



In the Shadow of the Marcellus Boom

How Shale Gas Extraction Puts Vulnerable Pennsylvanians at Risk



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Executive Summary

Hydraulic fracturing with horizontal drilling – a form of natural gas extraction rapidly spreading across Pennsylvania – poses serious potential for harm to our environment and our health. Gas companies are injecting water, sand and chemicals at high pressures deep beneath the earth, fracturing the underground Marcellus Shale rock formation to extract the gas trapped within. Blowouts and fires can occur at well sites, and drilling and extraction can contaminate the state’s air and water. These impacts put the health of Pennsylvanians at risk – especially children and other vulnerable populations.

From Pittsburgh to Scranton, gas companies have already drilled more than 3,000 hydraulic fracturing wells, and the state has issued permits for thousands more. **Permitted well sites exist within two miles of more than 320 day care facilities, 67 schools and nine hospitals statewide.**

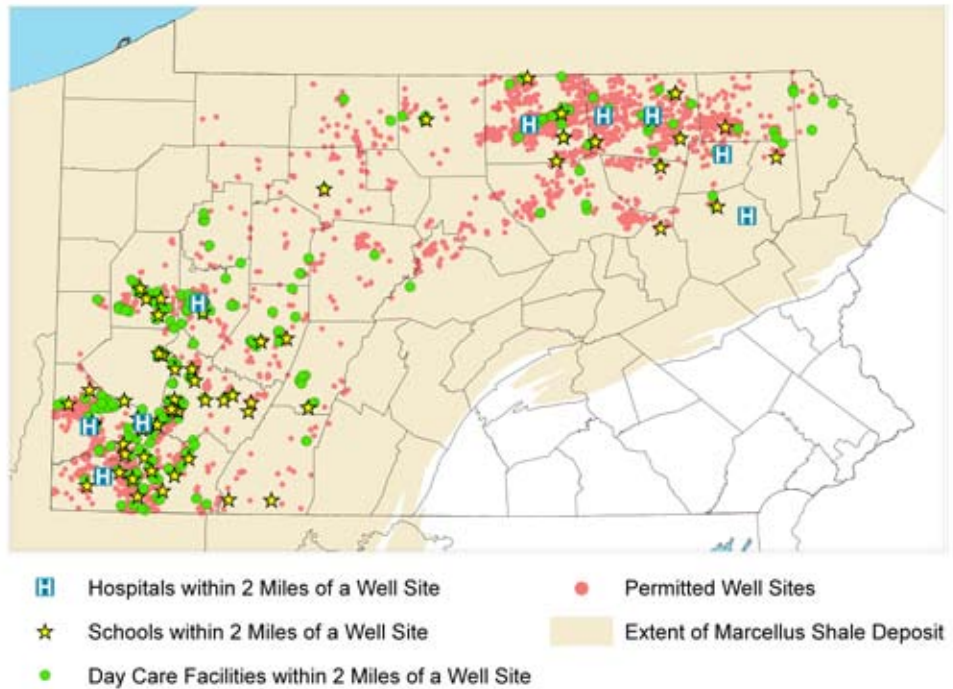
Federal and state regulations have not kept up with the speed at which gas companies have deployed into Pennsylvania’s communities. Governments should require gas companies to take

greater precautions to protect citizens’ health and environment.

Marcellus Shale drilling and gas extraction is happening in close proximity to many vulnerable Pennsylvanians.

- Gas companies have already drilled more than 3,000 hydraulic fracturing wells in Pennsylvania’s Marcellus Shale (as of April 2011). During 2010, the state Department of Environmental Protection (DEP) issued permits to gas companies to drill or deepen nearly 3,450 additional wells. So far in 2011, the DEP has issued more than 10 well permits per day, on average. In a broad strip from southwest of Pittsburgh to northeast of Scranton, very few places in the region are located farther than 10 miles from permitted well site. (See Figure ES-1.)
- Children are likely more vulnerable to the impacts of gas extraction because they are still developing. The sick and diseased, meanwhile,

Figure ES-1 – Hospitals, Schools and Day Care Facilities within Two Miles of a Permitted Well Site



have fewer defenses against pollution exposure. Across the state, Marcellus Shale well sites exist within two miles of more than 320 day care facilities, 67 schools, and 9 hospitals – providing a limited snapshot of the proximity of gas extraction to these vulnerable groups. (See Table ES-1.)

- The DEP recorded 241 violations of environmental regulations at Marcellus wells within two miles of a day care facility, and 40 violations within two miles of a school, from January 2008 to June 2010 alone – not including traffic safety violations by tanker trucks.
- With industry projecting on the order of 50,000 new wells over the next two decades, gas extraction activity is likely to move into even greater proximity to more vulnerable populations across the region.

Blowouts and fires at well sites create immediate health threats.

- In April 2011, a well in Bradford County blew out during the hydraulic fracturing process. Thousands of gallons of chemicals spilled, contaminating nearby farm fields and Towanda Creek. Emergency officials evacuated at least seven families.

Table ES-1: Proximity of Vulnerable Populations to Permitted Well Sites

Facility Type	Number Within One Mile of a Well Site	Number Within Two Miles of a Well Site
Day Care	104	320
School	14	67
Hospital	2	9

- In June 2010, a well blew out in Clearfield County, northeast of Pittsburgh. The well spewed gas and drilling fluid 75 feet into the air for 16 hours.
- In 2007, gas from an improperly sealed well in Ohio infiltrated a nearby home, where it exploded, seriously damaging the structure.
- In April 2010, a tank and open pit storing wastewater from a well in Hopewell Township, Washington County, caught fire, sending a plume of black smoke across the nearby countryside. And in February 2011, four chemical storage tanks exploded at a Chesapeake Energy well site in Washington County, injuring three workers and spewing pollution into the air for three hours.

At every stage in the process, Marcellus Shale gas extraction creates risks for water pollution.

- The DEP recorded more than 1,000 violations of regulations intended to protect water quality and the environment at gas extraction sites between 2008 and August 2010.
- Spills or leaks can pollute rivers, lakes or groundwater with chemicals used in hydraulic fracturing fluid, some of which have ties to acute and chronic health impacts ranging from neurological damage to cancer. Among them are chemicals including diesel fuel, benzene, toluene and 2-butoxyethanol.
- Additionally, the well drilling and fracturing process releases naturally occurring metals and salts from the shale formation, many of which can threaten human health, including arsenic, barium, chromium, lead, strontium and radioactive materials such as radium. These substances

could contaminate water supplies through underground leaks, surface spills or improper disposal at water treatment plants.

- Gas has been documented to contaminate aquifers up to seven miles from a well site, suggesting that pathways exist for contaminants to travel long distances underground.

Extracting gas from the Marcellus Shale also creates hazardous air pollution.

- Gas fields can become major sources of health-threatening smog. For example, gas extraction and processing activities in the Barnett Shale region of Texas generate 70 percent as much smog-forming pollution as all motor vehicles operating in the nine-county Dallas-Fort Worth Metropolitan area. Wyoming's Sublette County, home to thousands of gas wells but only 9,000 people, has suffered from unhealthy levels of air pollution more commonly associated with big cities since a drilling boom that began in 2005.
- In addition to smog, well operations produce a variety of hazardous air pollutants, including diesel soot from thousands of truck trips and pump engines operating 24 hours a day, gases vented from wells, contaminants from processing the substances that come up out of the well, and fumes evaporating from wastewater ponds, including benzene, methanol and formaldehyde. These substances pose risks for acute and chronic health impacts, from dizziness to rashes to cancer.

Anecdotal reports suggest that living near gas extraction sites can cause health impacts, although little formal scientific study has been completed to date. For example:

- Fifteen residents of Dimock, PA, filed a lawsuit against Cabot Oil & Gas in 2009, alleging that the company's gas extraction activities polluted their water supplies and harmed their health. The suit cites health problems including neurological illnesses and gastrointestinal problems. It also alleges that one person's blood showed toxic levels of the same metals found in drilling wastewater. The DEP has also taken legal action against Cabot in this case.
- Residents of western Colorado and Texas communities near hydraulic fracturing gas extraction operations have reported strange odors and health problems including nose bleeds, rashes, burning eyes, breathing difficulty, asthma, dizziness, fatigue, nausea, muscle aches, severe headaches and blackouts. Several residents have developed rare cancers.
- In a small town called Dish in the Barnett Shale region of Texas, tests have found a variety of hazardous pollutants related to gas extraction and processing in the air, in well water and in samples of residents' blood.

Government at all levels must protect Pennsylvanians' health and environment from gas extraction.

- The Commonwealth should designate pristine places and locations near where people live or work off-limits to gas extraction. This should include areas near day care facilities, schools, hospitals and other vulnerable populations.
- The Commonwealth should ensure gas companies pay the full cost of gas extraction and clean-up through

higher bonding requirements, impact fees and higher mandatory penalties for companies that break the law, pollute the environment, or put public health at risk.

- Additionally, the state should strengthen clean water laws, halt the use of toxic chemicals in the hydraulic fracturing process in favor of safer alternatives, increase the resources available to state regulators for enforcing the law, revoke drilling privileges for the worst offenders, and return erosion and sedimentation review authority to Pennsylvania's County Conservation Districts to help manage the gas well permitting process.
- The state should require gas companies to report important information to the general public as well as the DEP, including the types and amounts of chemicals used during drilling and fracturing and the composition and disposal of wastewater, in a timely fashion and on a well-by-well basis.
- Federal law exempts gas extraction from regulation under key elements of the Safe Drinking Water Act, the Clean Air Act, the Clean Water Act, the National Environmental Policy Act, and the Resource Conservation and Recovery Act. Additionally, the industry faces no federal obligation to account for quantities of potentially toxic chemicals left underground, or to report toxic emissions to the Toxic Release Inventory. The federal government should end the special treatment for the gas industry and apply the nation's core public health and environmental laws to gas extraction just as it would regulate any potential threat to public health or the environment.

Introduction

Pennsylvania is no stranger to energy booms and busts. Nor are Pennsylvanians strangers to the long-lasting environmental, economic and public health consequences of energy extraction gone wrong.

Pennsylvania fueled America's industrial revolution with coal. From the rise of the railroads in the 1800s, to the construction of large power plants in the 1900s, Pennsylvania provided more than 10 billion tons of coal to the American economy.¹ Pennsylvania was also home to the nation's first oil boom during the late 19th and early 20th century – indeed, the Keystone State produced half of the world's oil until 1901.²

Pennsylvanians are still paying the price for fossil fuel extraction that, in some cases, occurred more than a century ago. In former coal mining regions of the state, large piles of coal waste litter the landscape, leaching heavy metals and acid mine drainage into local waterways.³ More than 2,400 miles of Pennsylvania streams remain polluted with acidic,

toxic, orange-tinted water draining from old mines, killing stream life and making water supplies undrinkable.⁴ The Pennsylvania Department of Environmental Protection has estimated that addressing all of the impacts of acid mine drainage in the Commonwealth would cost roughly \$16 billion.⁵ Meanwhile, over the past century and a half, more than 250,000 oil and gas wells were drilled in Pennsylvania – primarily in the northwestern Pennsylvania “oil patch.” Many older oil and gas wells were simply abandoned when production ceased, creating a series of environmental risks including the leaking of oil to the surface and the contamination of groundwater with methane or brine.⁶

Today, Pennsylvanians find themselves in the midst of another energy boom – the extraction of natural gas from the Marcellus Shale. And again – thanks to ineffective regulation by both state and federal authorities – Pennsylvania runs the risk of paying a severe price in environmental degrada-

tion and health damage from fossil fuel extraction.

Hydraulic fracturing of wells drilled horizontally into the Marcellus Shale is relatively new, and there is much about its environmental and public health impact that we don't know. Thanks to decades of science linking discharges of toxic chemicals in the air and water to human health problems – as well as the persistent toxic legacy of former fossil fuel booms in Pennsylvania – we know far more than our ancestors did about the potential costs of fossil fuel extraction. We know more than enough, in fact, to be concerned about the impact that poorly conducted hydraulic fracturing operations in the Marcellus Shale are having on the health of nearby residents – particularly the most vulnerable Pennsylvanians, including children and the sick.

In this report, PennEnvironment Research & Policy Center explores the possible consequences that expanded gas extraction in Pennsylvania's Marcel-

“The Marcellus Shale is a huge gas field. It may seem like there are a lot of companies up here now, but there really isn't – yet.”

– Kristi Gittins, spokeswoman for Chief Oil & Gas, in the *Pittsburgh Tribune Review*, June 13, 2010.⁷

lus Shale could bring. We explore how rapidly the gas boom is expanding, and how close permitted well sites are to day care facilities, schools and hospitals.

The philosopher George Santayana wrote that “those who cannot remember the past are condemned to repeat it.” As natural gas extraction in the Marcellus Shale accelerates, Pennsylvanians must remember the lessons of our past. The health of our people and our environment depends on it.

Photo: Mark Schmerling



Marcellus Shale Gas Extraction Risks Pollution of Pennsylvania's Air and Water

Natural gas companies are flooding into Pennsylvania in the 21st century equivalent of a gold rush – staking claim on vast deposits of gas trapped in an underground rock formation called the Marcellus Shale.

To reach the gas inside the shale, gas companies are employing techniques called horizontal drilling and hydraulic fracturing. The process involves drilling a deep well into the ground vertically, turning the drill bit horizontally into the Marcellus Shale rock formation, injecting a solution of sand and chemicals to fracture the rock and extract the gas trapped within, and then processing and shipping the gas to market.

Gas extraction in the Marcellus Shale poses threats including the acute risk of blowouts and fires; the risk of polluting water supplies with chemicals used in hydraulic fracturing, or with chemicals and radioactive minerals dislodged from deep underground; and the risk of exposure to air pollution from diesel exhaust pipes, chemical ponds, gas flaring or accidental

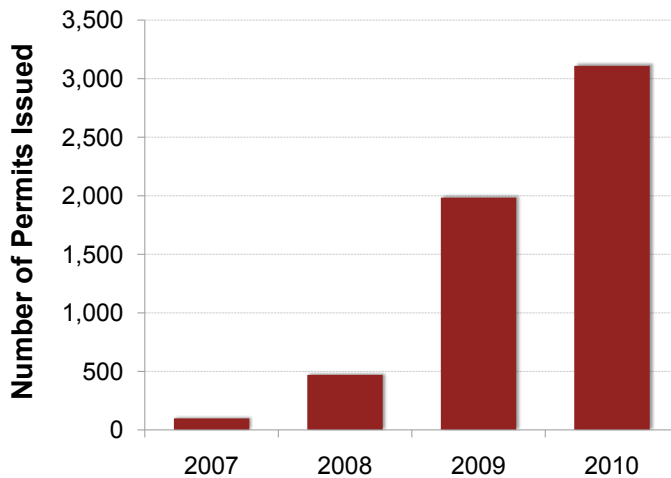
fires. Anecdotal reports suggest that living near well sites can cause health impacts.

Extracting Natural Gas from Pennsylvania's Marcellus Shale

The Marcellus Shale stretches beneath 60 percent of Pennsylvania's land mass, at depths of 5,000 to 9,000 feet.⁸ The gas industry estimates that the rock formation could contain enough energy to power the entire world economy for nearly three years – making it potentially the second-largest gas field on earth.⁹

For decades, the gas industry pursued cheaper resources, believing that the gas trapped in the Marcellus Shale was too difficult to extract economically. However, with rising energy prices, and the development of more effective hydraulic fracturing techniques, the gas industry discovered that Marcellus Shale gas could be extracted at a profit. Industry

Figure 1: The Shale Boom: The State Is Issuing an Increasing Number of Permits for Marcellus Shale Wells Each Year¹⁷



officials and observers alike have called this discovery a “game changer.”¹⁰

The gas industry has moved quickly to develop Pennsylvania’s Marcellus Shale. Gas companies drilled the first test well into Marcellus Shale in 2004.¹¹ Gas extraction began in earnest in 2007. Since then, the number of state-issued permits for Marcellus Shale wells has been growing at a rate of more than 200 percent per year.¹² (See Figure 1.) Today, more than 80 companies are actively developing this resource in Pennsylvania.¹³

The leading player is Chesapeake Energy, which controls more than 1,000 permitted well sites.¹⁴ Other major players in the industry include Range Resources, Atlas Resources, Anadarko, EOG Resources (formerly Enron), Talisman Energy, Ultra Resources, East Resources, Cabot Oil & Gas, Chief Oil & Gas and Fortuna Energy.

These companies – joined by major international players including Exxon Mobil and Statoil – are planning a massive expansion of drilling to capture the resources in the Marcellus Shale.¹⁵ Gas

production in Pennsylvania could expand nearly 40-fold in the next decade.¹⁶

Hydraulic Fracturing

The gas in the Marcellus Shale is trapped within microscopic cracks in the rock. The gas is inaccessible with conventional drilling techniques, which are better suited for tapping consolidated pockets or reservoirs of oil or gas underground. In order to release the gas from the shale, gas companies have deployed technology known as “hydraulic fracturing” – sometimes called “fracking” for short.

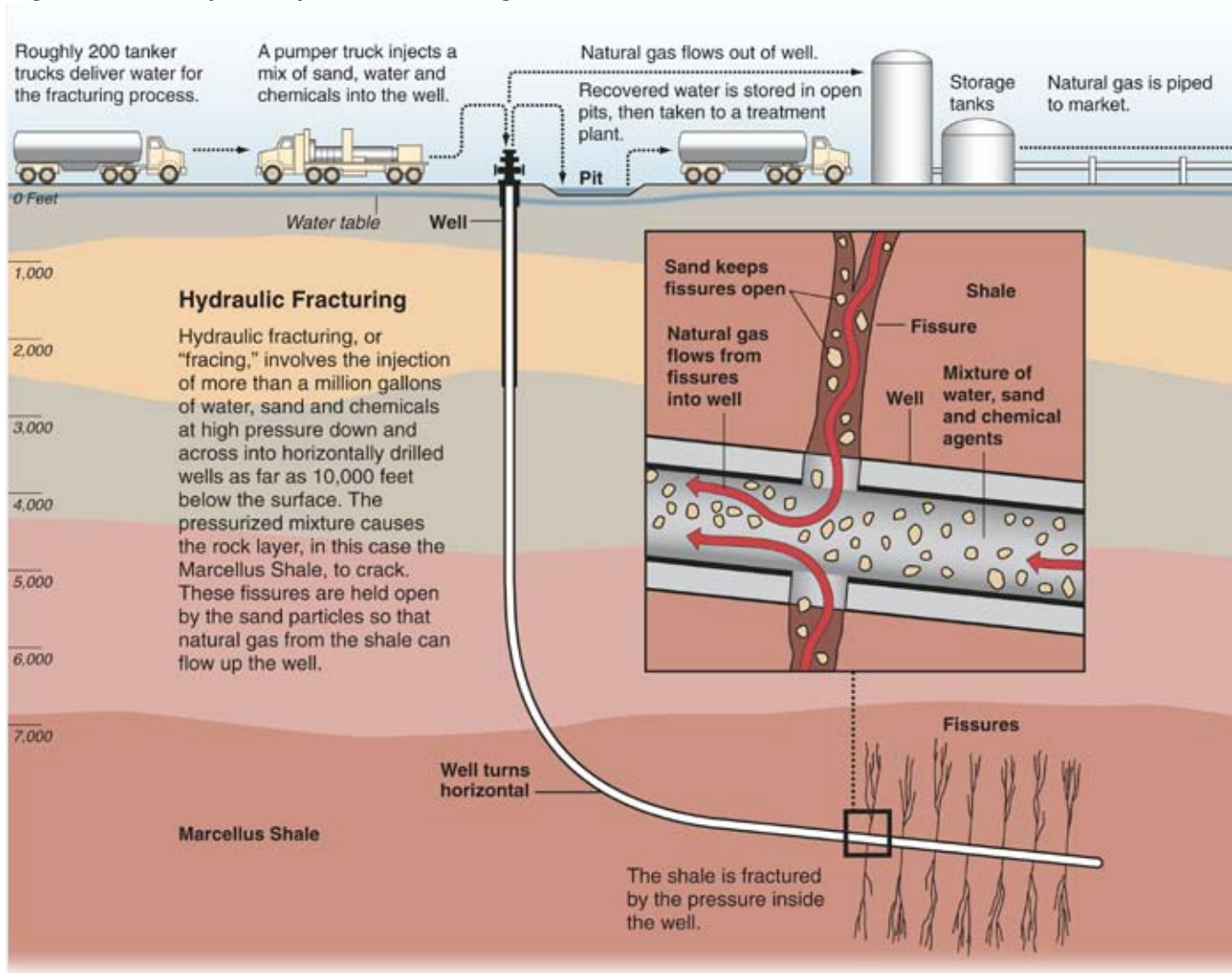
The process of hydraulic fracturing widens cracks in the shale, allowing gas trapped there to escape and flow into the well. First, a gas company drills a vertical well into the shale formation. Then, drilling operators cut horizontal branches into the shale, radiating outward as much as 5,000 feet to reach sections of rock away from the central well and increase the ability of the well to produce gas.¹⁸

Once the wells are drilled, operators pump water containing sand and a mixture of chemicals into the ground at high pressure. The water forces its way into cracks in the rock, widening them, and the sand holds those cracks open wide enough for gas to escape. (See Figure 2.) After drilling a well, operators can repeat the process of hydraulic fracturing to boost gas production anywhere from a

year to 10 years after the well begins operation.¹⁹

The oil and gas industry has been using fracturing and horizontal techniques for years. However, using these techniques in combination is a relatively new development. This technology has helped make gas extraction in the Marcellus Shale a profitable enterprise.

Figure 2: Anatomy of a Hydraulic Fracturing Well



Al Granberg/ProPublica

*Photo: New York Department of Environmental Conservation, 2009*²⁰



Once the wells into the Marcellus Shale are drilled, operators pump water containing sand and a mixture of chemicals into the ground at high pressure. The three wellheads in this photo, owned by Fortuna Energy, are undergoing preparation for the fracturing process.

Vast Fortunes at Stake

The gas trapped in the Marcellus Shale is potentially worth trillions of dollars. Gas companies have a clear financial interest in extracting as much of the gas as possible, and they have already invested more than \$10 billion in developing Pennsylvania's Marcellus Shale.²¹ Some rural landowners have also cashed in on

the shale gas boom, accepting payments on the order of thousands of dollars per acre – plus the promise of production royalties – in exchange for allowing drilling to proceed on their land.

However, the price of Marcellus Shale gas extraction extends beyond money. It also includes exposure to the risk of accidents and pollution.

“We are witnessing the industrialization of rural Appalachia and no one is ready for it.”

– Victoria Switzer, Resident of Dimock, Pennsylvania, speaking to the *Globe and Mail* in 2010.²²

The Impacts of Marcellus Shale Gas Extraction

At every stage in the process, extracting gas from the Marcellus Shale poses significant risks, including blowouts, and air and water pollution.

Accidents at a well site immediately threaten the well-being of anyone in the area. Gas migrating into a water supply can create the risk of explosions within nearby buildings. Spills or leaks can contaminate water supplies with chemicals used in hydraulic fracturing fluid, or with naturally occurring toxic metals and salts from the shale formation. Documented incidents of gas contamination of underground aquifers suggest that gas – and potentially other contaminants – can travel underground at least one mile and up to seven miles or more from a well site.²³

Further, improper disposal of wastewater could result in contamination of Pennsylvania’s surface water supplies.

Exhaust from thousands of trucks and diesel-fueled equipment operating 24 hours a day, smoke from flares or fires – plus hazardous chemicals evaporating from the well, from wastewater or from gas processing or transport equipment – could contaminate local areas with unhealthy levels of air pollution.

Blowouts, Fires and Explosions

Blowouts and fires at well sites, or in nearby homes with contaminated water supplies, create immediate health threats for anyone in the area – including burns, smoke inhalation or exposure to especially high concentrations of air pollution. Several high-profile incidents in the past several years in Pennsylvania and neighboring states illustrate the risk.

Blowouts and Fires

- In April 2011, a well on the Morse Farm in Leroy Township, outside Canton in Bradford County, blew out during the hydraulic fracturing process. The well, owned by Chesapeake Energy, spilled thousands of gallons of chemicals, contaminating nearby farm fields and Towanda Creek, a tributary of the Susquehanna River. Emergency officials evacuated at least seven families.²⁴
- In April 2010, a tank and open pit storing waste well fluid in Hopewell Township, Washington County, caught fire, sending flames 100 feet into the air and spewing a plume of black smoke across the countryside.²⁵ Kyle Lengauer, a nearby resident, told the *Pittsburgh Post-Gazette* that the explosion came after days of smelling gas odors. “We actually left our house on Sunday because the fumes were so bad and we were so nauseated,” he said.
- In June 2010, a well owned by EOG Resources (formerly Enron) in Lawrence Township, in Clearfield County northeast of Pittsburgh, blew out. The well spewed gas and drilling fluid 75 feet into the air for 16 hours before crews were able to bring it back under control.²⁶ In a situation eerily similar to the BP Macondo well disaster in the Gulf of Mexico,

EOG had installed a broken blowout preventer with no backup system, allowing the pressure of the earth to blast the contents of the well up and out.²⁷

- In January 2011, a blowout accident happened at a well owned by Talisman Resources in Tioga State Forest, near Blossburg.²⁸ And in February 2011, four chemical storage tanks at a Chesapeake Energy well site in Avella, Washington County, exploded, injuring three workers and spewing pollution into the air for three hours.²⁹

Home Explosions

Gas is flammable and explosive. When gas escapes from a well into the surrounding groundwater, it can infiltrate homes through drinking water wells and water pipes. If the gas builds up to a sufficient concentration, and a spark or source of flame ignites the gas, an explosion will result. This has already happened several times in Pennsylvania and neighboring states. For example,

- In 2007, a home in Cleveland, Ohio, exploded after gas built up in the basement. State officials blamed faulty construction in a nearby hydraulic fracturing gas well, which allowed gas to seep into an underground aquifer and into the home's water system.³⁰ Fortunately, the residents were not home, but the explosion severely damaged the structure. Twelve days before the explosion, gas had reached the water system of the local police department – nearly a mile from the gas well.³¹
- In 2009, Norma Fiorentino, a resident of Dimock, PA, came home to find that the building housing her drinking water well had exploded.

The state theorized that gas from nearby hydraulic fracturing operations contaminated the aquifer beneath her home, built up in her well, and caused an explosion when the water pump activated.³²

Water Pollution

Fracturing a Marcellus Shale well requires on the order of 2 to 8 million gallons of fluid for a single well.³³ That is vastly more fluid than required to drill a conventional gas well – providing proportionally more opportunities to contaminate local water resources.

Surface spills of fuels, fracturing fluids, or wastewater can contaminate soils and local groundwater supplies. Improperly sealed wells can allow drilling fluids or naturally-occurring contaminants to leak into groundwater. Finally, disposal of wastewater can contaminate Pennsylvania's rivers and streams after improper treatment.³⁴ Pennsylvania is the only state that allows gas companies to use surface waters rather than deep underground injection wells as the primary receptacle for drilling waste water.³⁵

Photo: Mark Schmerling



An accident at a well site near buildings, such as this well located between several homes in Bradford County, could create immediate health threats for anyone in the area.

Potential Contaminants

Gas extraction in the Marcellus Shale can contaminate water supplies with pollutants including methane gas, drilling fluid, hydraulic fracturing fluid, or naturally occurring contaminants forced up through the well. Many of these substances have toxic properties and can cause both acute and long-term health impacts.

Hydraulic Fracturing Fluid

Many companies have been unwilling to identify all of the specific ingredients used in fracturing fluid, claiming some as trade secrets. In particular, the largest supplier of fracturing services, Halliburton, has resisted requests from federal and state environmental agencies to disclose the chemical composition of some of its products in order to protect its “competi-

tive advantage.”³⁸ In Pennsylvania, drillers have to report to the DEP the types of chemicals used at fracturing sites and their concentrations. However, the law prevents DEP from disclosing information designated as trade secrets.³⁹

From this reporting, we know that fracturing fluid contains many chemicals that would be problematic if they contaminated water supplies.⁴⁰

In general, fracturing fluid contains about 90 percent water, nine percent sand, and one percent chemical additives, by weight.⁴¹ Although the chemical additives are a relatively small fraction of the fracturing fluid by volume, because fracturing requires huge volumes of water, this represents a large amount of chemicals. A well that requires three million gallons of fluid would require on the order of 250,000 pounds of chemicals.⁴²

Photo: New York Department of Environmental Conservation³⁶



Chemical additives destined for use at a hydraulic fracturing gas well.



Trucks delivering fracturing water (above) and hydrochloric acid (below) to a well site.

Given that the industry expects to drill as many as 50,000 Marcellus wells, that could require introducing more than 10 billion pounds of chemicals into Pennsylvania's environment.

The chemical additives give the fluid the ability to carry grains of sand deep into cracks in the shale, propping open fractures. Fracturing chemical additives include acids, friction reducers, surfactants, gelling agents, bacterial growth retardants, corrosion and mineral deposit inhibitors, and clay stabilizers.⁴³ Gas companies customize the exact contents of a fracturing fluid based on the characteristics of the rock formation where the gas deposit lies.

In 2010, in response to requests from New York state regulators, a subset of

gas companies submitted a list of more than 200 different chemicals that can be used in fracturing additives to the state Department of Environmental Conservation. The Pennsylvania DEP has a similar listing on file.⁴⁴ These chemicals include:

- **Amides**, including formamide and acrylamide;
- **Petroleum distillates**, including diesel fuel, mineral spirits, and related solvents;
- **Aromatic hydrocarbons**, including benzene, toluene and xylene; and
- **Other chemicals**, including 1-4 dioxane, 2-butoxyethanol and tar bases.

Doctors and health scientists have associated many of these pollutants with a wide variety of acute illnesses and long-term diseases, including cancer, asthma and liver, kidney or central nervous system problems.⁴⁵ Evolving understanding of long-term exposure to small amounts of these types of contaminants suggests that contaminants from gas extraction could have serious impacts on public health, especially near well sites.⁴⁶

The New York Department of Health provided an overview of the health effects of different types of chemicals used in hydraulic fracturing to the state's environmental regulators. Among their findings:⁴⁷

- Breathing or ingesting **diesel fuel and petroleum-derived solvents** can harm the central nervous system.
- **Benzene and related aromatic hydrocarbons** can be found in petroleum-derived solvents. They can harm the nervous system, liver, kidneys and blood cell-forming tissues. Benzene increases leukemia risks in workers who inhale relatively low levels of the chemical over long periods of time. Exposure to xylene damages the unborn offspring of laboratory animals, and evidence points to human harm as well.⁴⁸ Ingestion or inhalation of naphthalene damages red blood cells. Over longer periods of exposure, naphthalene damages respiratory tissues and increases the risk of respiratory system cancers.
- **Acrylamide** can cause nervous system damage and cancer in laboratory animals. **Formamide** harms the reproductive system in female laboratory animals. **Formaldehyde** is a carcinogen and can cause asthma. Laboratory animals exposed to **1-4 dioxane** through drinking water developed liver cancer.

Naturally Occurring Contaminants

The process of drilling and fracturing a Marcellus Shale well releases large quantities of naturally occurring chemicals, which could also contaminate water supplies. These contaminants include:

- **High levels of salt.** The Marcellus Shale developed from an ancient ocean, and the process of hydraulic fracturing causes high levels of salt to mobilize in the fracturing fluid.
- **Heavy metals.** A limited analysis of flowback water from wells in Pennsylvania found a variety of hazardous metals, including arsenic, antimony, barium, cadmium, chromium, cobalt, copper, iron, lead, molybdenum, nickel, silver, strontium, thallium and titanium.⁴⁹ Arsenic causes cancer.⁵⁰ Very low levels of lead exposure have been linked to kidney damage, learning difficulties, mental and physical developmental problems and behavioral changes.⁵¹
- **Radioactive elements.** In flowback water samples from eight Marcellus wells reviewed by the New York Department of Environmental Conservation, scientists found radioactive components, including radium, 100 percent of the time.⁵² Radium levels were “as high as 267 times the limit safe for discharge into the environment and thousands of times the limit safe for people to drink.”⁵³ In February 2011, the *New York Times* published an investigation of previously unreleased field reports from the U.S. EPA and the Pennsylvania DEP, dated between 2008 and 2009, which found that 42 wells in Pennsylvania produced wastewater with radium levels higher than federal drinking water standards – in some cases almost 20,000 times higher.⁵⁴

Long-term exposure to even low levels of radioactivity can increase the odds of developing cancer.

How Contaminants Reach Water Supplies

Contaminants can reach water supplies through faulty well construction, through surface spills, or through improper wastewater disposal.

Faulty Well Construction

In their first thousand feet, all gas wells pass through a layer of earth that contains aquifers, or underground reservoirs of water. Many people rely upon these underground supplies for drinking water – especially in more rural areas of the state, where municipal water supplies may not be available.

Thousands of feet of rock separate drinking water aquifers and the Marcellus Shale.⁵⁵ However, the act of drilling a well creates a conduit that could carry contaminants into groundwater.

To protect groundwater supplies, Pennsylvania requires gas companies to use metal casing pipes and cement to seal wells.⁵⁶ The casing pipes are intended to isolate the well from non gas-bearing rock layers and allow gas and fluids to pass into or out of the well without contaminating drinking water supplies. Casing occurs in stages, with the inner casing reaching all the way to the bottom of the well, and intermediate and outer layers extending to progressively more shallow depths below the groundwater layer.

Between 65 and 90 percent of any hydraulic fracturing fluid injected into a well may stay underground indefinitely.⁵⁷ If the well casings do not function properly, this fluid could contaminate groundwater supplies. Any errors in casing could provide a pathway for contaminants to escape the inner well, migrate upward along the well shaft, and eventually contaminate underground water supplies. During



Surface spills of fuels, fracturing fluids, or wastewater from gas extraction can contaminate soils, streams, rivers and groundwater supplies.

fracturing, operators increase the pressure inside the well to as high as 10,000 pounds per square inch – pressure that could force contaminants through any improperly sealed gaps in the casing.⁵⁸ After fracturing, the pressure of the earth could potentially force anything in the well up into groundwater layers through any poorly sealed gaps in the casing.

Surface Contamination at the Well Site

Spills caused by tank ruptures, wastewater impoundment failures, overfills or accidents – or by sloppy handling of dangerous substances – can contaminate nearby soils, groundwater, streams or wetlands. States have documented thousands of instances of water contamination resulting from surface spills at gas well sites. For example:

- In March 2010, Talisman Energy spilled hundreds of gallons of diesel fuel at a gas well in Armenia Township, Bradford County, PA. To clean the spill, Talisman had to

excavate 3,800 tons of soil and collect and treat more than 100,000 gallons of contaminated water.⁵⁹

- In November of the previous year, Talisman spilled more than 4,000 gallons of contaminated flowback water from a hydraulic fracturing operation into a tributary of Weiber Creek in Bradford County.⁶⁰
- In September 2009, Cabot Oil and Gas caused three spills in Dimock Township in less than a week, dumping 8,000 gallons of fracturing fluid components into Stevens Creek and a nearby wetland.⁶¹
- In May 2010, a fracturing wastewater pit owned by East Resources leaked into a farm field. The state Department of Agriculture quarantined 28 cattle exposed to the fluid to prevent any contaminated meat from reaching the market.⁶²
- The 2010 EOG well blowout in Clearfield County spilled 35,000 gallons of wastewater, some of which reached the Little Laurel Run, a stream that feeds the Susquehanna River.⁶³

In the state of Colorado, where hydraulic fracturing has become increasingly common since 2003, regulatory officials have documented more than 1,500 spills. In one case, a waste pit leaked 1.6 million gallons of fracturing fluids near the western Colorado town of Parachute. The waste was particularly obvious because groundwater currents carried it to a large cliff, where it formed an unusual 200 foot frozen waterfall.⁶⁴ In New Mexico, then-Governor Bill Richardson passed tougher regulations for wastewater storage pits after a study revealed 400 incidents where leaks, seepage or pit overfilling contaminated the state's water resources.⁶⁵

Wastewater Disposal

The impacts of shale gas extraction on water supplies extend beyond the well site. In particular, there are no problem-free methods for disposing of drilling wastewater.

After the pressure of hydraulic fracturing is released on a well in the Marcellus formation, on the order of 9 to 35 percent of the fracturing fluid flows back up to the surface – totaling between 200,000 and 3 million gallons per well.⁶⁶ The waste fluid contains fracturing chemicals, salt, and other substances from the rock formation that have been liberated by the drilling and fracturing process, and any results of chemical reactions happening in the well. Waste fluid can contain radioactive minerals as well.

Gas companies in Pennsylvania typically collect the wastewater and store it in lined pits or closed tanks, before either minimally treating it and re-using it for fracturing, hauling it off to a public or private water treatment plant for disposal, or selling it to another entity for uses including roadway de-icing.

Wastewater Treatment Plants

Up until recently, Pennsylvania gas companies primarily disposed of drilling wastewater by sending it to public or private wastewater treatment plants. These plants processed the waste and then discharged it to local waterways, which form the drinking water source for millions of Pennsylvanians and residents of other nearby states.

Unfortunately, Pennsylvania's water treatment plants are not equipped to deal with the contaminants often found in fracturing wastewater. Treatment plants are designed to treat biological contaminants coming from human waste – but not chemical salts, industrial toxicants, or radioactive minerals. Treatment

plants merely dilute and then discharge these materials into the state's rivers and lakes.

According to an investigation published by the *New York Times* in February 2011, "More than 1.3 billion gallons of wastewater was produced by Pennsylvania wells over the past three years, far more than has been previously disclosed. Most of this water — enough to cover Manhattan in three inches — was sent to treatment plants not equipped to remove many of the toxic materials in drilling waste."⁶⁷

In 2008, workers at a steel mill and a power plant along the Monongahela River noticed that water from the river was corroding their equipment. Nearby residents found that their dishwashers stopped working, and plates were left with mineral deposits. The Pennsylvania Department of Environmental Protection concluded that drilling wastewater, discharged through an upstream treatment

plant, had raised the mineral content of the river to the point where downstream users noticed and complained.⁶⁸ Drainage from old coal mines in the area could have also contributed to the problem.⁶⁹

The DEP chose to dilute the pollution, opening upstream dams. It also required gas companies to spread out the location of their wastewater disposal sites so as not to overburden a single waterway.⁷⁰

Pennsylvania DEP does not consider "total dissolved solids" — the official name of the contaminant that caused problems along the Monongahela River in 2008 — to be a health threat. However, many other contaminants in drilling wastewater could increase the risk of health effects for users downstream.

For example, the chloride and bromide salts in the wastewater can combine with organic materials in the water to create trihalomethanes, chemicals that can cause cancer and increase the risk of reproductive or developmental health problems.⁷¹

Photo: www.marcellus-shale.us



A tanker truck loading fracturing wastewater from a storage pit for disposal at a sewage plant.

Pennsylvania public water utilities downstream from waste treatment plants accepting hydraulic fracturing wastewater have experienced difficulty in keeping levels of trihalomethanes below health standards.⁷²

Jim Riggio, water system manager in Beaver Falls, Beaver County, told the *Pittsburgh Post-Gazette* in March 2011, “We went from non-detectable levels of bromide to increased levels a couple of years ago. When I see the whole frack water thing taking off and the same time we start to have problems, well, until you can tell me different, that’s what I assume it is. And it seems like a lot of the water suppliers on the Beaver and Mon rivers had similar problems to what we did.”⁷³

Total dissolve solids can also include radioactive materials, which can also cause cancer.⁷⁴

In part because of these concerns, the DEP adopted tougher standards for the emission of total dissolved solids from water treatment plants in 2010.⁷⁵ By 2011, only 15 treatment plants in the state accepted drilling wastewater. In April 2011, the DEP asked these treatment plants to stop.⁷⁶

Reusing Wastewater

In place of trucking wastewater to far-flung water treatment plants, many gas companies have begun “recycling” wastewater to use in new fracturing operations.⁷⁷ The *New York Times* reported that in the last 6 months of 2010, well operators reused about 65 percent of their wastewater.⁷⁸

Two problems remain with reusing wastewater. First, gas companies may have to add more chemicals to the fluid to create the appropriate properties necessary for fracturing. Second, since so much of the wastewater remains underground, this practice is effectively the same as using injection well disposal, albeit by a different name. Injection well disposal

is tightly regulated by the EPA under the Safe Drinking Water Act. However, injection well disposal achieved through hydraulic fracturing is effectively unregulated.

Moreover, once the “recycled” water becomes too contaminated to use in further fracturing operations, drilling operators have continued to dispose of it at local sewage treatment plants that are not equipped to remove all of the contaminants.⁷⁹ In the last six months of 2010, well operators disposed of 260 million gallons of wastewater – enough to fill tanker trucks lined up end to end from New York City to Richmond, Virginia – at waste treatment plants, and ultimately into local rivers.⁸⁰ Once Pennsylvania plants stop accepting wastewater, gas companies may find willing recipients in other nearby states.

Alternatively, well operators sell the wastewater to townships that spread it on roadways because of its high salt content, which helps melt ice and keep down dust – despite the fact that any contaminants run off into aquifers, rivers and streams after snowmelt or storms, or dry out and blow away on particles of dust.

According to a *New York Times* analysis of state records, a gas company called Ultra Resources sold more than 150,000 gallons of wastewater to nine Pennsylvania towns for use in dust suppression in 2009. The water contained radium – a radioactive contaminant – at levels close to 700 times higher than health standards for drinking water.⁸¹

Incidents of Water Pollution

From 2008 through August 2010, the Pennsylvania Department of Environmental Protection recorded more than 1,000 violations of regulations intended to protect water quality, according to a report by the Pennsylvania Land Trust Association.⁸² Improper casing and faulty blowout preventers resulted in 54 viola-

tions. More than 370 violations were for faulty pollution prevention or improper wastewater containment, and more than 150 violations were for illegal discharge of industrial waste.⁸³

The analysis did not include traffic violations by chemical, water, or waste hauling trucks, which can also pose safety and environmental hazards. For just one indication of how common these are, the Pennsylvania Land Trust Association reported that a 3-day traffic enforcement blitz in June 2010 resulted in 669 traffic citations and 818 written warnings to wastewater haulers.⁸⁴

Nationally, an investigation by the non-profit investigative journalism organization ProPublica identified more than 1,000 cases over an 18-month span where gas extraction operations harmed water supplies. The incidents included surface “spills of fracturing fluid waste, cracking of underground cement and well casings meant to enclose the fracturing process, and methane gas traveling large distances underground through faults and fractures.”⁸⁵

For example:

- State tests revealed contamination in nine separate wells in Dimock, a town in northeastern Pennsylvania where Cabot Oil & Gas had been drilling and fracturing wells in the Marcellus Shale. Test results included high levels of aluminum and iron – signals that fracturing fluids could have invaded the aquifer.⁸⁶ The Department of Environmental Protection blamed the problem on faulty well construction, which allowed contaminants to escape the well into groundwater.⁸⁷

Water contamination has occurred in other states as well. For example:

- In July 2008, a federal scientist discovered benzene – a carcinogen –

in a drinking water well in Sublette County, WY, at levels 1,500 times higher than health standards meant to protect people from diseases such as leukemia.⁸⁸ While no direct evidence linked the contamination with gas extraction, the drinking water well was near a large natural gas well field, where companies had been using hydraulic fracturing technology. Further tests revealed that the underground benzene plume stretched for more than 28 miles.⁸⁹

- In 2009, U.S. Environmental Protection Agency scientists found chemicals used in hydraulic fracturing, including 2-butoxyethanol, in 11 of 39 drinking water wells tested in a Sublette County neighborhood near natural gas extraction activity.⁹⁰ In 2010, agency scientists found additional chemicals, including metals, benzene, naphthalene, phenols and methane. Government officials warned residents not to drink their water, and to ventilate their homes well to avoid the risk of explosion.⁹¹ Tests definitively showed that the methane came from the formation being drilled rather than an unrelated shallow source, although researchers could not rule out previous oil extraction activity as a cause.⁹²
- Nationwide, more than 1,000 incidents where gases from nearby fracturing operations contaminated home wells demonstrate that contaminants can travel through underground fissures. In one case, experts at Isotech Laboratories documented that gases that led to an explosion at a business in Hutchinson, Kansas, were from a gas storage well that was seven miles away – much further than industry officials have said should be possible.⁹³

Methane is likely the most mobile contaminant coming from a gas well. If methane is reaching an aquifer, it could indicate that a pathway exists for other contaminants from gas extraction to infiltrate underground water supplies as well.

A study commissioned by the government of Garfield County, CO – where hydraulic fracturing has been occurring in earnest for a decade – found that methane in some area drinking water wells came from the same deep underground deposits where hydraulic fracturing was occurring, and not from shallowly buried organic matter, a possibility often suggested by the natural gas industry.⁹⁴ The study found that the levels of methane gas and chloride salts in the groundwater increased in parallel with the amount of gas extraction activity in the region.⁹⁵ Tests of methane in water supplies of Dimock residents also showed that the methane came from a deep layer of shale, rather than from a shallow source of gas.⁹⁶

The Garfield County study couldn't pinpoint whether the gas was migrating through cracks in the ground or leaking from poor seals in the well. However, Judith Jordan, a Garfield County official and former lawyer for the Pennsylvania Department of Environmental Protection, told ProPublica that the study "challenges the view that natural gas [...] is isolated from water supplies by its extreme depth." "Our concern is that [methane gas is] a sort of sentinel, and there are going to be worse contaminants behind it."⁹⁷

Air Pollution Risks

Gas production from the Marcellus Shale also creates air pollution. From the diesel exhaust produced by trucks and equipment to gases vented from wells, condensers or waste ponds, this air pollution poses risks to the health of nearby residents.

Photo: Mark Schmerling



Gas production from the Marcellus Shale creates air pollution, including diesel exhaust produced by trucks and equipment as well as gases vented from wells, condensers or waste ponds.

Smog-Forming Emissions

Gas extraction creates large amounts of smog-forming pollution. According to estimates by the New York Department of Environmental Conservation, constructing and operating a single well generates more than 140,000 pounds of smog-forming emissions in the first year of operation.⁹⁸

Studies in Texas, Colorado and Wyoming provide a good illustration of the types and scale of smog-related impacts that may be occurring – or may occur in the future – in the Marcellus Shale region.

- Hydraulic fracturing has been underway in the Barnett Shale region of Texas for more than a decade. The five-county region north of Dallas-Fort Worth where the shale is located now has more than 7,000 active gas wells.⁹⁹ Dr. Al Armendariz at Southern Methodist University studied the air pollution impacts of gas extraction in this area in 2009. He estimated total smog-forming emissions from the operation of compressor engines and drilling rigs, plus pollution escaping from condensate tanks, wells, gas transmission lines and gas processing stations. In total, Dr. Armendariz estimated that gas extraction activities produced 70 percent as much smog-forming pollution as all motor vehicles operating in the nine-county Dallas-Fort Worth Metropolitan area.¹⁰⁰ This amount of pollution – more than 13 billion pounds per year – is significant in an area which already fails to meet federal health-based air quality standards for smog.¹⁰¹
- In Colorado, the Department of Public Health and Environment concluded that smog-forming emissions from Colorado's oil and gas operations exceed motor vehicle

emissions for the entire state.

Colorado regulators have enacted progressively tougher rules to reduce the role of gas extraction in the region's persistent and unhealthy "brown cloud."¹⁰²

- Wyoming's Sublette County is one of the least-densely populated places in the United States, with a population of less than 9,000 – but it is home to thousands of gas wells. Due to the geography of the area, air pollution from the wells tends to get trapped in valleys in the winter, allowing the sun to bake it and transform it into smog. Since 2005, the region has suffered from unhealthy levels of air pollution more commonly associated with big cities.¹⁰³

The experience of these states could be a preview of how increased shale gas extraction could worsen air quality in Pennsylvania. Counties in and around the Pittsburgh and Philadelphia metropolitan areas are already in violation of federal health standards for smog.¹⁰⁴

Hazardous Air Pollutants from Trucks, Equipment and Gas Flaring

Gas extraction operations produce a variety of hazardous air pollutants, including diesel soot from trucks and pump engines, contaminants from processing the substances that come up out of the well, and fumes evaporating from fracturing water waste ponds.

Diesel Soot

Trucks and engines, often running on diesel fuel, operate throughout the drilling and fracturing process. These engines produce sooty exhaust, packed with dangerous and toxic chemicals. Drilling a well takes between 15 and 30 days. During the entire period, diesel engines on the drilling rig operate 24 hours a day.¹⁰⁵

After drilling, gas companies fracture the shale with millions of gallons of water, sand and chemicals. Transporting all of the equipment and material to the well pad, and then trucking away the waste, requires on the order of 900 to 1,300 truck trips per well.¹⁰⁶ At that rate, to drill the 3,000-plus Marcellus Shale wells now present in Pennsylvania required on the order of 3 to 4 million truck trips.

Additionally, injecting the fracturing fluid into the well and pressurizing the system requires the operation of pumps, typically powered by diesel engines.¹⁰⁷

Diesel particulate exhaust can remain suspended in the air for weeks. The particles can travel through building shells and conventional heating and air conditioning filters. When inhaled, they are able to penetrate deep into the lung. The chemicals delivered into the body by inhaled particulates are very dangerous. Some of them cause cancer, some cause

irritation to lung tissues, and some cause changes in the function of the heart.¹⁰⁸ As a result, particulates cause and aggravate a host of health problems, including lung cancer and cardiovascular disease.

Particulate pollution can cause irreversible damage to children, interfering with the growth and development of the lungs. For example, researchers at the University of Southern California followed the health of over 1,000 ten-year-olds until they reached 18. Children who lived in areas with higher levels of particulate pollution were less able to breathe with normal capacity.¹⁰⁹

Particulate pollution is also deadly, killing upwards of 50,000 Americans across the country every year. In fact, according to the largest study of the effects of particulates on mortality, breathing sooty air at the levels found in major U.S. cities is about as dangerous as living or working with a smoker.¹¹⁰

Photo: www.marcellus-shale.us



A gas flare near a home in Hickory, Pennsylvania.



A gas flare at night.

Gas Flares, Venting and Blowouts

The drilling process itself can puncture underground pockets of gas, which return to the surface in drilling fluid, and can be vented into the atmosphere, creating air pollution. A well blowout produces the same impacts – but at a higher volume. For example, the 2010 EOG well blowout in Clearfield County injected an untold amount of pollution into the air as gases and fracking water blasted 75 feet into the air over a span of 16 hours.¹¹¹

Once a well is fractured, wastewater, often containing gas, returns to the surface. Gas companies often dispose of the extra gases by simply lighting them on fire, creating a flare. (See photo). Incomplete combustion of the waste gas results in air pollution.

After the wastewater has stopped flowing out of the well, gas companies

connect the gas flow to a pipeline. Before the gas can be shipped to market, it must be cleaned of impurities, including water and larger hydrocarbon molecules. The Pennsylvania Department of Environmental protection detected some larger hydrocarbon molecules, including benzene and methyl mercaptan, near two gas compressor stations in Greene and Washington Counties.¹¹² Gas processing units typically vent impurities to the atmosphere as air pollution.

Often the pressure from the weight of the earth is enough to move the gas through the initial stages of the pipeline. However, to transport the gas from the well on to market, gas companies operate compressor stations, typically within four to six miles from a group of wells.¹¹³ These compressor stations are typically powered by combustion engines fueled

by raw or processed natural gas, which generates pollution-laden exhaust.¹¹⁴

According to estimates by the New York Department of Environmental Conservation, in the nearby vicinity of a Marcellus Shale well, the process of drilling, well completion, dealing with flowback gas, and finally producing gas from the well for a year produces the following emissions:¹¹⁵

- 195,000 pounds of carbon monoxide;
- 12,000 pounds of sulfur dioxide and combustion soot; and
- 1,000 pounds of toxic air pollutants, such as benzene.

Hazardous Air Pollutants from Fracturing Wastewater Ponds

When wastewater is stored in an open-air pit, chemicals used in the fracturing fluid can evaporate into the air, creating pollution.

The New York Department of Environmental Conservation estimates that the flowback water from a single well could emit 6,500 pounds of methanol into the air from a storage pit.¹¹⁶ Other compounds of concern that could evaporate from a flowback pit in harmful amounts include formaldehyde, acrylamide, naphthalene, glutaraldehyde and other chemicals that evaporate easily.¹¹⁷

Overall, the agency determined that a flowback water storage pond could be defined as a “major source” of hazardous air pollution.¹¹⁸

Reports of Health Impacts Near Gas Extraction Sites

Anecdotal reports suggest that living near well sites can cause health impacts,

although little formal scientific study has been completed to date.

Gas drilling and extraction in the Marcellus Shale offers many possible opportunities for human exposure to hazardous chemicals – either through spills of fracturing chemicals, the release of substances from deep underground, or the operation of the heavy equipment used to produce, process, condense and transport natural gas and waste products. News reports of people near well sites suffering ill-effects give ample reason for concern. For example:

- Residents of western Colorado communities located near active gas fields have complained of symptoms including nose bleeds, burning eyes, breathing problems, rashes and blackouts. Other residents have developed rare cancers, blaming the illness on exposure to gas extraction activity.¹¹⁹
- Fifteen residents of Dimock, PA, filed a lawsuit against Cabot Oil & Gas in 2009, alleging that the company’s gas extraction activities contaminated their water supplies and harmed their health. The suit cites health problems including neurological illnesses and gastrointestinal problems. It also alleges that one person’s blood showed toxic levels of the same metals found in drilling wastewater.¹²⁰
- In a Texas town called Dish, residents live near gas extraction infrastructure above the Barnett Shale formation. In 2009, air sampling revealed hazardous pollution – including benzene and related compounds – in the town at levels exceeding state safety guidelines.¹²¹ Further testing found many of these same contaminants in residents’ blood.¹²² In a survey, town residents

reported strange smells appearing as often as two times a day, associating them with nearby compressor stations, wells and gas processing plants. Residents reported more than 130 different medical conditions – 61 percent of which could be at least partially caused by exposure to the types of toxic chemicals identified in the air.¹²³ Health issues included difficulty in breathing, asthma, chronic eye irritation, dizziness, fatigue, frequent nausea, muscle aches, severe headaches, sinus problems, throat irritation and allergic symptoms. In a press release, the author of the survey, Wilma Subra, a chemist on the board of the organi-

zation Earthworks, said, “What is most revealing is that the community is reporting health symptoms that overlap significantly with the known health effects of chemicals already detected. We are seeing not only respiratory ailments and headaches, but brain disorders, pre-cancerous lesions and impairment of motor skills.”¹²⁴

Without adequate safeguards, these types of impacts could become more frequent in Pennsylvania as gas extraction proliferates in the Marcellus Shale, especially given the close proximity between well sites and places where vulnerable people live.

Marcellus Shale Gas Extraction Is Happening in Close Proximity to Vulnerable Pennsylvanians

To gain a deeper understanding of just how closely gas extraction is happening to the most vulnerable people in Pennsylvania, PennEnvironment Research & Policy Center conducted a study of where permitted well sites are located in relation to day care facilities, schools and hospitals.

The results show that gas companies have already drilled more than 3,000 Marcellus Shale wells, and the state has issued permits for thousands more. Permitted well sites exist within two miles

of more than 320 day care facilities, 67 schools and 9 hospitals. (See Table 1.) A breakdown of the number of day care centers, schools and hospitals within one or two miles of a well site by county can be found in the appendix on page 44.

Children are Particularly Vulnerable to Chemical Exposures from Gas Extraction Activity

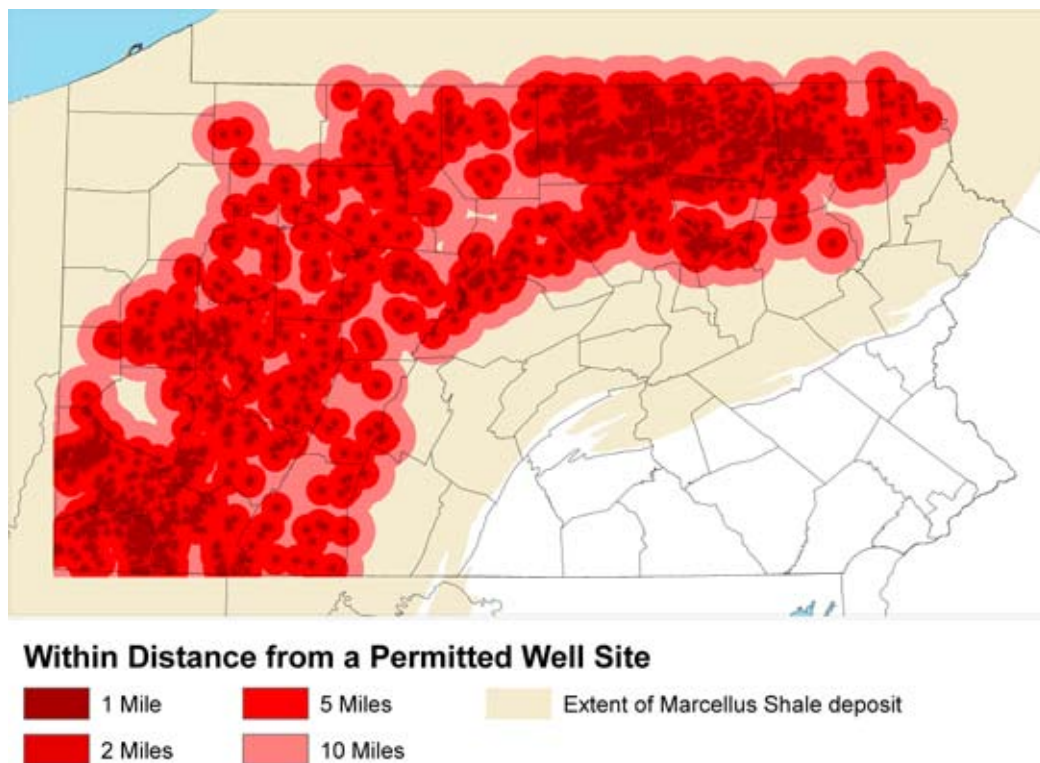
We looked at day care facilities and schools in particular because children are especially vulnerable to health damage from exposure to hazardous chemicals.

Children are rapidly growing and developing, and their respiratory, immune and nervous systems are susceptible to damage from toxic chemicals. Children are also more likely to play outdoors, where their exposure to dangerous substances in the air would be relatively

Table 1: Proximity of Vulnerable Populations to Permitted Well Sites

Facility Type	Number Within One Mile of a Well Site	Number Within Two Miles of a Well Site
Day Care	104	320
School	14	67
Hospital	2	9

Figure 3 – Very Few Locations Between Southwest of Pittsburgh and Northeast of Scranton are Farther than 10 Miles from a Marcellus Shale Gas Extraction Site



higher than an adult. Finally, children have less ability to detoxify dangerous chemicals compared to adults.¹²⁵

Short-term exposure to hazardous pollutants could cause acute distress, with higher exposures leading to more severe symptoms. Symptoms could include difficulty breathing, wheezing, watery or itchy eyes, rashes and headaches. Very high exposures could cause nausea, vomiting, lack of coordination or more serious impacts.¹²⁶

However, children are far more likely to be exposed to sustained, low levels of mixtures of different chemicals over long periods of time – which may not produce obvious symptoms right away. Exposure to low levels of many of the chemicals used in or generated by gas extraction activities could contribute to a variety of health effects, including

asthma, cancer, birth defects, damage to the reproductive system and impaired brain development.¹²⁷

The results of this analysis provide a conservative and limited snapshot of the exposure of vulnerable populations to the risks of Marcellus Shale gas extraction. In particular, they do not consider the location of residences, nor the location of gas processing or transportation infrastructure. (See Methodology on page 41.)

Marcellus Shale Gas Extraction Sites Are Widespread

Gas companies have already drilled more than 3,000 hydraulic fracturing wells in Pennsylvania’s Marcellus Shale

Figure 4: Day Care Facilities Within Two Miles of a Marcellus Shale Well Site

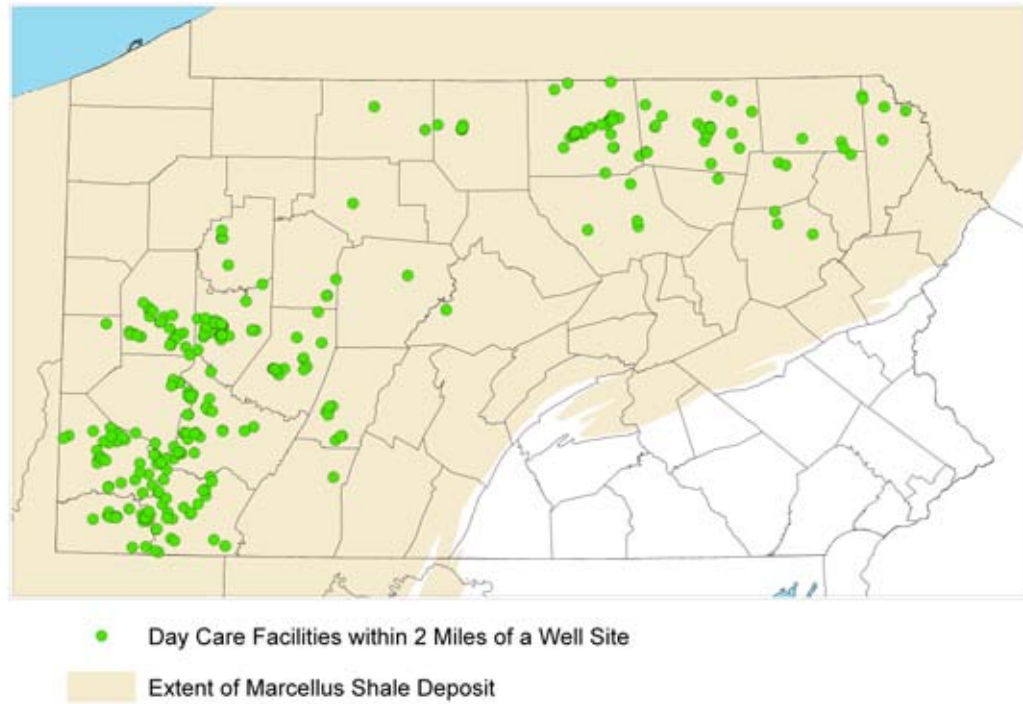
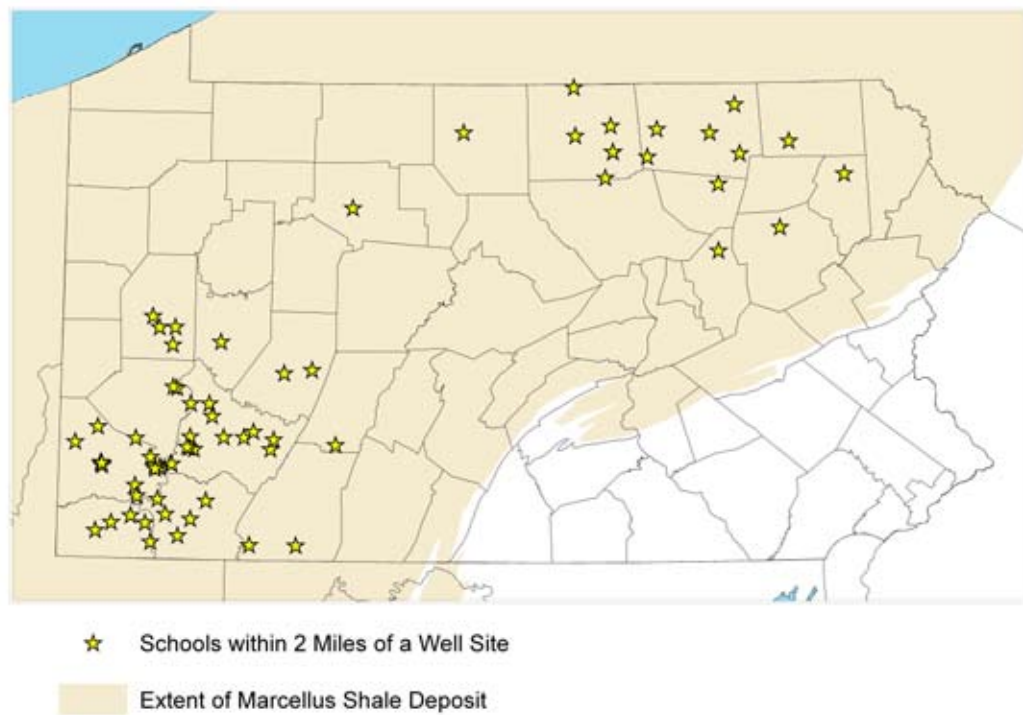


Figure 5: Pennsylvania Schools Within Two Miles of a Marcellus Shale Well Site



(as of April 2011).¹²⁸ That number is certain to increase. During 2010, the state Department of Environmental Protection issued permits to gas companies to drill or deepen nearly 3,450 additional wells.¹²⁹ So far in 2011, the DEP has issued more than 10 well permits per day, on average.

In a broad strip from Pittsburgh to Scranton, very few places in the region are located further than 10 miles from an active or permitted hydraulic fracturing site. (See Figure 3.) Wells are particularly concentrated in Bradford, Tioga, Greene, Washington, Susquehanna and Fayette counties.

Marcellus Well Sites Exist in Close Proximity to Vulnerable Pennsylvanians

Day Cares

Pennsylvania licenses more than 8,600 day care facilities across the state, including both day care centers and family-run day care facilities in private homes. Almost 2,000 of these facilities are located in the broad swath of land between southwestern and northeastern Pennsylvania where most Marcellus Shale gas extraction is happening.

Across the state, permitted hydraulic fracturing well sites exist within one mile of 104 day care facilities. Within two miles of existing wells or permitted leases, there are more than 320 day care facilities. (See Figure 4.) The closest day care facility is 400 feet from a well site.

Nearly four million Pennsylvanians rely on private well water for drinking.¹³⁰ Children at day care facilities that rely on well water drawn from aquifers near gas

extraction sites are particularly at risk for water pollution exposure. All children at facilities in close proximity to wells are vulnerable to air pollution.

Schools

There are about 1,750 schools in Pennsylvania where children from kindergarten to 12th grade go to learn and prepare for life in the larger world. About 480 of these schools are located in the broad swath of land between Pittsburgh and Scranton where Marcellus Shale gas extraction is underway. Children at school facilities that rely on well water are particularly vulnerable to gas extraction-related water contamination. All children at schools in close proximity to well sites are vulnerable to air pollution exposure.

Fourteen of these schools are within one mile of a permitted well site and 67 are within two miles of a well site. (See Figure 5.) The closest school is 900 feet from a well site.

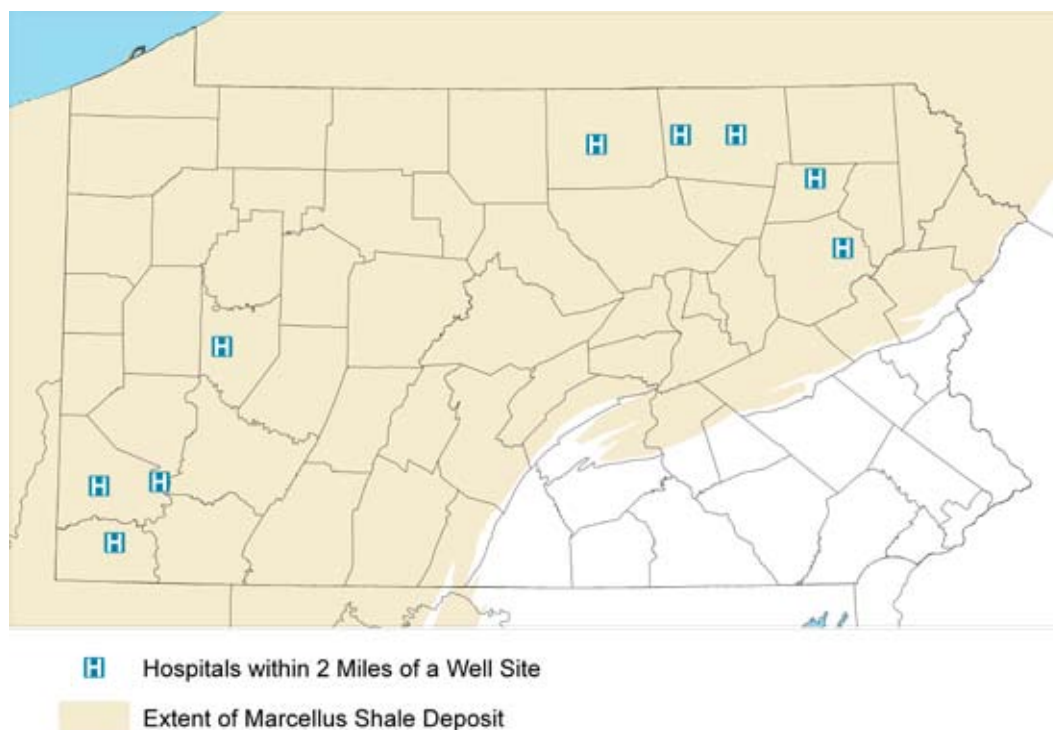
Hospitals

Children are not the only vulnerable population to be concerned about. People who are already suffering from illness severe enough to require hospitalization are particularly ill-suited to handle the effects of acute exposure to air or water pollutants.

Pennsylvania has 268 hospitals. More than 70 of those facilities are located in the general swath of Marcellus Shale gas extraction activity between the southwest and northeast corners of the state.

Two hospitals are within one mile of a well or a permitted well site. Within two miles of such a site, there are nine hospitals. (See Figure 6.) The closest hospital is one half-mile from a well site.

Figure 6: Pennsylvania Hospitals Within Two Miles of a Marcellus Shale Well Site



The Proximity of DEP Reported Violations to Vulnerable Pennsylvanians

From January 2008 through June 2010, the Pennsylvania Department of Environmental Protection recorded more than 1,000 violations of regulations intended to protect water quality and the environment, according to a report by the Pennsylvania Land Trust Association.¹³² A violation implies that a gas company broke any relevant rule, indicating a spill, leak, erosion, improper construction, poor waste disposal, or other rule violation associated with gas extraction, and that an official with the Department of Environmental Protection caught the violator. Traffic and road safety violations by chemical, water and waste haulers

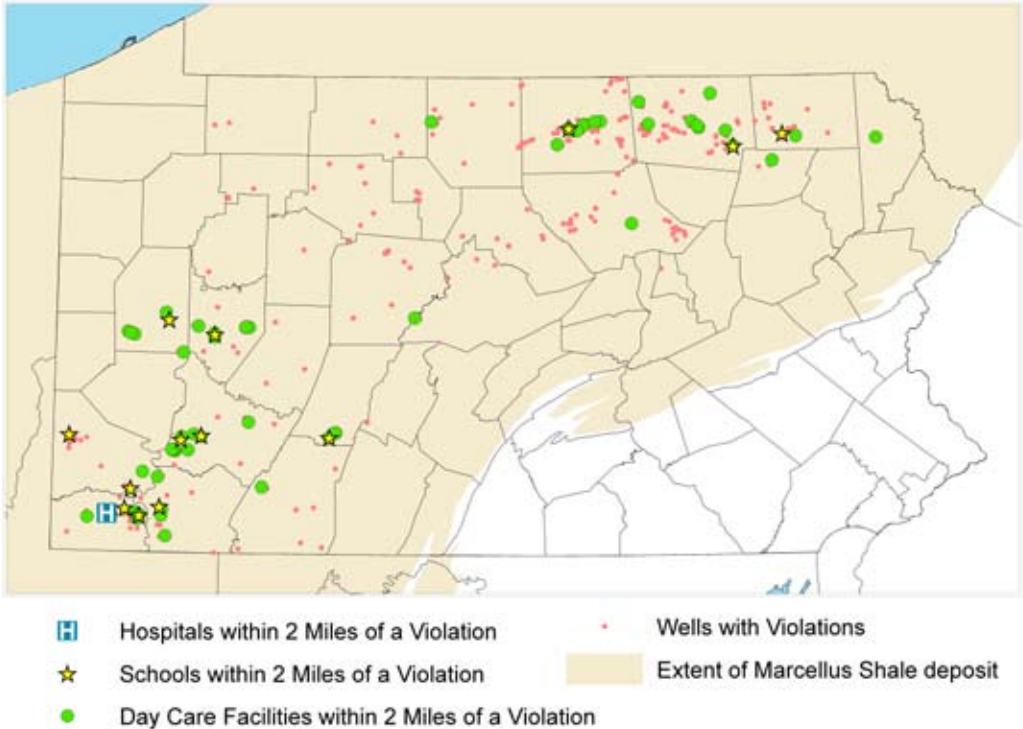
are not included in these figures. The number of unrecorded rule infractions is unknown.

The leading violators during this period were Cabot Oil & Gas, Chief Oil & Gas, and Turm Oil – each with an average of more than two recorded violations per well.¹³³

Mapping experts at the University of Pittsburgh were able to plot the locations of more than 1,100 of these events. (See Figure 7.) Many were in close proximity to vulnerable Pennsylvanians:

- 241 violations were within 2 miles of a day care facility;
- 40 violations occurred within 2 miles of a school; and
- 5 violations happened within 2 miles of a hospital.

Figure 7: Marcellus Wells Found in Violation of State Regulations (January 2008 - June 2010) and Day Cares, Schools and Hospitals Within Two Miles¹³¹



Conclusion

Given how closely Marcellus Shale gas drilling and extraction is occurring to day cares, schools and hospitals, many possible opportunities exist for children or the sick to be exposed to hazardous chemicals. Any impacts of spills of

fracturing chemicals, the release of substances from deep underground, or the operation of the heavy equipment used to produce, process, condense and transport natural gas and waste products are likely to impact these groups most severely.

Policy Recommendations

Federal and state regulations have not kept up with the speed at which gas companies have deployed hydraulic fracturing in Pennsylvania's communities. Governments at all levels should require gas companies to take greater precautions to protect citizens' health and environment.

Gaps in State Policy

Pennsylvania's constitution states that its citizens "have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and aesthetic values of the environment."¹³⁴ With all the holes in federal policy governing the operations of oil and gas companies (see below), the Commonwealth is left to ensure that resource extraction does not take away those rights.

Over the past year, Pennsylvania has taken several significant steps forward.

For example:

- New laws require gas companies to prevent groundwater contamination with better well casing, cementing, testing and monitoring procedures.
- Gas companies are now required to use blowout preventers to avoid uncontrolled discharge of well fluids and gas into the atmosphere in the event of an accident.
- New rules require wastewater treatment plants accepting drilling wastewater to meet effluent standards for some contaminants including total dissolved solids, chlorides and sulfates.
- In April 2011, the DEP asked wastewater treatment plants accepting drilling wastewater to stop altogether.

- In 2009 and 2010, the Delaware River Basin Commission, which is charged with protecting the watershed of the Delaware River, determined that any shale gas well drilling required its approval, and has applied a moratorium on shale gas exploration or production in the watershed until it crafts rules.

However, these new protections do not go far enough. Instead of enabling more and faster gas extraction, state leaders and the Pennsylvania Department of Environmental Protection should increase oversight of gas companies and hydraulic fracturing. Among needed improvements are:

- **The Commonwealth should designate pristine places and locations near where people live or work off-limits to gas extraction.** This should include areas near day care facilities, schools, hospitals, and other vulnerable populations. Existing law allows gas extraction to occur as close as 200 feet to a building or structure, which is too close. Additional areas that deserve protection include the remainder of state forests that have not been leased to gas companies; state parks; areas that supply drinking water to downstream communities; sensitive or threatened ecosystems such as wetlands; and important habitat for threatened or endangered species.
- **Pennsylvania should strengthen its clean water laws.** Needed improvements include expanding the protective buffer zone around streams, rivers and drinking water supplies beyond 100 feet; requiring pre-drilling surveys of waterways near a proposed gas well; setting reporting requirements on discharges and wastewater disposal; setting water

withdrawal limits from rivers and streams; and requiring the state to account for the cumulative impacts of natural gas exploration from multiple drilling sites when permitting new wells. Additionally, the state should presume that a gas company is liable for the contamination of any water well within 2,500 feet of a gas well within one year of drilling or modifying a gas well – current law presumes liability for contamination within 1,000 feet if gas drilling activity has occurred within six months.¹³⁵

- **Pennsylvania should require gas companies to halt the use of toxic chemicals in the hydraulic fracturing process.** Safer alternative chemicals can be substituted in for the most dangerous materials in hydraulic fracturing, and the state should require gas companies to deploy those alternatives.¹³⁶ Using safer alternatives can reduce the hazard of hauling fracturing chemicals and the consequences of spills.
- **The state should recognize the public's right to know** by requiring gas companies to report to the general public as well as the DEP the types and amounts of chemicals used during drilling and fracturing and the composition and disposal of wastewater, in a timely fashion and on a well-by-well basis. The information should be easy to obtain and easy to read. Additional reporting should include the process used to extract gas from underground, where the water for fracturing comes from, and emergency response plans detailing steps to be taken to protect public health and the environment in the event of a worst-case accident.
- **Pennsylvania should increase the resources available to state regulators for enforcing the law.**



Federal and state regulations have not kept up with the speed at which gas companies have deployed hydraulic fracturing in Pennsylvania's communities. Governments at all levels should require gas companies to take greater precautions to protect citizens' health and environment.

After years of budget cuts, funding for crucial state agencies such as the Department of Environmental Protection, Department of Conservation and Natural Resources, and the Fish and Boat Commission is inadequate to keep pace with gas industry growth. For example, as of April 2011, DEP estimates that it employs only 70 inspectors to monitor oil and gas extraction activities.¹³⁷ DEP regulators have testified in a lawsuit that they spend as little as 35 minutes reviewing well permit applications, that they give no additional scrutiny to permits for drilling in the vicinity of pristine streams, that they do not consider impacts on protected watersheds, and that they do not consider whether wells comply with municipal or

regional zoning laws.¹³⁸ Moreover, the DEP has rejected less than one-half of one percent of drilling permit applications.¹³⁹ According to the *Associated Press*, "The staffers' statements indicate that the state regulators are overburdened – and possibly ignoring environmental laws – as they struggle to deal with an unprecedented drilling boom".¹⁴⁰ Regulatory agencies need the resources to properly oversee the gas industry and enforce state policies. Additionally, the agency is approving gas company spill response plans that "often appear to be in violation of the law" and do not taken into consideration cumulative impacts and multiple points of exposure.¹⁴¹ To improve the permitting process, authority for erosion and sedimenta-

tion review should be returned to Pennsylvania's County Conservation Districts to help manage the gas well permitting process, and their budgets should be increased accordingly.

- **The Commonwealth should increase bonding requirements for gas companies.** Current law requires oil and gas companies to post a bond to provide a financial incentive for companies to avoid causing water quality problems, to reclaim gas well sites, and to plug wells when they are no longer useful. Any company that fails to comply with regulations forfeits its bond. However, the bond is capped at \$2,500 per well, or \$25,000 for all wells owned by one company in the Commonwealth.¹⁴² These amounts are far too low to provide a meaningful financial incentive for gas extraction companies to behave responsibly, and they should be increased with no cap. Additionally, the state should retain some of the bond funds to pay for cleaning up any abandoned wells or pollution problems that occur long after gas extraction has ended.
- **The DEP should revoke drilling privileges for the worst offenders.** The companies with the worst records in terms of rule violations per well should not be allowed to operate in Pennsylvania.

Gaps in Federal Policy

Federal law exempts Marcellus Shale gas extraction from regulation under six key environmental policies that typically apply to industrial activities.¹⁴³

1. The **Safe Drinking Water Act** is meant to protect the quality of drinking water in the United States, whether in surface rivers or underground aquifers. In 2005, Congress amended the law to exempt gas extraction through hydraulic fracturing from all of the provisions of the law, except when diesel fuels are injected underground.
2. The **Clean Water Act** is the key law protecting America's rivers, streams and lakes from industrial discharges and runoff. For decades, all runoff from oil and gas extraction or production facilities has been exempt from regulation, except for sediment runoff caused by construction activity. In 2005, Congress passed the Energy Policy Act, which removed the Environmental Protection Agency's authority to regulate even sediment runoff from oil and gas-related construction sites.
3. The **Clean Air Act** is the cornerstone tool for ensuring that all Americans have healthy air to breathe. The law treats oil and gas wells – and often pipeline compressors and pump stations – as individual and separate sources of pollution. By failing to aggregate these sources of emissions by company and industry, the law fails to require operators to adequately control their polluting emissions – allowing the industry to pollute the air with few federal restrictions.
4. The **National Environmental Policy Act** ensures that all branches of government consider the impacts of any activity they undertake on the health and well-being of people and their air, land and water. In 2005, the Energy Policy Act allowed the oil and gas industries to carry out

a variety of activities without the thorough environmental review normally required by the National Environmental Policy Act, instead allowing a more limited review under a designation called a “categorical exclusion.” For example, the categorical exclusion allows a company to drill new wells in an existing gas field, or add a new pipeline to an existing corridor, without new environmental review, even if the original review did not consider that level of development. This categorical exclusion puts the burden on the public to show that harm is occurring, rather than on the oil and gas company to prove that their plans are safe.

5. The **Resource Conservation and Recovery Act** includes provisions governing hazardous waste management. Congress exempted wastes from oil and gas fields from regulation under this law. As a result, the Environmental Protection Agency allows wastes produced from oil and gas wells – which can include cancer-causing chemicals such as benzene that are regulated when used in other industries – to contaminate the environment and risk public health.
6. The **Toxics Release Inventory** – which is authorized under the Emergency Planning and Community Right-to-Know Act – compiles

information from a wide variety of industries about their discharges of hazardous chemicals to air, water and land. However, the Environmental Protection Agency, which implements the law, exempts the oil and gas extraction industry from reporting emissions. This leaves the public in the dark about the amounts of chemicals emitted into the air or water – or left underground after hydraulic fracturing operations are complete.

The federal government should eliminate these exemptions and apply the nation’s core public health and environmental laws to the hydraulic fracturing industry just as it would regulate any other potential threat to public health or the environment. In particular, hydraulic fracturing should be covered under the “underground injection” provisions of the Safe Drinking Water Act.

In addition, the federal government should increase transparency and oversight of the hydraulic fracturing process by requiring well operators to disclose to regulators and to the public the specific identities of chemicals and their quantities used at each and every well site. In the case of a medical emergency, operators should be required to disclose the amounts and formulation of chemical additives in hydraulic fracturing fluids to medical professionals, even if they are considered trade secrets.

Methodology

We used ESRI ArcMap geographic information system software to plot the locations of permitted well sites, day care facilities, schools and hospitals, and we used the software to calculate the distances between the different points.

Throughout the calculations, we maintained all data layers in the NAD 1983 State Plane Pennsylvania North projected coordinate system, with units in United States feet, to ensure accurate distance calculation.

Sources of Data

Locations and Identities of Well Sites

We obtained information about the locations of permitted well sites and details about the companies that applied for

permits from the Pennsylvania Department of Environmental Protection, with assistance from the Center for Healthy Environments and Communities of the University of Pittsburgh Graduate School of Public Health.

Information on permits issued from 2007 through November 15, 2010 was obtained from the Pennsylvania Department of Environmental Protection through Fracktracker.org. Information on permits issued in the latter part of 2010 was obtained directly from the Department of Environmental Protection at www.dep.state.pa.us/dep/deputate/minres/OILGAS/RIG10.htm.

The proximity data reported in this report reflect permitted well sites as of the end of 2010.

Data on additional well drilling and permitting activity that occurred in 2011 were used to report statistics on the

number of active wells in the state, and the number of permits issued through the end of March 2011. This data, obtained from the Pennsylvania DEP at www.dep.state.pa.us/dep/deputate/minres/oilgas/RIG11.htm, was not included in the proximity analysis because of time constraints.

Information on violations at Marcellus wells was compiled by Matt Kelso at the Center for Healthy Environments and Communities of the University of Pittsburgh Graduate School of Public Health and downloaded from Fracktracker.org.

Locations of Day Care Facilities, Schools and Hospitals

We obtained a listing of addresses of day care facilities from Dr. Phil Sirinides with the State of Pennsylvania, Office of Child Development and Early Learning, Research Department (www.ocdelresearch.org) on January 6, 2011.

We obtained a listing of school facility addresses from the Pennsylvania Dept. of Education, *EdNA: Education Names and Addresses*, available at www.edna.ed.state.pa.us/ReportSearch.asp. Facilities included intermediate units, diocese schools, charter schools, licensed private schools, approved private schools, school districts, and state-owned schools, accessed on December 28, 2010.

Hospital addresses came from a database maintained by the Pennsylvania Department of Health, *Health Facility Locator and Survey Information*, available at app2.health.state.pa.us/commonpoc/content/publiccommonpoc/normalSearch.asp, accessed on January 6, 2011.

We used the Google Maps service to translate these addresses in to X,Y coordinates for use in the mapping software.¹⁴⁴ The geocoding service is not guaranteed to 100 percent accuracy. Any discrepancies between the geocoded coordinates and the actual location of the facility

building could introduce error into the distance calculations we describe below.

Calculating Distances

We used ESRI ArcMap geographic information system software to plot the locations of the permitted well sites, day care facilities, schools and hospitals together on a map.

We used the “buffer” proximity analysis tool to draw circles of one-mile and two-mile radii around each well. We then selected day care, school and hospital facilities that fell within the boundary of the circles at each radius. Counting the relevant facilities at each distance yielded the number of facilities within the specified distance of a permitted well site.

To calculate the distance to the nearest day care, school or hospital from each well site, we performed a “spatial join” between the permitted well site data layer and the data describing the locations of the relevant facilities.

Finally, to determine average distance to a well within each county, we used the ESRI Spatial Analyst extension to calculate the distance from the nearest well for every point in the state, and then used Hawth’s Tools Zonal Statistics (++) to calculate well proximity statistics for each county.

Justification for Quantifying Facilities within 2 Miles of a Well Site

This analysis examines distance from day care centers, schools and hospitals as a first-order approach to better understand the risk that Marcellus Shale gas extraction poses to vulnerable populations in Pennsylvania. We chose to examine the number of facilities within one and two miles from a well site for the following reasons:

1. Evidence that gas can travel underground at least a mile and as much as seven miles from a well to contaminate a home's water supply suggests that people living within a one- or two-mile radius of a well are potentially vulnerable to water contamination.
2. Air pollution goes where the wind blows, and it is likely that all of the activities related to gas extraction – or the impacts of an accident – could raise the average level of diesel soot, smog and hazardous air pollutants within a one- or two-mile radius of a well or associated infrastructure.

The analysis does not attempt to estimate potential exposures to specific chemicals at specific distances from well sites. Further research will be necessary to quantify potential risk at that level. On that score, we look forward to the U.S. Environmental Protection Agency's review of gas extraction through hydraulic fracturing, due in 2012.¹⁴⁵ However,

we believe that interim examination of the gas industry, such as provided in this report, is necessary in the meantime to provide a better picture of what the consequences of greater gas development could be for Pennsylvanians.

Limitations

The analysis is limited to well sites only, and does not consider gas processing and refining infrastructure. The analysis also does not consider the locations of homes; only the locations of day care facilities, schools and hospitals. The potential for exposure to the risks of gas extraction also exists in residential areas, for vulnerable populations including the children and the sick, as well as other Pennsylvanians. Additionally, as more wells are permitted and drilled, the number of wells in close proximity to sensitive populations will only increase.

As a result, this study paints a conservative picture of the proximity of gas extraction in the Marcellus Shale to vulnerable populations.

Appendix

Number of Facilities Within Specified Distance of a Marcellus Well Site by County (as of January 2011)

County	Day Cares, 1 Mile	Day Cares, 2 Miles	Schools, 1 Mile	Schools, 2 Miles	Hospitals, 1 Mile	Hospitals, 2 Miles
Allegheny	4	12	2	4		
Armstrong	8	31		1	1	1
Beaver		1				
Bradford	11	28		5		2
Butler	4	24	1	4		
Cambria	2	8		1		
Centre	1	1				
Clarion	2	6				
Clearfield		1				
Elk		1		1		
Fayette	7	25	1	5		
Greene	21	29	2	5		1
Indiana	2	17		2		
Jefferson	2	3				
Lackawanna	1	1		1		
Luzerne	1	3		1		2
Lycoming	2	4				
McKean		2				
Potter	1	7		1		
Somerset		1		2		
Sullivan	1	1		1		
Susquehanna	2	3	1	1		
Tioga	13	35		6		1
Washington	11	39	4	11	1	2
Wayne	3	5				
Westmoreland	4	31	3	14		
Wyoming	1	2				1

Density of Marcellus Shale Well Activity by County (as of January 2011)*

County	Average Distance from a Permitted Well Site (Miles)
Bradford	1.2
Tioga	1.5
Greene	1.6
Washington	2.0
Fayette	2.3
Susquehanna	2.3
Armstrong	2.5
Indiana	2.6
Westmoreland	2.6
Sullivan	2.9
Elk	3.0
Clarion	3.3
Butler	3.3
Jefferson	3.3
Lycoming	3.6
Wyoming	3.7
Somerset	3.7
Clearfield	3.8
McKean	3.8
Forest	3.9
Potter	4.2
Cambria	4.5
Clinton	5.5
Cameron	5.7
Allegheny	5.9
Beaver	7.0
Lackawanna	7.9
Wayne	8.3
Luzerne	9.8
Centre	9.8
Warren	10.2
Blair	11.2
Columbia	11.9
Montour	12.5
Venango	12.9
Bedford	13.7
Lawrence	14.0

*The information in this table is not specific to day care centers, schools or other institutions. Instead, it represents the density of Marcellus Shale well coverage across the entire area of a county. Specifically, the number represents the average distance from any point within a county to the nearest well site.

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