, saying they signed confidentiality agreements with EXCO. The Strohls' account bears striking similarities to a report issued almost 25 years ago by the Environmental Protection Agency, which concluded that hydraulic fracturing (colloquially known as "fracking") could – and did – contaminate underground drinking water sources. That all-but-forgotten report from December 1987, uncovered by Environmental Working Group and Earthjustice, contradicts the drilling industry's insistence that there has never been a documented case of groundwater contamination caused by hydraulic fracturing.

Used in more than 90 percent of natural gas and oil wells, fracking involves injecting a mix of water, sand and chemicals into a well under high pressure in order to fracture underground rock formations and unlock trapped gas and oil.

EPA's long-ignored 1987 report found that fracturing fluid from a shale gas well more than 4,000 feet deep had contaminated well water just across the road from the Strohls' home, that the contamination was "illustrative" of the types of pollution associated with natural gas and oil drilling, and that EPA's investigation had been hampered by confidentiality agreements between industry and affected landowners.

Since then, the industry has hydraulically fractured hundreds of thousands of wells and is continuing a historic push into natural gas-bearing shale formations, once considered inaccessible, that lie beneath populated areas in a number of states, including West Virginia, New York, Pennsylvania, Ohio, Michigan, Louisiana and Arkansas. To access these formations, drillers often use a relatively new combination of horizontal drilling and higher-volume fracturing. As drilling activity has intensified, reports of pollution have sparked a growing national debate over the actual or potential environmental risks, including contamination of groundwater, the source of drinking water for more than 100 million Americans, according to the U.S. Geological Survey.[3] As the West Virginia case and others like it indicate, the risk of groundwater contamination is greatly increased because decades of oil and gas exploration have left many regions of the country riddled with thousands of abandoned and often poorly sealed wells. Government and industry studies show that fracking fluids from new wells can potentially infiltrate these older bores and rise back up to the level of drinking water aquifers closer to the surface.

In the debate over these risks, EPA and Congress have never cited the agency's own 1987 report and have largely exempted fracturing from regulation.

"During the fracturing process," EPA investigators wrote in the 1987 report, which focused on the handling of natural gas, oil and geothermal wastes generally, "fractures can be produced, allowing migration of native brine, fracturing fluid and hydrocarbons from the oil or gas well to a nearby water well. When this happens, the water well can be permanently damaged and a new well must be drilled or an alternative source of drinking water found."[4]

In an introduction to the chapter on contamination cases, including the case in Jackson County, the EPA noted that "within each [geographic] zone, the report presents one or more categories of damages that EPA has selected as fairly illustrative of practices and conditions within that zone."[5]

Industry representatives reviewed EPA's report and appeared to reach different conclusions about the case.

In the EPA docket center in Washington, EWG discovered comments submitted by the American Petroleum Institute (API), the natural gas and oil industry's major trade association. Although API was generally critical of EPA's investigation, calling it "inaccurate" and "careless,"[1] API did not specifically dispute EPA's conclusions about the West Virginia case in several written comments. Indeed, the industry's comments indicate that the association agreed with EPA that the case involved contamination of groundwater as a result of fracturing.

"One case," the API wrote, referring to the West Virginia contamination case, "resulted in a workover operation fracturing into groundwater as a result of equipment failure or accident. As described in the detail write-up this is not a normal result of fracturing as it ruins the productive capability of the wells." Another document attached to API's comment noted that in the West Virginia case "the damage here results from an accident or malfunction of the fracturing process….The process requires the fractures to be created to be limited to the producing formation. If they are not as is the apparent case here oil and gas are lost from the reservoir and are unrecoverable."[6]

A group of state oil and natural gas associations took a different approach in comments submitted to EPA in 1988. "EPA is incorrect in its statement that the fracturing of a well can result in contamination of nearby water wells…." the associations wrote. "Such a statement is completely without support in the study. In fact, we know of no case where this has occurred given proper casing. The zones which are fractured are several thousand feet below the deepest fresh water zones making contamination of the fresh water zones extremely unlikely."[7]

Environmental Working Group recently conducted its own year-long investigation and concluded that a variety of evidence indicates that the West Virginia case was indeed an example of hydraulic fracturing pollution of groundwater, though it could not rule out that another stage of the drilling process could have caused the problem.

A former EPA official who worked on the 1987 report and asked not to be named said that the agency was aware of other cases of groundwater pollution involving hydraulic fracturing but did not include them in the report because the details were sealed under confidential legal settlements reached between affected property owners and energy companies. The 1987 document noted that such settlements often presented hurdles for the EPA's investigation.

"Private citizens rarely bring cases to court because court cases are expensive to conduct," the EPA reported, "and most of these cases are settled out of court…. In addition to concealing the nature and size of any settlement entered into between the parties, impoundment curtails access to scientific and administrative documentation of the incident."[8]

The former official said the EPA identified other cases of groundwater contamination caused by fracturing but excluded them from the report because they involved pollution by migrating natural gas or oil, not by the chemical-laced fluids injected in the fracking process itself. Contamination by leaking natural gas and oil was considered outside the scope of the report, which focused only on the management of wastes from the natural gas, oil and geothermal industries. The report also noted that because EPA had only three months to collect cases from across the nation, "there was limited time available for damage case review."[9] The former EPA official explained that EPA had to complete the study quickly because the agency had missed a Congressionally mandated deadline and was working under a court-ordered timetable.

Both the 2006 incidents in West Virginia and the 1987 EPA study, which involved dozens of documented incidents of apparent contamination by fracking, drilling wastewater stored in pits and other drilling techniques, raise new questions about the agency's commitment to protecting the public as it pursues its current two-year study of hydraulic fracturing's risks.

Inexplicably, the EPA failed to mention its own finding when it produced a second report in 2004, a document that an internal whistleblower sharply criticized for its lack of scientific rigor and for relying on a review panel stacked with current or former industry employees.[10] The 2004 analysis concluded that hydraulic fracturing in coal bed methane natural gas wells, a relatively small subset of natural gas and oil wells, posed no risks to underground water supplies. The study set the stage for a Congressional vote in 2005 that legally exempted fracking for all types of natural gas and oil wells from regulation under the federal Safe Drinking Water Act, a law specifically designed to prevent contaminants injected underground from migrating through abandoned natural gas and oil wells.[11]

In its 2004 report, the EPA announced that it was limiting its review to coal bed methane wells in large part because such wells "tend to be shallower and closer to [underground sources of drinking water] than conventional oil and gas production wells" and "EPA has not heard concerns from citizens regarding any other type of hydraulic fracturing."[12]

It made that decision despite the findings of its own 1987 report on the West Virginia case, which found that hydraulic fracturing for natural gas in a shale deposit more than 4,000 feet deep had polluted a water well only 400 feet from the surface.

EWG's investigation also turned up recent industry and government reports that sharpen concerns about fracturing and may help explain the West Virginia case featured in the EPA's report. These documents show that fractures from one well can spread unpredictably and are known to have caused fracturing fluid to migrate into other nearby natural gas and oil wells, sometimes known as "offset wells."

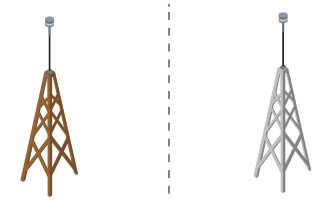
"Fractures are usually enormous features," wrote engineer and drilling industry consultant M.C. Vincent in a paper that he presented at a hydraulic fracturing conference held near Houston in January 2009. "In many reservoirs, fractures are mapped to extend beyond 1,000 feet (half-length) from the wellbore. In some reservoirs, half-lengths exceeding 2,200 feet have been confirmed as treatments have broken into offset wellbores…"[13]

State regulators in Illinois and Texas, as well as Congress' investigative arm, the Government Accountability Office, have also documented contamination problems caused when oil and gas waste fluids injected underground for disposal migrated up nearby older wells and broke out near the surface, where groundwater is found, a phenomenon sometimes called "saltwater breakout."[14] One case in Texas involved fluid that traveled half a mile underground from an injection well and then migrated up through an old, improperly plugged well.[15] There were four abandoned natural gas wells within about 1,700 feet of the gas well and water well involved in the West Virginia case documented by the EPA in 1987.

Currently, both EPA and the Department of Energy are reviewing the environmental risks of hydraulic fracturing. These multiple pieces of independent evidence underscore how essential it is that both agencies tackle these issues in a far more thorough way than EPA did in its cursory and deeply flawed 2004 review.

EPA Traced Pollution of Underground Water Supply to Hydraulic Fracturing

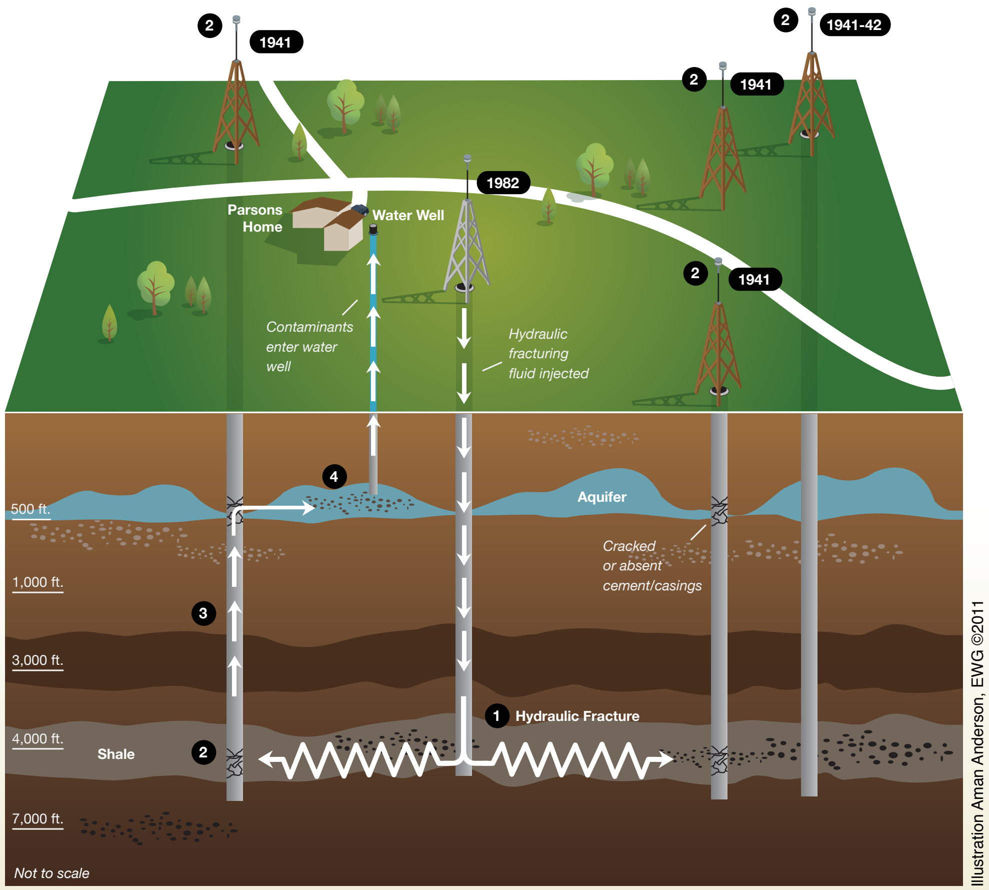
In 1982, Kaiser Gas Co. drilled and hydraulically fractured a natural gas well on the property of James Parsons in Jackson County, W. Va. The EPA concluded in a 1987 report to Congress that the process contaminated Parsons' water well with fracturing fluid. It is unclear how the "fracking" fluids may have entered the water well, but four old natural gas wells nearby could have been the conduits for contamination.



Old Well
Drilled 1941-42

New Well
Drilled 1982

Jackson County, WV



1 Hydraulic Fractures

According to industry studies, hydraulic fractures can extend up to 2,500 feet horizontally, well within range of old natural gas wells near Parsons' property. Studies found that fractures have broken into nearby oil and gas wells and that fracking fluid has migrated up old wells to the surface.

2 1940s Wells Nearby

Four old natural gas wells were located within 1,700 feet of the gas well drilled on James Parsons' property. Each of the wells was "shot," an early fracturing process in which companies detonated explosives inside a well to help access gas or oil deposits.

3 Fluid Migration

Government studies have found that oil and natural gas waste fluids injected underground can migrate up old oil and natural gas wells.

4 Breakout into Aquifer

These fluids can break into aquifers near the surface if the old wells have deteriorated casings, lack cement plugs or contain cracked cement. This phenomenon is known as "salt water breakout." It is possible that hydraulic fracturing fluids migrated in a similar way into Parsons' water well.

EPA Report Contradicts Industry Claims

Fracturing in the drilling industry dates to the 1800s, when companies began exploding glycerin or dynamite deep inside their wells to open passages through which natural gas or oil could flow more rapidly into drilling pipes for collection. In 1947, drillers for the first time used hydraulic fracturing on a gas well operated by the Pan American Petroleum Corp. in Kansas, and the process is now used in more than 90 percent of natural gas and oil wells.[16]

In hydraulically fracturing a well today, also known as "stimulating" it, drillers inject a mix of water, sand and chemicals (some of them toxic) under extremely high pressure. The process, which uses anywhere from tens of thousands to millions of gallons of fluid, creates new fractures in the rock or re-opens pre-existing natural fractures. The sand props the fractures open, dramatically increasing production. The chemicals facilitate various aspects of the process, including helping to thicken the fluid so that sand can be carried farther into the fractures.[17]

The industry maintains that hydraulic fracturing has never contaminated groundwater. "To our knowledge, there have been a million wells fracked, and no documented cases of contamination of groundwater from hydraulic fracturing," Exxon CEO Rex Tillerson told the House Energy and Commerce Committee in January 2010, echoing other industry representatives.[18]

"In its 60-year history, hydraulic fracturing has not resulted in a single case of water contamination – a fact reinforced by the Environmental Protection Agency," wrote Lee Fuller, executive director of Energy In Depth, an industry-backed website, and vice president of government relations for the Independent Petroleum Association of America, in a 2010 letter to the Ithaca (N.Y.) Journal.[19]

A 1987 Environmental Protection Agency report tells a different story.

In concluding that hydraulic fracturing can – and did – contaminate groundwater, the EPA detailed its investigation of a contaminated water well on land owned by James Parsons of Ripley, W. Va., a town of 3,300 in Jackson County, halfway between Charleston and Parkersburg. The case summary reads:

> *In 1982, Kaiser Gas Co. drilled a gas well on the property of Mr. James Parsons. The well was fractured using a typical fracturing fluid or gel. The residual fracturing fluid migrated into Mr. Parson's water well (which was drilled to a depth of 416 feet), according to an analysis by the West Virginia Environmental Health Services Lab of well water samples taken from the property. Dark and light gelati-*

nous material (fracturing fluid) was found, along with white fibers. (The gas well is located less than 1,000 feet from the water well). The chief of the laboratory advised that the water well was contaminated and unfit for domestic use, and that an alternative source of domestic water had to be found. Analysis showed the water to contain high levels of fluoride, sodium, iron and manganese. The water, according to DNR officials, had a hydrocarbon odor, indicating the presence of gas. To date Mr. Parsons has not resumed use of the well as a domestic water source. (API states that this damage resulted from a malfunction of the fracturing process. If the fractures are not limited to the producing formation, the oil and gas are lost from the reservoir and are unrecoverable.)

Parsons Well Was Drilled and Fractured

On Aug. 8, 1982, according to records on file with the West Virginia Office of Oil and Gas, the state issued a permit to Ravenswood, W. Va.-based Kaiser Exploration and Mining Co. to drill a natural gas well on the Parsons property. By Aug. 25, Kaiser had bored through ten layers of shale, limestone and sandstone to complete the 4,572-foot-deep well, which reached a Devonian Brown Shale formation that is similar to the shale formations where companies are drilling for natural gas today. The company was seeking to extract gas from a "pay zone" between 4,216 and 4,364 feet underground, nearly 4,000 feet beneath Parsons' water well but less than two football fields away horizontally.[20]

On Aug. 31, Kaiser fractured the well in the pay zone with more than 13,000 gallons of water, 60,000 pounds of sand and 760,000 standard cubic feet of nitrogen injected at a pressure of up to 3,100 pounds per square inch.[21] [By comparison, water generally flows through a fire hose at between 100 and 150 pounds per square inch.[22]]

West Virginia state records show that Kaiser used three layers of casing and cement to seal the new gas well from adjacent rock formations and that Jerry Tephabock, a state inspector, checked the well three years later and found the casing and cement to be in compliance with state standards (State records do not reflect any earlier inspection of the casing and cement).[23] Prior to reviewing documents associated with the case, EWG spoke briefly with Tephabock by telephone, but he did not comment substantively. Tephabock did not respond to two later calls seeking comment.

Parsons' water well was lined with a steel casing, according to a state well inspection form and a lawsuit Parsons later filed.[24]

Gas, Gel in Parsons' Water Well

A year and a half after Kaiser fractured the gas well, Parsons' well water became polluted.

Parsons declined to speak to EWG about the incident, citing privacy concerns, but a well inspection form completed in June 1984 by the West Virginia Department of Mines Office of Oil and Gas reported that a problem first developed in "March-April" 1984 when someone (the form does not say who) smelled a rotten egg odor coming from the water well. In June, there were white fibers and natural gas in the water. "Gas in water well…will burn at vent tube," the state report said.[25]

On Oct. 2, 1984, Michael Lewis, an engineer with the West Virginia Office of Oil and Gas, wrote in a letter to Parsons that "the well drilled on your property by Kaiser could have been a possible source of contamination as you have suggested. The Office of Oil and Gas, however, can not determine fault or liabilities in such a matter. State law does address this matter in Code 22-4-19, which says 'there shall be a rebuttable presumption that any oil or gas well drilled within 1000 feet of a water supply is the proximate cause of contamination or deprivation of such water supply'… I know you are concerned about compensation for your trouble and expenses incurred with the water problems. The Office of Oil and Gas has no means of awarding you compensation. Should you feel that Kaiser's well was indeed the source of contamination to your water and that they, therefore, owe you compensation and will not pay, your only recourse is to file a civil suit for damages. In such an action, Code 22-4-19 is applicable and for your protection."[26]

The West Virginia Department of Public Health's Environmental Health Services Lab collected and tested five samples of Parsons' well water between June and November 1984.[27] On Nov. 8, James E. Rosencrance, chief of the lab, wrote to Perry Merritt, a water official in Jackson County, regarding tests on three of the samples:

> *"… an evaluation of the three reports (copies enclosed) would indicate that this water supply is contaminated from a chemical point of view, which may have resulted from oil and gas drilling operations in the vicinity of the Parsons water supply. It is not unusual to find high alkalinity, high fluoride, high sodium and high total dissolved solids in the underground water in that particular area of Jackson County, but is (sic) would be unusual to find the gelatinous material which we isolated unless it had been used by the drilling industry. This laboratory has identified the presence of hydrocarbons in one of the samples, which is indicative of petroleum type products. The laboratory is not familiar with the chemical characteristics of this well previous to the samples analyzed in July, August and*

September of 1984. Any attempt to filter the water would be futile since the gelatinous material would clog the filter in a very short period of time. Such things as sodium, fluoride, high alkalinities and extraneous materials are not easily removed in home type supplies. A new source of water is suggested for the Parsons residence.[28]

In one of the lab reports, Rosencrance typed, "The gelatinous material in this sample is not of bacterial origin. It does appear to be a gel type material and perhaps used as a sealant in the oil and gas drilling industry. Microscopi[c] exams rule out bacterial populations."[29] In another report, Rosencrance described "dark and light gelatinous material indicative of a gel."[30] In a third report, he noted: "Microscopic examination reveals large glossy gelatinous masses indicative of a gel. There were numerous rod-shaped particles present which were not readily distinguishab[le] as a nuisance bacterial growth. The…odor is of a putrefying description."[31]

According to legal records in the Parsons case, Kaiser commissioned BCM, a company based in Dunbar, W. Va., to conduct its own test of Parsons' well in November 1984. In March 1985 it commissioned a second test by NOWSCO Well Service Ltd., based in Calgary, Canada. NOWSCO concluded that "these results are indicative of very fresh water… no contamination from frac water is evident in the sample from the water well." The BCM report did not draw a conclusion.[32]

BCM, NOWSCO and the West Virginia state lab did not report testing for benzene, toluene, ethylbenzene or xylene (known as BTEX), common pollutants in drilling and fracturing, nor did they report testing the chemical composition of the gel.[33] An employee at BCM's office in Plymouth Meeting, Penn., said the company no longer has a laboratory and she did not know how to reach those who worked for the lab in the 1980s. NOWSCO is now owned by B.J. Services, one of the world's largest hydraulic fracturing companies, according to a representative who answered the phone at NOWSCO's former office in Calgary. A phone message left last November for one of the NOWSCO representatives listed on the lab report was not returned.

On April 3, 1985, Rosencrance wrote to Parsons that "it is our understanding that a gas well was fractured within 600 feet of your water well and may be involved with the pollutants found in the water. There are no funds or programs available within the State of West Virginia which would financially assist you in correcting the pollution problem with your well water."[34] Rosencrance died on June 24, 1999, according to an obituary in the Charleston Gazette.[35]

On Feb. 4, 1986, Parsons and his wife, N. Ruth Parsons, filed suit against Kaiser in the Circuit Court of Jackson County, W. Va., seeking $50,000 (equivalent to $100,000 today) in compensation for damages to their water well, according to court records. Kaiser denied the charges. On May 29, 1987, the parties agreed to an undisclosed settlement and the case was dismissed.[36]

R.A. Pryce, the agent for Kaiser Gas listed in the state records, passed away several years ago, said his son, Lance, in a telephone interview.[37] According to state records, Kaiser has been taken over by a succession of companies since it drilled the well on Parsons' property. It is now owned by Dallas-based EXCO Resources (WV) Inc. Larry Sanders, the regulatory manager for EXCO, told EWG in November 2010, that he had passed questions about the company's past and present drilling operations to EXCO's legal department. The legal department has not responded.

On the same day that the Parsons settled with Kaiser, Ted M. Streit, deputy director of West Virginia's Inspection and Enforcement Division, said in a letter to a lawyer representing several state oil and gas associations, including the West Virginia Oil and Natural Gas Association, that as a result of Parsons' case, the state had discovered a previously unknown source of fresh water underground near Parsons' water well and had implemented tougher requirements for cementing oil and natural gas wells nearby.[38]

Gel in Water Consistent with Fracturing

While the West Virginia lab did not conclude that hydraulic fracturing caused the contamination of Parsons' well, the gel found in the water is consistent with contamination from hydraulic fracturing fluid. Drilling companies have used gels in hydraulic fracturing since the process was first developed in 1947, bolstering the EPA's conclusion that the gel in Parsons' water came from fracturing. In the Stimulation Treatment Handbook, published by PennWell Books in 1985, chemist and industry consultant John W. Ely wrote that, "The first fracturing fluid, utilized in the late 1940s, was war surplus napalm. Napalm is an aluminum gel used to thicken gasoline." In the 1960s, Ely wrote, companies began using guar, an additive found in food, to make fracturing gels. Ely noted that "this material was also marketed as the toy called 'Slime'".[39]

According to the EPA's 2004 study, gels are important in fracturing fluid because they can carry sand or other "proppants" deeper into rock fractures than water alone. Proppants literally prop open the fractures to prevent them from closing. "Diesel fuel has been frequently used in lieu of water to dissolve the guar powder because its carrying capacity per unit volume is much higher," the EPA found.[40]

The fact that Kaiser reported using nitrogen could mean that the company used a nitrogen-based foam, called a "foamed gel" by EPA in 2004. The agency noted that "the most widely used foam fracturing fluids employ nitrogen or carbon dioxide as their base gas… foaming agents can be used in conjunction with gelled fluids to achieve an extremely effective fracturing fluid."[41] Richard Morris, who inspected the gas well drilled by Kaiser in 1982 when he worked for the West Virginia Oil and Gas Division, said he did not recall details about the well, but that the fracturing mix would likely have contained a gelling agent, along with nitrogen, water, sand and foam. He added that while it is possible that hydraulic fracturing caused the contamination, he believes another explanation is more likely. Morris left the state agency later that year to open his own natural gas and oil drilling company.[42]

The hydrocarbons in Parsons' water could be explained if Kaiser used diesel or other petroleum distillates in its fracturing fluid. Officials in Pennsylvania and New York report that companies currently use a variety of petroleum distillates in fracking fluid.[43] A liquid hydrocarbon called "condensate," which typically comes to the surface with natural gas and contains carcinogenic benzene, could also have accounted for the hydrocarbons and "putrefying odor" in Parsons' well. Marathon, a natural gas and oil company, has reported that "condensate sour" smells like rotten eggs, a smell similar to that reported by West Virginia inspectors.[44]

Aquagel: An Alternative Explanation

Former West Virginia inspector Morris said that while it is possible that the gel in Parsons' water came from hydraulic fracturing fluid, he believes that an underground limestone layer would have prevented the fluid from migrating upward enough toward the surface to enter an aquifer. A more likely explanation for the contamination, he said, is that the material in Parsons' water was Aquagel, a mixture of bentonite clay and water. Companies regularly inject Aquagel into a well bore after drilling is complete to remove loose rock cuttings, he said. These cuttings can prevent cement from forming a tight bond with the adjacent rock when drillers subsequently cement a well's steel casing into place. Morris said the aquagel could have migrated into the underground aquifer before the company installed the layers of casing and cement to protect the aquifer from drilling fluids.[45] Maurice Dusseault, a professor at the University of Waterloo in Ontario who specializes in rock mechanics and is a member of the Society of Petroleum Engineers, said that this explanation is, indeed, possible.

The only way to know the exact source of the gel would have been to test it and compare it to the aquagel and the fracking fluid. However, there is no record that West Virginia's or Kaiser's scientists conducted such testing. If they had, they would have had to know the composition of

Kaiser's fracking fluid for comparison – information that companies have routinely kept secret.

Were Older Wells the Source?

Morris and Dusseault also said, however, that the water contamination could have come from hydraulic fracturing fluid that migrated into nearby abandoned gas wells that had not been properly plugged and cased to seal them off. From there, the fluid could have traveled up the wells, broken out near the surface and migrated into the aquifer serving Parsons' water well. In the 1980s, the EPA, state regulators in Illinois and Texas, and Congress' investigative arm, the Government Accountability Office, all highlighted this type of contamination from the injection of natural gas and oil industry waste fluids into underground disposal wells.[46] There are four old natural gas wells dating to the 1940s within 1,700 feet of the gas well drilled on Parsons' property in 1982 – well within range of hydraulic fractures, according to modern industry and government studies.

In its 1987 report, the EPA noted the risk of contamination via old wells, citing Illinois' investigation of drilling pollution. "To avoid degradation of ground water and surface water, it is vital that abandoned wells be properly plugged," the EPA noted. "Plugging involves the placement of cement over portions of a wellbore to permanently block or seal formations containing hydrocarbons or high-chloride waters (native brines). Lack of plugging or improper plugging of a well may allow native brines or injected wastes [from a waste fluid disposal well] to migrate to freshwater aquifers or to come to the surface through the wellbore."[47]

The EPA did not specifically address the risk of contamination via old wells as a result of hydraulic fracturing, but both hydraulic fracturing and injection disposal wells involve underground injection of fluid under pressure.

In the files for EPA's 1987 report at the EPA headquarters in Washington, D.C., is a 1985 study from the Texas Department of Agriculture (TXDA), which investigated 4,658 complaints related to natural gas and oil production. "When a water well is experiencing an oilfield pollution problem (typically, high chlorides)," the Texas agency found, "the pollution source is often difficult to track down. The source could be a leak in the casing of a disposal well, leakage behind the casing due to poor cement bond, old saltwater evaporation pits, or, most often, transport of contaminants through an improperly plugged abandoned well" (underscore in original).[48]

In 1989, the General Accounting Office (now the Government Accountability Office) found that "if these abandoned wells are not properly plugged – that is, sealed off – and have cracked casings, they can serve as pathways for injected brines [waste fluids from natural gas and oil drilling] to enter drinking water. Because groundwater moves very slowly, any contaminants that enter it will remain concentrated for long periods of time, and cleanup, if it is technically feasible, can be prohibitively costly."[49]

According to a 1999 report from the Department of Energy, there were then approximately 2.5 million abandoned oil and natural gas wells in the U.S.[50] At least tens of thousands of these abandoned wells are located in states that are home to shale formations that companies have been targeting in recent years for natural gas. According to 2010 data supplied by the West Virginia Geological and Economic Survey, there are nearly 39,000 documented abandoned wells in that state.[51] New York's Department of Environmental Conservation estimates that 75,000 wells have been drilled in the state since the 1820s and that about half are undocumented.[52]

The Pennsylvania Department of Environmental Protection estimates that 325,000 natural gas and oil wells have been drilled in that state since 1859. Of these, about 130,000 are currently operating, 47,000 are known to be plugged and about 8,500 are unplugged. The status of the remaining estimated 185,000 wells is either partially documented or unknown.[53] In Ohio, according to 2011 data from the Ohio Department of Natural Resources, there were about 64,000 documented plugged or abandoned natural gas and oil wells and 40,000 wells of unknown status.[54]

Dusseault said that, in general, it is "highly improbable" that hydraulic fractures could intersect with an abandoned well and cause contamination, noting that it would take a complex series of events for this to occur. First, companies would have to have used enough fluid to create a fracture that extended as far as an adjacent well. The odds of such long fractures are probably greater in shale formations such as the one involved in Parsons' well, he said, because shale has few pores into which fluid can leak off; all or most of the fluid is channeled into the fracture. Second, fractures tend to spread in just one direction, depending on the formation in which a well is located, reducing the odds that a fracture would spread in the very direction of an abandoned well. Third, the old well would have to be improperly plugged, enabling fluid to migrate and break out into an aquifer. And last, the fracturing fluid or other contaminants would have to have enough force to make it from the bottom of the old well to the aquifer.

"Those things put together make it improbable," he said. However, he added that in the case of the Parsons well, in which there were multiple abandoned wells in several different directions, "your probability of intersecting those wells has just gone up tremendously."

Four Old Wells Within 1,700 Feet

According to digital latitude and longitude data and satellite maps provided by the West Virginia Geological and Economic Survey (WVGES), when Kaiser drilled its gas well in 1982 on the Parsons' property, there were four abandoned gas wells within 1,700 feet – well within the documented distance that hydraulic fractures can spread. One of the old gas wells was drilled in 1941 less than 1,100 feet north of the gas well drilled in 1982 and about 700 feet northeast of the Parsons' water well. The old well is in the backyard of Janet and Paul Strohl, located just across the road from the Parsons' home.[55]

The Strohls, who can light a flame from a vent on top of their own salt-tainted water well, suspect that this old gas well is the source of their contamination (salty water is often produced along with natural gas), which they discovered the moment they moved into their home in 2004 and drilled for water. For washing and cleaning, they fill a Volkswagen Beetle-sized plastic tank in their basement with rain water from their gutters and supplement that by paying $106 per truckload to have water delivered. They drink bottled water.[56]

A rusted metal pipe sticking out of the ground, marked as well number 470350160, is still visible at the site of the old gas well next to their fence. According to records on file at the state Oil and Gas Division, United Carbon Co., based in Charleston, W. Va., drilled the well between June 13 and Sept. 21, 1941. On the way down, the company hit gas once and water three times, including "salt water" at 1,455 feet, before it completed the well in a layer of limestone 5,244 feet down, approximately 700 feet deeper than the 1982 gas well drilled on Parsons' property.

On Sept. 21, 1941, United Carbon used the fracturing technique of its day when it "shot" the well by exploding 80 quarts of glycerin between 5,161 and 5,201 feet underground in a sandstone formation.[57]

According to the 2007 edition of the Texas Comptroller of Public Accounts' Oil Well Servicing Tax Manual, "in the years between 1890 and 1950, the oil industry used liquid and later solidified nitroglycerin to stimulate wells by detonating an explosive charge in the wellbore. The object of shooting a well was to fracture the oil or gas bearing formation in order to increase both the initial flow and the ultimate recovery of oil… Shooting of the formation with explosives was very hazardous to those working with the explosives and frequently damaged the well casing, preventing subsequent selective treatment of the producing zone. Then with the advent of commercial hydraulic fracturing in 1948, shooting an oil or gas well was practically eliminated."[58]

State records show that United Carbon

removed most of the casing when it plugged the well between Sept. 28, 1945 and Oct. 12, 1946, including all seven-inch casing above a depth of 4,800 feet. This casing might have protected the well at the 4,216 foot-to-4,364 foot depth where Parsons' 1982 gas well was fractured. The company installed four plugs above this level with red clay, wood plugs and cement, beginning at 2,360 feet down and at several shallower depths.[59]

Dusseault said that removing casings has been a relatively common cost-saving technique in the industry, because they can be reused on subsequent wells. He said that plugging a well with cement in the absence of steel casing probably creates a more effective seal because the casing can corrode over time, providing a pathway for gas and other contaminants to rise up the well and potentially contaminate aquifers. The 1987 EPA study, citing the state of Illinois' research, indicated that casings could corrode and lead to fluid migration.[60]

Dusseault has also noted in a published paper that vertical pathways are likely to develop due to shrinkage and fracturing of cement placed between the casing and rock wall. The upward pressure of natural gas likely exacerbates the fractures, he wrote. Both Dusseault and the EPA's 1987 study also indicated that cement alone would not necessarily guard against the upward migration of contaminants.[61]

Dusseault said that it is virtually impossible to know whether a company had properly sealed a well.

"Was the cement high-quality cement?" Dusseault asked in an interview with EWG. "Was it properly placed or did they just fill out the forms? The records from [old] wells are so bad," he said. "Ninety-five percent of these things that are done [to plug a well] are done without the presence of a regulator," he said. He added that perhaps the only way to know whether an old well was properly sealed would be to drill out the old cement and seal it again. "It's a nightmare to try to fix up those old wells," he said.[62]

Because of their own contaminated water well, the Strohls persuaded the state Department of Environmental Protection to re-plug the old gas well in their backyard with cement in 2005. "No casing in the well," the Office of Oil and Gas inspection and release form read. The agency re-plugged the well to a depth of 900 feet, but the Strohls have continued to see gas in their water and showed EWG researchers in June 2010 that they could light a flame from their well.[63]

Oil and Gas Division records show that United Carbon Company drilled a second gas well near Parsons' property in 1941, this one approximately 1,500 feet southeast of the gas well drilled in 1982 and about 2,000 feet southeast of Parsons' water well. United Carbon drilled the well between Jan. 22 and May 13, 1941 to a depth of 5,210 feet, approximately 640 feet deeper than the well drilled in 1982. On the way down, the company hit water at four different depths. On May 13, United Carbon "shot" the well at a depth of 5,113 to 5,150 feet, using 75 quarts of glycerin. United Carbon plugged the well between July 28 and August 18, 1949. The company pulled out much of its casing, but left some of it in the well at a depth of 4,216 to 4,364 feet, where Parsons' well was fractured. The company plugged the well using alternating placements of cement, clay and "clay and stone."[64]

According to WVGES records, in 1941 the Columbian Carbon Co. also drilled a gas well at a spot about 1,150 feet northwest of the 1982 gas well on Parsons' property and about 850 feet northwest of his water well – the third documented well within 1,700 feet of the 1982 gas well. The Columbian Carbon Company drilled the old well between Sept. 16 and Dec. 13, 1941 to a depth of 5,125 feet, 550 feet deeper than Parsons' gas well. Like United Carbon, Columbian Carbon also "shot" this well, this time on Dec. 14, 1941, at a depth of 5,051 to 5,106 feet. State records are unclear on exactly what substance Columbian used to shoot the well, but it appears to have been 550 pounds of explosive, 80 percent of which was gelatin or, in the terminology of the state form, "550# 80% gelatin." The Bureau of Alcohol, Tobacco and Firearms publishes an annual list of explosives that includes "blasting gelatin," "explosive gelatins," "gelatinized nitrocellulose" and "nitrogelatin explosive," suggesting that the company used one of these types of explosives.[65]

According to the Oil and Gas Division records, Columbian Carbon plugged the well between July 3 and July 13, 1944. The company left in place the bottom 2,310 feet of seven-inch casing, which spanned the 4,216-to-4,364 feet depth at which Parsons' 1982 well was fractured, and extracted the rest along with portions of other casings. Records indicate that the company set several cement plugs in the well and injected aquagel between them – potentially an alternative source of the gel in Parsons' water if it persisted underground for 40 years.[66]

Paul and Janet Strohl near their contaminated water well.

Columbian Carbon drilled the fourth documented gas well near the Parsons' property in 1941-1942 at a location about 1,700 feet northeast of the 1982 gas well and 1,600 feet northeast of the Parsons' water well. The company drilled the well between Aug. 13, 1941 and Feb. 18, 1942 to a depth of 5,160 feet, about 600 feet deeper than the 1982 gas well. Columbian Carbon shot the well between 5,073 and 5,133 feet deep with what appears to have been 600 pounds of explosive, 80 percent of which was gelatin or, in the terminology of the state, "600# 80% Gelatin."[67]

According to Oil and Gas Division records, Columbian Carbon plugged the well between June 28, 1945 and July 9, 1945. The company removed the casing at the depth of 4,216 to 4,364 feet at which Parsons' 1982 well was fractured, along with some of the other casing, and set a series of cement plugs throughout the well. The company used aquagel both in drilling and plugging the well, another potential source of the gel that later appeared in Parsons' water well.[68]

Fractures Can Extend up to 2,500 Feet

Recent industry and government studies show that fractures can spread unpredictably underground, have broken into adjacent oil and gas wells and can travel up to 2,500 feet horizontally, approximately 800 feet farther than the distance between the gas well fractured on Parsons' property in 1982 and the most distant of the nearby older gas wells.

On May 20, 2010, the British Columbia Oil and Gas Commission issued a safety advisory after hydraulic fracturing caused a large "kick," or unintended entry of fluid or gas, in an adjacent gas well. The commission reported that it was aware of 18 incidents in British Columbia and one in Western Alberta in which hydraulic fractures had broken into adjacent gas wells. "Large kicks resulted in volumes up to 80m^3 [about 100 cubic yards] of fluids produced to surface. Invading fluids have included water, carbon dioxide, nitrogen, sand, drilling mud, other stimulation fluids and small amounts of gas." These incidents occurred in horizontal wells with a distance between wellbores of up to 2,300 feet, the commission reported. "It is recommended," the commission advised, "that operators cooperate through notifications and monitoring of all drilling and completion operations where fracturing takes place within 1000m [3,280 feet] of well bores existing or currently being drilled."[69]

Engineer and drilling industry consultant M.C. Vincent echoed the British Columbia commission in a paper published by the Society of Petroleum Engineers that he presented at a hydraulic fracturing conference held near Houston in January 2009.

"Contrary to common expectations," he wrote, "there are numerous examples of fractures intersecting offset wells [existing oil or natural gas wells near the well being fractured] but subsequently providing little or no sustained hydraulic connection between the wells. There is an understandable reluctance to publish reports documenting the intersection of adjacent wellbores with hydraulic fractures. Such information could unnecessarily alarm regulators or adjacent leaseholders who may infer that well spacing or fracture treatments are allowing unexpected capture of reserves."[70]

EWG asked Vincent about his findings by telephone and email, but he declined to comment on the record.

According to his paper, fractures have intersected with offset wells in the Piceance field in Colorado and Utah, Wyoming's Jonah field, Alaska's Prudhoe field, Texas' Barnett Shale, the Middle Bakken formation in Montana and North Dakota, and the Dan Field in the North Sea. Vincent noted that in one case in the Barnett Shale near Fort Worth, Texas, fracking fluids entered the wellbores of five adjacent vertical wells, temporarily halting gas production.[71]

"In the design of hydraulic fractures, it is necessary to make simplifying assumptions," Vincent wrote. "Although computing tools have improved, as an industry we remain incapable of fully describing the complexity of the fracture, reservoir, and fluid flow regimes."[72]

Another paper highlighting the complexity of hydraulic fractures, co-authored by M.K. Fisher, vice president of Business Management at Pinnacle, a service of Halliburton "specializing in the optimization of hydraulic fracturing," referred to the "highly complex fracture behavior in the Barnett shale" and the shale's "extremely complex fracture network." In the paper, published by the Society of Petroleum Engineers in 2005, Fisher and his coauthors noted that in one well drilled in the Barnett Shale, a fracture spread approximately 2,500 feet horizontally in two directions. The authors include the case cited by Vincent in which fractures from a well in the Barnett Shale broke into five adjacent wells.[73]

"Because of several factors, including the presence of natural fractures," the authors wrote, "a fracture treatment in the Barnett is more likely to look like the 'very complex' fracture description than the 'simple' case. This allows a fracture fairway to be created during a treatment with many fractures in multiple orientations, resulting in large surface areas potentially contributing to production."[74]

"Natural fractures may be activated (i.e. opened) during a hydraulic fracture treatment," they added.[75]

In a telephone interview, however, Fisher said it would be unlikely for fracturing to contaminate underground water supplies. He said his firm has collected microseismic data on thousands of hydraulic fracturing operations in Texas' Barnett shale and the Marcellus shale beneath Eastern states and has found that the fractures remain thousands of feet below underground water supplies, a conclusion that he published in July 2010 in the American Oil & Gas Reporter, a Wichita, Kan.-based publication that serves the independent sector of the natural gas and oil industry. He said his firm has not conducted water testing, and the possibility of fractures contaminating water supplies by intersecting with abandoned wells was outside his area of research.[76]

Monte Besler, a consulting petroleum engineer who specializes in hydraulic fracturing, co-authored a 2007 paper that raised concerns about the unpredictability of fracturing behavior in Montana and North Dakota's Middle Bakken Formation. "Several operators have reported difficulty keeping fractures contained within the target Bakken horizon," Besler and his coauthors wrote. They delivered the paper at the Society of Petroleum Engineers' Annual Technical Conference and Exhibition in Anaheim, Calif.[77]

Like Fisher, Besler said that despite some unpredictability of fracture spread underground, there is little chance that fracturing would contaminate underground water supplies, in large part because fractures would not rise high enough to contaminate underground water sources that lie thousands of feet above.

He said, however, that there are three scenarios in which fracturing could potentially contaminate water supplies: 1) if a well is drilled in a shallow formation within several hundred feet vertically and horizontally of a water source – the distance most fractures are likely to travel, 2) if a well is improperly cemented, allowing the escape of fracturing fluids or hydrocarbons up the well bore, where they could pollute water closer to the surface; or 3) if the hydraulic fracture intersects with an old natural gas or oil well that was improperly plugged and cased, allowing fluid to migrate up the well and burst out near the surface. He said that he has personally fractured hundreds of wells and has never seen water contamination from hydraulic fracturing.

"We don't want produced water," he said. "We want oil and gas; we go out of our way to avoid fracking into water."[78]

West Virginians Say Problems Persist

West Virginia residents who live near the Parsons' property believe that drilling companies there are not doing enough to address water contamination problems that may have been caused by hydraulic fracturing. In these cases, old wells may have played a role, too.

In the case of contamination that the Strohls say they witnessed in 2006, state records show that when EXCO drilled and fractured its gas well, there were five old gas wells within 2,500 feet, including one within 440 feet and a second within 1,000 feet. Each of the older wells was deeper than the well EXCO drilled, meaning that a horizontal fracture from EXCO's well could have intersected with the old wells if it traveled far enough.[79] EXCO's gas well was less than 1,000 feet from the water wells that the Strohls said became polluted.

A "Well Operators Report of Well Work," filed with the West Virginia Office of Oil and Gas, shows that EXCO began drilling the well near two Jackson County homes on July 20, 2006. On July 22, according to handwritten notes on an inspector's permit form filed with the Office of Oil and Gas, EXCO "hit water could not continue – had to cement to shut off." The next day, the company "started drilling – hit water again – cemented to surface with expanding cement."

On July 31, after boring through 17 layers of shale, sandstone and limestone, EXCO finally completed the well at a total depth of 4,426 feet. EXCO used three layers of casing and cement to seal off the well from the surrounding formations.[80]

The company then hydraulically fractured two formations where it intended to extract natural gas, a berea sandstone between 2,560 and 2,564 feet deep and a brown shale formation between 3,936 and 4,380 feet deep. EXCO fractured the sandstone with 6,174 gallons of "gelled water," 29,500 pounds of sand and 340,000 cubic feet of nitrogen. The company fractured the shale with 7,812 gallons of "gelled water," 49,000 pounds of sand and 608,400 cubic feet of nitrogen. State records do not indicate when the fracturing occurred, but it is likely that it was before Aug. 28, when David L. Cox, manager of geology, completed the well operator's form for EXCO.[81]

Shortly thereafter, the Strohls reported that water wells for the two homes became polluted. The Strohls had a keen interest in the residents' water because they wanted to compare it to their own polluted well.

Before the 2006 drilling, "they were actually bragging about their water being good," Janet said of the other residents. "It *was* good," said Paul. Tyler Mountain Water, the company that began delivering water to the two homes according to the Strohls, did not return two phone calls requesting comment.

The Strohls have petitioned the Southern Jackson County Public Service District, on which Paul Strohl serves as a board member, to extend public water lines to their home and other homes with contaminated wells, including some wells that they believe were polluted by natural gas drilling. In November 2010, the district submitted an application to a clearinghouse for federal infrastructure funds to extend public water lines to the Strohls' general area. The project would cost approximately $3.6 million for 60 users. In April 2011, the clearinghouse said that the project was technically feasible and forwarded it to a funding committee for review to determine the most cost effective and environmentally sound alternative to address the area's drinking water needs.[82]

Couple Says Home Became Unlivable

In June 2010, at a board meeting of the public service district, Paul Strohl introduced EWG researchers to Dennis and Tammy Hagy of Sandyville, W. Va., both in their early 50s, who said that the area near Route 33 East is not the only part of Jackson County impacted by drilling and fracturing.

The Hagys, who once lived in nearby Romance, said drilling and fracturing ruined their water and left their home, set on 80 wooded acres, unlivable. In this case, too, previously drilled wells nearby may have played a role.

Records from the West Virginia Department of Environmental Protection show that between Nov. 15, 2007 and June 11, 2008, Equitable Production Co. of Charleston, W. Va., drilled three horizontal wells in a Devonian shale formation about 1,000 feet north of the Hagys' home and water well. At least part of the formation is in the Marcellus Shale, which holds one of the nation's largest natural gas deposits. Equitable drilled through several layers of sandstone, salt sand, limestone and shale to depths between 3,410 and 4,712 feet. Then, inside each well, the company steered the drill bit to bore horizontally another 3,000 to 4,000 feet before hydraulically fracturing the wells.[83]

Equitable fractured the first well in the Lower Huron Formation seven times on Feb. 19, 2008 at a depth of 3,410 feet, using a total of 7,388 gallons of water, 7.1 million cubic feet of nitrogen and 7,152 gallons of acid at a maximum pressure of 5,692 pounds per square inch.[84] Equitable fractured the well in the Marcellus Shale six times on Feb. 22, 2008 at a depth of 4,712 feet, using a total of 6,817 gallons of water, 4.8 million cubic feet of nitrogen and 6,018 gallons of acid at a maximum pressure of 5,798 pounds per square inch.[85] Equitable fractured a third well three times on Feb. 23, 2008 at a depth of 4,153 feet, using a total of 974 gallons of water, 1.4 million cubic feet of nitrogen and 2,030 gallons of acid at a maximum pressure of 5,498 pounds per square inch.[86] There is no record that Equitable completed a fourth well that was permitted for the site, but the Hagys say the company began drilling a fourth well and then stopped.[87]

The Hagys said that their water, which had been pristine, started turning brown in July 2008, five months after Equitable fractured its third well. Dennis Hagy said they experienced "weakness, headaches, nausea, eyes burning."

"You'd get in the shower and when you got out, you'd be sick," he said. Tammy Hagy said she developed a rash. She added that she stopped bottling water from their well for her son to take back to his home in Columbus, Ohio.

"My son called and said I'm going to have to stop drinking your water because I've got some problems with my throat," she said. The amount of water in the Hagys' wells and springs has declined significantly, they said.[88]

According to a "Complaint Information Form" dated Feb. 12, 2009, on file with the West Virginia Department of Environmental Protection's Office of Oil and Gas, Dennis Hagy first complained to the agency about water quality on Nov. 17, 2008, approximately nine months after Equitable fractured its third well. "He and his wife have been sick for over a year with Nausea (sic) and cramping stomach, etc. Silver flakes and black goo in well water," the form said. "DEP/OOG Inspector Jamie Stevens made inspections on several occasions. No violations were written."[89]

Stevens referred questions to James Martin, the chief of the Office of Oil and Gas. Martin told EWG that he had no more information than what appeared in the state's files.[90]

The state Department of Environmental Protection file included several tests of the Hagys' water on behalf of the department, Equitable Production Co. and Dennis Hagy. The tests were conducted both before and after Equitable drilled. However, none of the tests looked for common drilling-related contaminants benzene, toluene, ethylbenzene and xylene.[91]

According to the West Virginia Code of State Rules, drilling companies must conduct tests of water supplies if they are within 1,000 feet of

Dennis and Tammy Hagy in front of their former home.

a natural gas or oil well; the Hagys' water well was just outside this distance, according to the Hagys.[92] The rules require testing only for pH, iron, total dissolved solids, chloride, detergents and "any others (sic) parameters as determined by the operator [drilling company]."[93] Martin said that the state might require additional tests based on the nature of a particular complaint and, indeed, in October 2010, the state tested the Hagys' water for benzene, toluene, ethylbenzene and xylene (BTEX), among other contaminants. The state detected no BTEX. However, the state conducted the tests more than two years after the Hagys first noticed contamination. The EPA has found that volatile organic compounds such as BTEX can biodegrade over time, so it is possible that the chemicals were once present and biodegraded by the time of the state's test.[94]

The Hagys said that on Nov. 13, 2008, Jeremy White, an Equitable "landman" who negotiates drilling leases with landowners, told them that the company had contaminated their water. The next day, the company brought bottled water to their home, and it later paid for them to stay in a local motel for two months. But when Dennis refused to sign a form releasing Equitable from legal liability and retained an attorney, the Hagys said company officials stopped paying for the motel and denied that Equitable had contaminated their water. In November 2010, in a telephone interview, Kevin West, Equitable's managing director of external affairs, said he would look into the Hagys' case. Three days later, EWG left a voicemail for West, but he has not responded.

Next door to the Hagys, Ben Thornton, 23, said his family's water well also went bad after the drilling and fracturing. "We had some black stuff coming out the well that wasn't there before," he said. "Everybody got sick there for a while" before the family began buying bottled water.

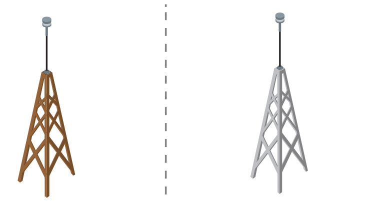
Thornton added that farm animals that had drunk the well water began to die after the drilling. He said he lost 70 chickens, eight or nine goats and 15 rabbits.

"I don't know if it was from the water, but they was doin' fine" before the drilling, he said, adding that he now waters his animals with rainwater collected from the roof of a shed. Thornton said he complained to Equitable, but the company did not offer help. "They ain't never give me nothing," he said.

State records show that existing wells in the area were close enough that they could have acted as conduits for the spread of contaminants from the hydraulic fracturing on the Hagys' land. In 1940, Godfrey L. Cabot, Inc. of Charleston, W.Va. drilled a gas well approximately 2,000 feet northeast of Equitable's wells.[95] The company drilled the well between June 8, 1940 and November 18, 1940 to a depth of 5,256 feet, more than 500 feet deeper than the deepest of the three wells drilled on the Hagys' property, meaning that a horizontal fracture from one or more of Equitable's three new wells could have intersected with the old well. Godfrey L. Cabot "shot" the old well twice on Nov. 19, 1940 – once with 20 quarts of explosive between 5,196 and 5,206 feet deep and

Families Say Drilling, Fracturing Polluted Their Water

In 2007 and 2008, a Charleston, W.Va.-based natural gas company, Equitable Production Co., drilled and hydraulically fractured three natural gas wells on the property of Dennis and Tammy Hagy in Jackson Co. W.Va. In July, 2008, five months after Equitable fractured its third well, the Hagys say their water started turning brown and they became sick. A neighbor, Ben Thornton, said his family's water also became polluted and that he and his family got sick until they switched to bottled water.



Old Wells
Drilled 1940-2007

New Wells
Drilled 2007-08

Jackson County, WV

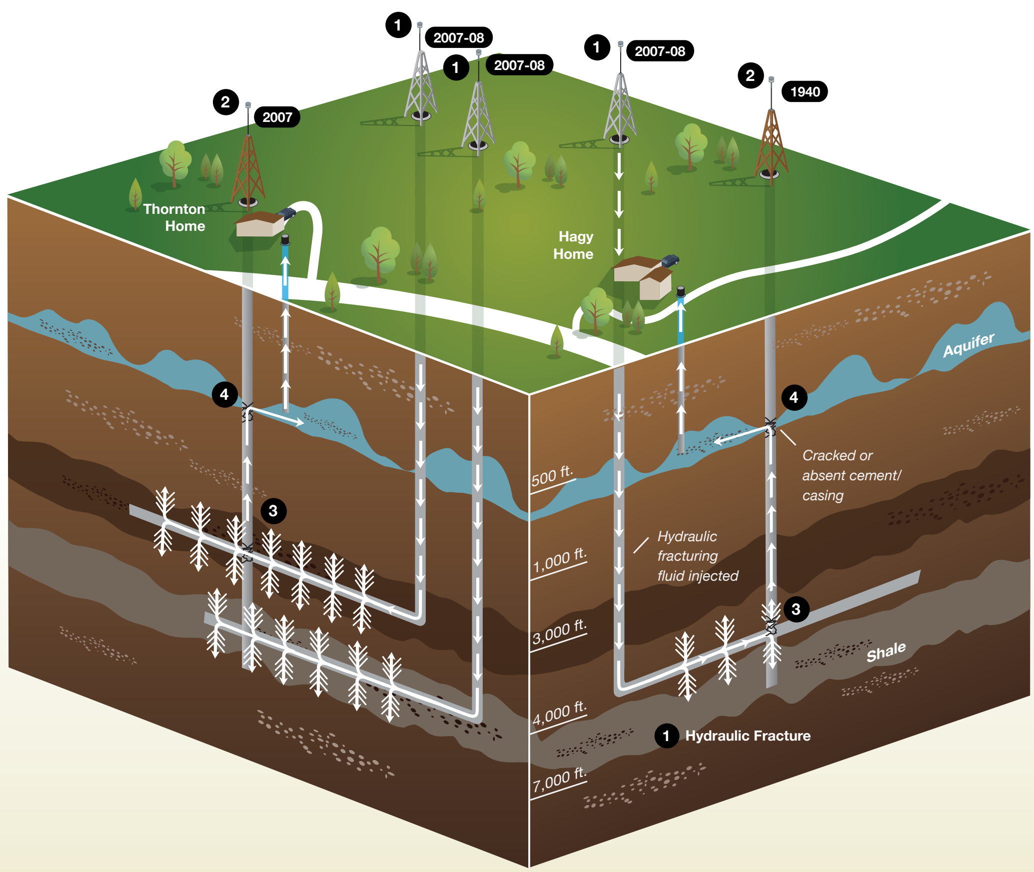


Illustration Aman Anderson, EWG ©2011

1 Hydraulic Fractures
According to industry studies, hydraulic fractures can extend up to 2,500 feet horizontally within range of two preexisting natural gas wells near the Hagys' and Thortons' homes. Studies found that fractures elsewhere have broken into nearby oil and gas wells and that fracturing fluid has migrated up the old wells to surface.

2 Two Preexisting Wells Nearby
Two natural gas wells, one drilled in 1940, the other in 2007, were located within 2,300 feet of the wells drilled near the Hagys and Thorntons.

3 Fluid Migration
Government studies have found that oil and natural gas waste fluids injected underground can migrate up old oil and natural gas wells.

4 Breakout into Aquifer
These fluids can break into aquifers near the surface if the old wells have deteriorating casings, lack cement plugs or contain cracked cement. This phenomenon is known as "salt water breakout." It is possible that hydraulic fracturing fluids migrated in a similar way into the Hagys' and Thorntons' water wells.

then a second time with 15 quarts of explosive between 5,243 and 5,250 feet deep.

The company sealed the well between Sept. 13, 1948 and Oct. 1, 1948 using several cement plugs. The company removed some of its casing from the well, including almost all of the casing below 2,019 feet, which would have been adjacent to the depths at which Equitable fractured its three nearby wells.[96]

Equitable drilled a well in June and July of 2007 approximately 2,300 feet west from the three wells it later drilled on the Hagys' property.[97] Equitable drilled this preexisting well between June 23 and July 26 to a depth of 5,130 feet, about 400 feet deeper than the deepest of the three wells drilled on the Hagys' property. Equitable fractured the preexisting well three times, once with 900,000 standard cubic feet of nitrogen and 750 gallons of acid at a maximum pressure of 3,135 psi, a second time with 900,000 standard cubic feet of nitrogen and 600 gallons of acid at a maximum pressure of 2,155 psi, and a third time with 247,226 standard cubic feet of nitrogen and 350 gallons of acid with a maximum pressure of 2,145 psi. There is no plugging data for the well in the public record; the state lists it as active.[98]

The Hagys said nearly 70 people in their community have signed a petition to the Southern Jackson County Public Service District requesting public water by an extension of public water lines. At least some of their neighbors signed because they believe natural gas drilling had polluted their water, they added. As of February 2010, the estimated project cost was $1.7 million, according to the Southern Jackson County Public Service District, though there is no guarantee that this project will be funded.[99]

In October 2010, the Hagys filed suit against four drilling companies, including Equitable, in Jackson County Circuit Court seeking damages for impacts to their property and health. In December 2010, the case was moved to U.S. District Court for the Southern District of West Virginia, where it is now pending before Chief Judge Joseph R. Goodwin.[100]

Summary and Recommendations:

Contrary to industry's insistence that hydraulic fracturing is safe for underground water supplies, EWG's investigation established that hydraulic fracturing poses significant risks to the drinking water sources on which more than 100 million Americans depend. The EPA's 1987 report, combined with industry and government papers showing that fractures can spread unpredictably and can intersect with adjacent wells, strongly indicate that hydraulic fracturing puts these water supplies in danger. Fracturing involves the use of toxic chemicals and is designed to open underground passages for natural gas and oil, which often come to the surface with naturally occurring toxics such as benzene. The prevalence of abandoned wells that could serve as conduits for contamination, current allegations of fracturing contamination, a lack of rigorous water testing and the industry's secretive practices all intensify the concern. Local, state and federal governments should take the following steps to protect water supplies and human health, recognizing that hydraulic fracturing is only one part of the drilling process and that other components of drilling carry their own risks:

1. Implement a moratorium on hydraulic fracturing near drinking water supplies until rigorous scientific investigation establishes the risks of fracking. Before fracturing is allowed near water supplies, citizens and policymakers must know the risks so that they can make informed decisions about when and how it should be permitted. Industry and government studies show that fractures can spread up to 2,500 feet underground and that hydraulic fracturing can open natural fractures, suggesting that the moratorium should apply to a considerable margin around water sources.

2. Repeal the exemption for hydraulic fracturing under the Safe Drinking Water Act. The act is specifically designed to protect underground drinking water from the spread of contaminants through underground injections. It already covers tens of thousands of disposal wells into which the drilling industry injects wastes, including fracturing fluid. The law should apply to hydraulic fracturing, too.

3. Require pre-drilling surveys to identify and remediate old abandoned and deteriorating wells and conduct seismic testing to locate and avoid natural fractures.
   Mandate testing of water supplies within 2,500 feet of drilling operations:
   a. before drilling begins
   b. after drilling and before fracturing, to determine if the drilling process itself has an effect on water supplies, and
   c. after fracturing, to determine if fracturing is having an effect on drinking water supplies.
   Labs should conduct tests for benzene, toluene, ethylbenzene, xylene and other likely contaminants from natural gas and oil operations. Tests should use standard test methods and should be designed to determine whether chemicals exceed established safe levels.

4. Require companies to publicly disclose the contents of their fracturing fluids so that the public can know whether the fluids are safe and researchers can know

what chemicals to test for. Disclosure should occur before and after fracturing and should be accessible to the public, including mailing notices to nearby residents and identifying each chemical by its unique Chemical Abstracts Service (CAS) registry number. CAS numbers would allow scientists, regulators and citizens to know precisely what substances are being used and would facilitate accurate testing of potentially contaminated water sources such as wells and springs.

5. Require all drilling companies to use non-toxic tracers in their fracturing fluid and require testing of nearby water supplies for these tracers after fracturing. The presence or absence of the tracers months or years later would enable scientists to link contamination to fracturing — or determine that there is no link.

References

1. West Virginia Division of Environmental Protection. Office of Oil and Gas, Well Operator's Report of Well Work, API No. 47-035-02717, Aug. 28, 2006. West Virginia Department of Environmental Protection. Inspectors Permit Summary Form, API No. 47-3502717, received Oct. 10, 2006.

2.Interview with Janet and Paul Strohl (June 16, 2010). Telephone interviews with Janet and Paul Strohl (Oct. 27 and 28, 2010).

3. U.S. Geological Survey. Briefing on Contaminants in Groundwater Used for Public Supply, News Release, May 14, 2010. Accessed online Dec. 6, 2010 at http://www.usgs.gov/newsroom/article.asp?ID=2462.

4. U.S. Environmental Protection Agency, Report to Congress: Management of Wastes from the Exploration, Development, and Production of Crude Oil, Natural Gas, and Geothermal Energy, Dec. 1987 [hereinafter EPA 1987].

5. EPA 1987, supra note 4, at IV-11.

6. American Petroleum Institute. API Comments on Preliminary Draft Report to Congress on Oil, Gas and Geothermal Wastes, Aug. 10, 1987, at 1375, 1416 (on file at EPA Docket Center, F-88-OGRA-SO679.) An online glossary on the website of Schlumberger Limited, one of the world's largest hydraulic fracturing companies, says that a "workover operation" involves "the repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons." See Schlumberger, Oilfield Glossary, Workover, noun, drilling. Accessed online Oct. 28, 2010 at http://www.glossary.oilfield.slb.com/Display.cfm?Term=workover. Hydraulic fracturing is a form of stimulation; hydrocarbons include natural gas and oil. The "detail write-up" may have been the second document about the West Virginia case included with API's comments. See U.S. Environmental Protection Agency. Damage Cases Report Form and Summary, File Ref# WV17, Mar. 4, 1987 (on file at EPA Library, Washington, DC).

7. Independent Oil and Gas Association of New York et al. Comments Regarding the United States Environmental Protection Agency's Report to Congress with Respect to the Management of Waste from the Exploration, Development and Production of Crude Oil, Natural Gas and Geothermal Energy, Mar. 14, 1988, at 1223 (on File at EPA Docket Center, F-88-OGRA-00073).

8. EPA 1987, supra note 4, at IV-9 and IV-11.

9. EPA 1987, supra note 4, at IV-1, IV-2, IV-9..

10. Wilson, Weston. Letter from Weston Wilson, EPA Employee, Denver Colorado to U.S. Senator Wayne Allard et al., Oct. 8, 2004. Accessed online November 8, 2010 at http://www.earthworksaction.org/publications.cfm?pubID=372. Hamburger, Tom and Alan C. Miller. A Changing Landscape: Halliburton's Interests Assisted by White House, Los Angeles Times, Oct. 14, 2004, at A1.

11. Safe Drinking Water Act Hydraulic Fracturing Exemption. Pub. L. No. 109-58 (codified at 42 USC 300h (d)(1)(B)(ii) (2008)). Congress exempted fracturing from the Safe Drinking Water Act except for fracturing with diesel fuel.

12. U.S. Environmental Protection Agency. Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs, Final, June 2004, at ES-7 [hereinafter EPA 2004]. Accessed online Mar. 13, 2009 at http://www.epa.gov/safewater/uic/wells_coalbedmethanestudy.html.

13. Vincent, M.C. Examining Our Assumptions – Have Oversimplifications Jeopardized Our Ability to Design Optimal Fracture Treatments? Presented to 2009 Society of Petroleum Engineers Hydraulic Fracturing Technology Conference held in The Woodlands, Texas, Jan. 19-21, 2009, Published by Society of Petroleum Engineers, Number SPE 119143, 2009. Schlumberger, Oilfield Glossary, Flowline. Accessed online Nov. 2, 2010 at http://www.glossary.oilfield.slb.com/Display.cfm?Term=flowline (defining a "flowline" as a pipe on the surface that directs drilling mud flowing out of the wellbore into equipment for treating the mud; a flowline can also be a surface pipeline for oil, gas or water that connects the wellhead to production facilities or to an arrangement of piping used to control or monitor fluids known as a "manifold"). Schlumberger, Oilfield Glossary, Test Separator. Accessed online Nov. 2, 2010 at http://www.glossary.oilfield.slb.com/Display.cfm?Term=test%20separator (defining a "surface test separator" as "a vessel used to separate and meter relatively small quantities of oil and gas."

14. EPA 1987, supra note 3, at III-48. Illinois Oil Field Brine Disposal Assessment, Staff Report, Illinois Environmental Protection Agency, 1978. Illinois Oil Field Brine Disposal Assessment, Phase II Report, Illinois Environmental Protection Agency, 1981. Status of the Brine Problem in Illinois, Illinois Department of Energy and Natural Resources, Document No. RE-EA-85/05, 1985. Texas Department of Agriculture, Department of Natural Resources. Agricultural Land and Water Contamination from Injection Wells, Disposal Pits, and Abandoned Wells used in Oil and Gas Production, 1985. U.S. General Accounting Office, Report of the Chairman, Environment, Energy, and Natural Resources, Subcommittee, Committee on Government Operations, House of Representatives, July 1989.

15. Texas Department of Agriculture, supra note 14, at 13.

16. EPA 2004, supra note 11, Appendix A. Texas Comptroller of Public Accounts, Oil Well Servicing Tax Manual, Chapter 3, Description of Oil and Gas Well Services. Accessed online Oct. 22, 2010 at http://www.

window.state.tx.us/taxinfo/audit/oilwellservicing/. Carrillo, Victor (IOGCC Carrillo). 2005. Testimony submitted to the House Committee on Energy and Commerce by Victor Carrillo, Chairman, Texas Railroad Commission Representing the Interstate Oil and Gas Compact Commission, Feb. 10, 2005. Accessed online Oct. 18, 2005 at http://www.rrc.state.tx.us/commissioners/carrillo/press/energytestimony.php.

17. EPA 2004, supra note 11, at ES-11, Chapter 4 (reporting that coalbed methane wells can use between 50,000 and 350,000 gallons of fluid for fracturing and that fracturing fluids include thickeners). Schein, Gary. Hydraulic Fracturing in Gas Shale Plays – Are They all the Same? Presentation at Barnett Shale Breakfast Symposium, Feb. 29, 2008. Accessed online Mar. 15, 2009 at http://www.barnettshalenews.com/studies.htm (commenting that shale formations in the Barnett Shale may require four million gallons of fracturing fluid). Burnett, D.B. and Vavra, C.J. Desalination of Oil Field Brine, Presentation for "The Future of Desalination in Texas," Global Petroleum Research Institute, Texas A&M University, College Station, Texas, Aug. 6-8, 2006. Accessed online Mar. 15, 2009 at http://www.pe.tamu.edu/gpri-new/home/BrineDesal/MembraneWkshpAug06/Burnett8-06.pdf (commenting that wells in the Barnett Shale use five to six million gallons of fracturing fluid; an industry source told Environmental Working Group that the figure can range as high as six million gallons). New York Department of Environmental Conservation. Draft Supplemental Generic Environmental Impact Statement Relating to Drilling for Natural Gas in New York State Using Horizontal Drilling and Hydraulic Fracturing, Sept. 30, 2009, at Chapter 5 [hereinafter NYDEC DSGEIS 2009]. Accessed online Nov. 6, 2009 at http://www.dec.ny.gov/energy/46288.html. Besler, Monte et al. Improving Well Productivity and Profitability in the Bakken – A Summary of Our Experiences Drilling, Stimulating, and Operating Horizontal Wells, Presented to 2007 Society of Petroleum Engineers Annual Technical Conference and Exhibition in Anaheim, California, Nov. 11-14, 2007, Published by Society of Petroleum Engineers, 2007.

18. Tillerson, Rex. Testimony to U.S. House of Representatives, Committee on Energy and Commerce. "The ExxonMobil-XTO Merger: Impact on U.S. Energy Markets" (Washington, D.C., Jan. 20, 2010), p.87. Accessed online June 1, 2010 at http://energycommerce.house.gov/index.php?option=com_content&view=article&id=1873:the-exxonmobil-xto-merger-impacts-on-us-energy-markets&catid=130:subcommittee-on-energy-and-the-environment&Itemid=71.

19. Fuller, Lee. "Fracking Would be a Boon to Region," Ithaca Journal, Dec. 3, 2010. Accessed online Dec. 4, 2010 http://www.theithacajournal.com/article/20101203/VIEWPOINTS03/12030303/1129/Fracking-would-be-a-boon-to-region.

20. West Virginia Department of Mines, Oil and Gas Division. Well Operator's Report of Drilling, Fracturing and/or Stimulating, or Physical Change, Well Number 47-35-1746 Oct. 26, 1982 (on file with West Virginia Office of Oil and Gas).

21. Id.

22. Willette, Ken, Telephone interview with Ken Willette, Manager of the Public Fire Protection Division of the National Fire Protection Association (Oct. 20, 2010).

23. West Virginia Department of Mines, supra note 20. See also West Virginia Department of Mines, Oil and Gas Division, Well Operator's Report of Drilling, Fracturing and/or Stimulating, or Physical Change, July 16, 1985 (on file with West Virginia Office of Oil and Gas). West Virginia Department of Mines, Oil and Gas Division. Final Inspection Report, Inspectors Compliance Report, Aug. 7, 1985 (on file with West Virginia Office of Oil and Gas).

24. West Virginia Department of Mines, Oil and Gas Division. Water Well Inspection Report, 1984 (exact date is indecipherable) (on file at EPA Library, Washington, DC). Parsons v. Kaiser Exploration & Mining Co., complaint filed in the Circuit Court of Jackson County, West Virginia, Feb. 4, 1986.

25. West Virginia Department of Mines, supra note 24.

26. Lewis, Michael W. Letter from Michael W. Lewis, engineer, West Virginia Department of Mines, Oil and Gas Division, to James Parsons, Oct. 2, 1984.

27. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number 841023, Date of Collection, June 29, 1984, Date of Analysis, Aug. 3, 1984. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number 841516, Date of Collection, July 1, 1984, Date of Analysis, Sept. 20, 1984. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number 841420, Date of Collection, Aug. 31, 1984, Date of Analysis, Sept. 18, 1984. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number 841517, Date of Collection, Sept. 17, 1984, Date of Analysis, Sept. 24, 1984. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number 841842, Date of Collection, Nov. 23, 1984, Date of Analysis, Nov. 30, 1984.

28. Rosencrance, James E. Letter from James E. Rosencrance, Chief Environmental Health Services Lab to Perry R. Merritt, Sanitarian IV, Jackson County Health Department, Nov. 8, 1984 [hereinafter Rosencrance to Merritt].

29. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number

841023, supra note 27.

30. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number 841420, supra note 27.

31. West Virginia State Health Department, Water Analysis Report – Inorganics, Environmental Health Services Laboratory, Laboratory Number 841516, supra note 27.

32. NOWSCO Well Service Ltd., Re: Kem 244 Parsons Contamination Analysis, Report No. NRD – 85 – 202. March 11, 1985. BCM Laboratory Division, Appalachian Group, BCM Number D408760, Client Sample ID James Parsons, Date Sampled Nov. 15, 1984, Date Received Nov. 15, 1984, Date of Final Report Nov. 21, 1984.

33. Batheja, Aman (Batheja). 2010. Texas Proposes New Rules for Gas, Oil Drillers, Fort Worth Star-Telegram, July 29, 2010 (reporting that Texas "is proposing to change the air emission limits on drilling sites that would focus more on toxic chemicals most associated with natural gas drilling, including benzene and toluene"). Accessed online Dec. 6, 2010 at http://www.mcclatchydc.com/2010/07/29/98309/texas-proposes-new-rules-for-gas.html#ixzz14idYZvw3. Environmental Working Group, Drilling Around the Law, Jan. 20, 2010 (finding that BTEX are often found in petroleum distillates used for hydraulic fracturing). Accessed online Nov. 8, 2010 at http://www.ewg.org/drillingaroundthelaw. Marathon, Material Safety Data Sheets, Marathon Oil Company Products, Natural Gas-Condensate C2-C8, 0197MAR001 (showing that benzene is a component of condensate, a naturally-occurring liquid hydrocarbon that is often produced along with natural gas). Accessed online Oct. 20, 2010 at http://www.marathonpetroleum.com/Products/MSDS/. NYDEC DSGEIS 2009, supra note 17 at 5-53 (finding that BTEX are used in fracturing). EPA 1987, supra note 4, at II-36 through II-38 (reporting that the EPA found benzene in oil and natural gas wastes).

34. Rosencrance, James E. Letter from James E. Rosencrance, Chief Environmental Health Services Lab to James Parsons, Apr. 3, 1985.

35. Charleston Gazette. James Rosencrance Obituary, June 26, 1999 at 12A (reporting that James Rosencrance died on June 24, 1999).

36. Parsons v. Kaiser complaint, supra note 24. Parsons v. Kaiser Exploration & Mining Company, answer filed in the Circuit Court of Jackson County, West Virginia, Jan. 24, 1987. Parsons v. Kaiser Exploration & Mining Co., dismissal order entered by Judge George M. Scott in the Circuit Court of Jackson County, West Virginia, May 29, 1987.

37. Pryce, Lance. Telephone interview (Aug. 12, 2010).

38. Streit, Ted M. Letter from Ted M. Streit, deputy director, Inspection and Enforcement, Division of Oil and Gas, West Virginia Department of Energy, to Dave Flannery, Robinson and McElwee, May 29, 1987.

39. Ely, John W. Stimulation Treatment Handbook, 1st Ed., 1985, at 52-61.

40. EPA 2004, supra note 12 at 1-3, 1-4, 4-3 and 4-4.

41. Id. at 4-5.

42. Morris, Richard. Telephone interview with Richard Morris, former inspector with the West Virginia Department of Mines, Oil and Gas Division (Nov. 17, 2010).

43. Rosencrance to Merritt, supra note 30. NYDEC DSGEIS 2009, supra note 18, at 5-53. Pennsylvania Department of Environmental Protection (PADEP). 2010. Chemicals Used by Hydraulic Fracturing Companies in Pennsylvania For Surface and Hydraulic Fracturing Activities. Accessed online Dec. 23, 2010 at http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_forms/marcellus/marcellus.htm. An earlier version of the list entitled Summary of Hydraulic Fracture Solutions – Marcellus Shale is on file with Environmental Working Group. It was accessed online Aug. 19, 2009 at http://www.dep.state.pa.us/dep/deputate/minres/oilgas/new_forms/marcellus/marcellus.htm. It includes information submitted by BJ Services, Fractech, Universal, Halliburton and Superior. Two companies said that they used petroleum distillates. BJ Services said that it used "petroleum distallate (sic) blend" and "hydrotreated light distillate." Superior said that it used "hydrotreated light distillate" and "mineral spirits." An official with the Pennsylvania Bureau of Oil and Gas said that the state received the list in 2008. Personal communication, Aug. 19, 2009.

44. Marathon, Material Safety Data Sheets, Marathon Oil Company Products, Natural Gas-Condensate C2-C8, 0197MAR001, supra note 35. Marathon. Material Safety Data Sheets, Marathon Oil Company Products, Natural Gas-Condensate Sour, 0245MAR001. Accessed online Oct. 20, 2010 at http://www.marathonpetroleum.com/Products/MSDS/.

45. Morris, Richard, supra note 42. Halliburton. Aquagel – Product Data Sheet. Accessed online Dec. 23, 2010 at http://www.halliburton.com/halcomsearch.aspx?k=aquagel. Halliburton. Aquagel Gold Seal® – Product Data Sheet. Accessed online Dec. 5, 2010 at http://www.halliburton.com/halcomsearch.aspx?k=aquagel.

46. Morris, Richard, supra note 45. Dusseault, Maurice B. Telephone interviews with Maurice Dusseault (Jan. 25, 2011 and June 28, 2011). Dusseault, Maurice B. et al. Why Oilwells Leak: Cement Behavior and Long-Term Consequences, prepared for presentation at the Society of Petroleum Engineers' International Oil and Gas Conference and Exhibition in Bejing, China, Nov. 7-10, 2000. EPA 1987, supra note 3, at III-47,

47. EPA 1987, supra note 4, at III-47. Illinois Oil Field Brine Disposal Assessment, Staff Report, Illinois Environmental Protection Agency, 1978. Illinois Oil Field Brine Disposal Assessment, Phase II Report, Illinois Environmental Protection Agency, 1981, supra note 14, at 44.

48. Texas Department of Agriculture. supra note 15, at 5.

49. U.S. General Accounting Office, supra note 15, at 2.

50. U.S. Department of Energy, Office of Fossil Energy, Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology, Technology Fact Sheets: Site Restoration, Oct. 5, 1999.

51. West Virginia Geological and Economic Survey, Oil and Gas Well Data for West Virginia on DVD, January 2010 (on file with Environmental Working Group).

52. New York Department of Environmental Conservation, Division of Mineral Resources. New York State Oil, Gas and Mineral Resources, 2008, at 23. Accessed online Dec. 5, 2010 at http://www.dec.ny.gov/pubs/36033.html.

53. Electronic mail from Pennsylvania Department of Environmental Protection to Environmental Working Group, July 19, 2011 and July 21, 2011 (on file with Environmental Working Group).

54. Ohio Department of Natural Resources, Division of Mineral Resources Management, RBDMS, received July 2011 (on file with Environmental Working Group).

55. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0160, completed September 21, 1941. Accessed online July 6, 2011 at "http://www.wvgs.wvnet.edu/oginfo/pipeline/pipeline2.asp"http://www.wvgs.wvnet.edu/oginfo/pipeline/pipeline2.asp. West Virginia Department of Mines. Oil and Gas Division, Well Record, Permit No. Jac-160, Oct. 15, 1941. GPS Latitude and Longitude Distance Calculator. Accessed online December 23, 2010 at http://www.csgnetwork.com/gpsdistcalc.html.

56. Interviews with Janet and Paul Strohl, supra note 2.

57. West Virginia Department of Mines. Oil and Gas Division, Well Record, Permit No. Jac-160, supra note 55.

58. Texas Comptroller of Public Accounts, supra note 16.

59. West Virginia Department of Mines, Oil and Gas Division, Affidavit of Plugging and Filling Well, Permit No. Jac-160, Oct. 12, 1946.

60. EPA 1987, supra note 4, at III-47, III-48.

61. Dusseault, Maurice B. Telephone interviews, supra note 46. Dusseault, Maurice B. et al., supra note 47. EPA 1987, supra note 4, at III-47, 48.

62. Dusseault, Maurice B. Telephone interviews, supra note 46.

63. West Virginia Department of Environmental Protection, Office of Oil and Gas, Well Plugging Inspection & Release Form, Well No. 47-035-0160, Dec. 15, 2005.

64. West Virginia Department of Mines, Oil and Gas Division, Well Record, Permit No. Jac-111, Oct. 15, 1941. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0111. Accessed online Feb. 21, 2011 at http://www.wvgs.wvnet.edu/oginfo/pipeline/pipeline2.asp. GPS Latitude and Longitude Distance Calculator, supra note 53. West Virginia Department of Mines, Oil and Gas Division, Affidavit of Plugging and Filling Well, Permit No. Jac-111, Aug. 18, 1949.

65. West Virginia Department of Mines, Oil and Gas Division, Well Record, Permit No. Jac-200, Feb. 4, 1942. West Virginia Department of Mines, Oil and Gas Division, Affidavit of Plugging and Filling Well, Permit No. Jac-200, July 18, 1944. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0200. Accessed online Feb. 21, 2011 at http://www.wvgs.wvnet.edu/oginfo/pipeline/pipeline2.asp. GPS Latitude and Longitude Distance Calculator, supra note 55. Bureau of Alcohol, Tobacco and Firearms. Commerce in Explosives; List of Explosive Materials (2009R–18T), 75 Fed. Reg. 1,085-1,087 (Jan. 8, 2010).

66. West Virginia Department of Mines, Oil and Gas Division, Affidavit of Plugging and Filling Well, Permit No. Jac-200, July 18, 1944, supra note 65.

67. West Virginia Department of Mines, Oil and Gas Division, Well Record, Permit No. Jac-188, March 23, 1942. West Virginia Department of Mines, Oil and Gas Division, Affidavit of Plugging and Filling Well, Permit No. Jac-188, July 16, 1945. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0188. Accessed online February 21, 2011 at http://www.wvgs.wvnet.edu/oginfo/pipeline/pipeline2.asp. GPS Latitude and Longitude Distance Calculator, supra note 55.

68. West Virginia Department of Mines, Oil and Gas Division, Well Record, Permit No. Jac-188, supra note 67. West Virginia Department of Mines, Oil and Gas Division, Affidavit of Plugging and Filling Well, Permit No. Jac-188, supra note 67. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0188, supra note 67.

69. British Columbia Oil and Gas Commission. Safety Advisory 2010-03, May 20, 2010. Accessed online December 19, 2010 at http://www.ogc.

gov.bc.ca/.

70. Vincent, supra note 13, at 13.

71. Id. at 13.

72. Id. at 13.

73. Fisher, M.K. et al. Integrating Fracture-Mapping Technologies to Improve Stimulations in the Barnett Shale, Presented at the 2002 SPE Annual Technical Conference and Exhibition in San Antonio, Texas, Sept. 29-Oct. 2, 2002, Published by Society of Petroleum Engineers in revised form, 2005, at 85, 87.

74. Id. at 85.

75. Id. at 85.

76. Fisher, Kevin. "Data Confirm Safety of Well Fracturing," The American Oil & Gas Reporter, July 2010. Fisher, Kevin. Telephone interview with Kevin Fisher, Vice President of Business Management at Pinnacle, a service of Halliburton (Nov. 17, 2010).

77. Besler, Monte et al. Improving Well Productivity and Profitability in the Bakken – A Summary of Our Experiences Drilling, Stimulating, and Operating Horizontal Wells, Presented to 2007 Society of Petroleum Engineers Annual Technical Conference and Exhibition in Anaheim, California, Nov. 11-14, 2007, Published by Society of Petroleum Engineers, 2007, at 1, 2, 4.

78. Telephone interviews with Monte Besler, consulting petroleum engineer (July 28 and 29, 2010).

79. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0111, supra note 64. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0160, supra note 55. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0188, supra note 67. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-0200, supra note 65. West Virginia Geological and Economic Survey. Pipeline Database, Well Number 47-35-1746. Accessed online Feb. 21, 2011 at http://www.wvgs.wvnet.edu/oginfo/pipeline/pipeline2.asp.

80. West Virginia Department of Environmental Protection. Inspectors Permit Summary Form, API No. 47-3502717, supra note 1.

81. West Virginia Division of Environmental Protection. Office of Oil and Gas, Well Operator's Report of Well Work, API No. 47-035-02717, supra note 1.

82. Southern Jackson County Public Service District staff. Telephone interview (Oct. 28, 2010).

83. West Virginia Department of Environmental Protection, Section of Oil and Gas, Well Operator's Report of Well Work, API # 4703502837, July 29, 2008. Plat for Well No. WV 511044, API Well No. 47-035-02837, Prepared by Gregory A. Smith, Professional Surveyor (indicating that the well's horizontal leg traveled northwest). West Virginia Department of Environmental Protection, Section of Oil and Gas, Well Operator's Report of Well Work, API # 4703502844, Sept. 26, 2008. Plat for Well No. WV 511356, API Well No. 47-035-02844, Prepared by Gregory A. Smith, Professional Surveyor (indicating that the well's horizontal leg traveled northwest). West Virginia Department of Environmental Protection, Section of Oil and Gas, Well Operator's Report of Well Work, API # 4703502846, Jan. 22, 2009. Plat for Well No. WV 511358, API Well No. 47-035-02846, Prepared by Gregory A. Smith, Professional Surveyor (indicating that the well's horizontal leg traveled southeast).

84. West Virginia Department of Environmental Protection, Section of Oil and Gas, Well Operator's Report of Well Work, API # 4703502837, supra note 83.

85. West Virginia Department of Environmental Protection, Section of Oil and Gas, Well Operator's Report of Well Work, API # 4703502844, supra note 83.

86. West Virginia Department of Environmental Protection, Section of Oil and Gas, Well Operator's Report of Well Work, API # 4703502846, supra note 83.

87. West Virginia Department of Environmental Protection, Section of Oil and Gas, Well Operator's Report of Well Work, API # 4703502845, Jan. 22, 2009.

88. Hagy, Dennis and Tammy. Interviews with Dennis and Tammy Hagy (June 16 and 17, 2010). Telephone interviews with Dennis and Tammy Hagy (Oct. 26 and 27, 2010).

89. West Virginia Department of Environmental Protection, Office of Oil and Gas, Complaint Information Form, Taken by Gene Smith, Reported by Dennis Hagy, Complaint against Equitable, February 12, 2009.

90. Telephone interview with James Martin, supra note 51.

91. Sturm Environmental Services. Water Test of Hagy Well for Equitable Production Company, Sampled by Smith Land Surveying, Ben Stewart, Oct. 17, 2007. Microbac Labratories, Inc. Electronic Certificate of Analysis, Sample 002 511044 5478/Hagy, Dates Sampled: 10/17/2007-10/23/2007, Date Recieved: 10/25/2007, Date Reported 11/05/2007. Sturm Environmental Services. Water Tests of Hagy Well for Equitable

Production Company, Sampled by Smith Land Surveying, Mike Shiflet Nov. 7, 2008 and Dec. 16, 2008. Sturm Environmental Services. Water Test of Hagy well and nearby wells for West Virginia Department of Environmental Protection, Sampled by Gene Smith, Mar. 31, 2009. West Virginia Department of Health and Human Resources/Bureau for Public Health, Office of Laboratory Services, Environmental Chemistry Laboratory, Laboratory Analytical Report, Submitter: Dennis Hagy, Sample # W09000554-01-001, Collection Point: Cellar faucet Date Collected: Mar. 26, 2009, Dates Sampled: Mar. 26, 2009-April 14, 2009.

92. Telephone interview with Dennis Hagy (July 15, 2011).

93. West Virginia Code of State Rules. W. Va. Code St. R. tit. 35, § 4-19 (2010).

94. Martin, James. Telephone interview with James Martin, supra note 51. Hagy, Dennis and Tammy. Interviews with Dennis and Tammy Hagy, supra note 88. REI Consultants, Inc., Analytical Results, Client: West Virginia Department of Environmental Protection, Client Sample ID: 1-Hagy Water Well, Collection Date: Oct. 8, 2010, Dates Analyzed: Oct. 9-Oct. 14, 2010 (the lab tested for BTEX on Oct. 11, 2010). U.S. Environmental Protection Agency, Technical Factsheet on Benzene. Accessed online July 9, 2011 at www.epa.gov/ogwdw000/pdfs/factsheets/voc/tech/benzene.pdf. U.S. Environmental Protection Agency, Technical Factsheet on Toluene. Accessed online July 9, 2011 at www.epa.gov/ogwdw000/pdfs/factsheets/voc/tech/toluene.pdf. U.S. Environmental Protection Agency, Technical Factsheet on Ethylbenzene. Accessed online July 9, 2011 at www.epa.gov/ogwdw/pdfs/factsheets/voc/tech/ethylben.pdf. U.S. Environmental Protection Agency, Technical Factsheet on Xylenes. Accessed online July 9, 2011 at *www.epa.gov/ogwdw000/pdfs/factsheets/voc/tech/xylenes.pdf.*

95. West Virginia Department of Mines, Oil and Gas Division, Well Record, Permit No. Jac-83, April 7, 1941. West Virginia Geological and Economic Survey, Pipeline Database, Well Number 47-35-0083. Accessed online February 21, 2010 at http://www.wvgs.wvnet.edu/oginfo/pipeline/pipeline2.asp.

96. West Virginia Department of Mines, Oil and Gas Division, Affidavit of Plugging and Filling Well, Permit No. Jac-83, October 18, 1948.

97. West Virginia Division of Environmental Protection, Office of Oil and Gas, Well Operator's Report of Well Work, API No. 47-035-02784, Nov. 7, 2007.

98. Id. . West Virginia Department of Environmental Protection, Office of Oil and Gas, Database Information, Search Oil and Gas Database, Oil and Gas Wells, Abandoned Well. Accessed online July 15, 2011 at http://apps.dep.wv.gov/oog/wellsearch_new.cfm?CFID=11197&CFTOKEN=41318047&jsessionid=3a3036420372e9a1f6524d182d4522e744a2TR.

99. Southern Jackson County Public Service District staff. Telephone interviews (Oct. 28, 2010 and July 8, 2011).

100. Telephone interview with Dennis Hagy (July 14, 2011). Telephone interview with staff of Joseph R. Goodwin, Chief Judge of U.S. District Court for the Southern District of West Virginia (July 14, 2011).