From: Andrea Weber
Sent: Wednesday, November 13, 2013 8:02 PM
To: Hanlon, Edward
Subject: Center comments

Dear Mr. Hanlon:

Please find attached our comments regarding Public Teleconference of the Hydraulic Fracturing Research Advisory Panel (FRL-9900-84-OA). Accompanying the comments are 4 citations noted below, and three attached articles, which serve as references.

Please let me know if you have any questions. Thank you for your assistance and consideration.

Sincerely,

Andrea Weber
Center for Biological Diversity
Climate Law Institute Paralegal
351 California Street, Suite 600
San Francisco, CA 94104

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2. Entrekin, S., Evans-White, M., Johnson, B., and Hagenbuch, E. Rapid expansion of natural gas development poses a threat to surface waters. 2011. *Front. Ecol. Environ*. 9(9): 503–511.

3. Fontenot, B.E., Hunt, L.R., Hildenbrand, Z.L., Carlton, D.D. Jr., Oka, H., Walton, J.L., Hopkins, D., Osorio, A., Bjornd, B., Hu, Q.H., and Schuga, K.A. An evaluation of water quality in private drinking water wells near natural gas extraction sites in the Barnett Shale Formation. 2013. *Env. Sci and Tech.* In Press – Accepted Manuscript.

4. Warner, N.R., Christie, C.A., Jackson, R.B., and Vengosh, A. Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania. 2013. *Env. Sci and Tech.* In Press – Accepted Manuscript.

November 13, 2013

Via Email

Edward Hanlon
Designated Federal Officer
EPA Science Advisory Board
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, NW
Washington, DC 20460
hanlon.edward@epa.gov

Re: *Comments regarding Public Teleconference of the Hydraulic Fracturing Research Advisory Panel [FRL-9900-84-OA]*

Dear Mr. Hanlon:

On behalf of the Center for Biological Diversity, I am writing to offer the Science Advisory Board Hydraulic Fracturing Research Advisory Panel (SAB) suggestions for improving the study of the effects of hydraulic fracturing. We request that the SAB consider these written comments as part of the November 20, 2013 Public Teleconference, announced in 78 Fed. Reg. 55253 (September 10, 2013).

Hydraulic fracturing and other types of unconventional oil and gas extraction techniques are becoming more dangerous while at the same time becoming more widely used. While we appreciate the SAB's role in providing the most recent scientific information to the U.S. Environmental Protection Agency (EPA), the fact is that the EPA already has evidence that hydraulic fracturing poses a substantial threat to human health and safety and the environment. The time for studies has passed, and we urge the SAB and the EPA to recognize the need for action.

I. The EPA Should Simply Complete Its Own Past Studies Showing Groundwater Contamination

EPA's continued studies of hydraulic fracturing are puzzling in light of two previous studies it has already undertaken and then abandoned.

The EPA investigated water contamination in Dimock, Pennsylvania, in response to complaints from several residents who alleged that groundwater had been contaminated. Though the EPA declared Dimock's water supply to be "safe," the EPA included no scientific justification and failed to explain the visible and obvious contamination of the water in Dimock. There is also evidence that EPA's decision to declare the water safe was the result of political pressure from the natural gas industry, not a scientific evaluation.

In 2012, the EPA announced, without explanation, that it was terminating an investigation into water contamination in Parker County, Texas. Reports suggest that this too, was a politically motivated decision and not one based in science.

In 2013, EPA abandoned a study of groundwater contamination in Pavillion, Wyoming, even though it had found evidence of water contamination in its draft report. The U.S. Geological Survey's separate study supported the findings of groundwater contamination. Rather than finalize its study, however, the EPA decided instead to abandon the study and allow state regulators to conduct it.

These cases should make it obvious that the EPA has *already studied* groundwater contamination resulting from hydraulic fracturing. There is strong evidence that these studies would have shown that groundwater may indeed contaminated had the EPA (1) allowed them to be completed and (2) used unbiased scientific evaluation rather than bowing to political pressure.

The repeated start-and-stop studies, the endless rounds of scientific studies, and the unwillingness of the EPA to stand up to political pressure have led to the public's distrust of the agency. Meanwhile, the addition of one more study does not protect public health and safety or the environment. The EPA already has the scientific basis to identify the harm, implement responsive regulatory action, and provide relief to communities suffering from the harm of hydraulic fracturing and other extreme forms of oil and gas extraction.

II. The Scope of the Study Must Be Broadened.

The Notification of Public Teleconference notes that the study is necessary to respond to public concern. While it is true that the public is deeply concerned over the potential risks from fracking, their concern is by no means limited to the effect of hydraulic fracturing on groundwater. Groundwater contamination is only one of many environmental harms that may result from hydraulic fracturing. Hydraulic fracturing may also lead to environmental harm through surface water contamination, air pollution, land use pattern changes, surface water and aquifer resource depletion, habitat destruction, stormwater runoff, greenhouse gas emissions, induced seismicity, and harm to threatened and endangered species and other wildlife.

In addition, hydraulic fracturing is only one of many different types of unconventional well stimulation or extraction techniques being used with increased frequency nationally. Acidization and gravel packing, for instance, also require the injection of many harmful chemicals. The study should not limit its focus to one type of oil and gas extraction, but instead study all forms.

Furthermore, the study should examine the entire lifecycle of oil and gas extraction, not just well "completion" or "stimulation." Oil and gas leases affect the environment not only through the well stimulation and recovery processes, but also through related activities needed to drill, construct, operate, maintain, monitor, and shut down each well. Each stage of the oil and gas extraction and recovery process carries its own set of public health, safety, and environmental concerns.

The study should cover not only the particular method of extraction, but all aspects of exploration and development, including but not limited to: drilling rig mobilization, site preparation, and demobilization; completion rig mobilization and demobilization; well drilling; well completion; and well production. Equipment cleaning, maintenance, and repair also become necessary and necessitate additional chemical use and expand the risks from exposure.

The equipment and ingredients used in production also require heavy truck traffic, both to haul necessary components into the site, and to haul them away; increased traffic will also have an impact on the environment. New roads will be built where none existed before. Existing roads will dilapidate at a faster rate under the increased burden of trucks going to and from a well site. The transportation of toxic chemicals also poses a risk if any trucks were to spill or otherwise leak contaminants due to accidents. The need for expansion of distribution and refining facilities will also contribute to the additional environmental impact that can be expected from allowing unconventional oil and gas extraction to proceed.

Unconventional oil and gas recovery also results in large amounts of waste fluid and produced water, byproducts that can potentially contaminate air, water, and soil and harm humans and wildlife. Under current practices in California, some flowback fluid is stored in open pits near the well pad. The study must review the risks posed by these pits, which can contaminate the soil, pollute nearby surface water through breaches and spills, and pollute the air through evaporation. Liners are known to tear, and spills and evaporation occur even when the lining remains intact. Both can kill wildlife that is exposed to the pits' toxic contents.

Wastewater also winds up in disposal wells, which have been linked to induced seismicity in states that have seen an increase in disposal wells. These injection wells are typically used for long-term storage of waste fluid, and thus the long term integrity and effect of these wells must be evaluated as part of the study. Injecting and storing wastewater underground in these injection wells has been shown to cause a variety of risks, including inducing earthquakes. An increase in unconventional methods of oil and gas recovery will expand the number of these disposal wells necessary to store the flowback fluid from extraction and production activity.

Accidental spills are also an inevitable occurrence and the risk of harms from such spills must be incorporated into the study. Improper well construction and loss of mechanical integrity are recognized as one of the highest risks of groundwater contamination and constitute another event through which chemicals can threaten public health and safety.

In addition, the study should assess the impact of refining and burning the newly accessible supply of oil and gas. Allowing unconventional oil and gas recovery would increase need for refineries as well as the total amount of oil and gas available for consumption. End-users who burn this oil will be polluting the air with many different air pollutants, not the least of which is carbon dioxide, the leading contributor to global warming. The study will be incomplete without assessing the effects of harmful air emissions from burning the fuel that would otherwise remain underground. In particular, the amount of carbon dioxide emitted as a result of oil and gas produced through unconventional extraction methods will lead us further toward irreversible and catastrophic climate change. Oil and gas extraction also emits a substantial amount of methane, a powerful greenhouse gas that will contribute significantly to the climate warming footprint of oil and gas activity.

In short, the entire lifecycle of oil and gas development and consumption must be included in the study. And because unconventional techniques subject new sites to production, each of these harms may extend far beyond the nation's current inventory of oil and gas development sites. SAB must assess the full impact of these environmental harms in which development expands to public land that previously could not be considered for production.

III. New Information Confirms Hydraulic Fracturing Is an Unacceptable Risk to Water Quality and Water Resource Adequacy.

Even within the limited scope of water contamination and depletion, the Progress Report is missing several key topics and studies. Multiple recent studies have confirmed that hydraulic fracturing likely poses a threat to groundwater quality. For example, a survey of private well groundwater in the Barnett Shale region in Texas showed levels of arsenic, selenium, strontium, and total dissolved solids (TDS).[1] Methanol and ethanol were also detected in 29 percent of samples.[2] The myriad chemicals used in hydraulic fracking are known to cause a variety of serious human health effects.[3]

Another recent study reiterated that hydraulic fracturing, coupled with associated activities such as increased pipelines and roads, collectively pose a significant threat to surface waters.[4] Storm runoff, reduced streamflow, and chemical contamination are all potential risks to surface water.[5]

Public health is threatened not only by the toxicity of these chemicals, but also from radioactive material brought to the surface through oil and gas extraction. An expansion of hydraulic fracturing and other types of unconventional oil and gas extraction would lead to dangerous levels of radioactive material such as radium being brought to the surface and potentially contaminating water resources.[6]

The enormous amounts of water that is required in hydraulic fracturing and other forms of unconventional oil and gas extraction poses a grave risk to water resources. Each well can use roughly 2-7 million gallons of freshwater per occurrence of hydraulic fracturing.[7] Nationally, the expansion of unconventional oil and gas techniques threatens to consume significant amounts of water resources,[8] which could damage ecosystems and wildlife habitats,

Wastewater disposal also poses a risk to human health and safety and the environment as well. A recent study found that, even after being processed at a waste treatment facility, surface water levels of chloride, bromide, barium, and radium were elevated.[9]

The SAB should also consider the risk of harm to wildlife. Countless species, including some that are listed as endangered or threatened, depend on habitats that may be imperiled by the use of hydraulic

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[1] Fontenot, et al, "An evaluation of water quality in private drinking water wells near natural gas extraction sites in the Barnett Shale Formation" Environmental Science and Technology, DOI: 10.1021/es4011724 (July 25, 2013).
[2] Id.
[3] See, e.g., Colborn, "Natural Gas from a Public Health Perspective," Human and Ecological Risk Assessment, DOI 10.1080 (Sept. 2011.).
[4] Entrekin, et al, "Rapid expansion of natural gas development poses a threat to surface waters," Front. Ecol. Environ. 2011 doi:10.1890/110053 (Oct. 2011)
[5] Id.
[6] White, "Consideration of radiation in hazardous waste produced from horizontal hydrofracking," Grassroots Environmental Education (October, 2012)
[7] Entrekin (2011).
[8] Freyman and Salmon, "Hydraulic Fracturing and Water Stress: Growing Competitive Pressures for Water," Ceres Report (May 2013).
[9] Warner, et al, "Impacts of Shale Gas Wastewater Disposal on Water Quality in Western Pennsylvania," Environmental Science and Technology (Sept. 10, 2013).

fracturing.[10] While human health effects are important, the potential harm to wildlife should not be ignored.

Conclusion

In sum, the scientific evidence shows that hydraulic fracturing and other types of unconventional oil and gas extraction pose serious risks to human health and safety and the environment. The EPA's own studies indicated (before they were abandoned) that hydraulic fracturing is the cause of groundwater contamination. The SAB should rely on existing studies to urge EPA to take action on protecting groundwater and surface water from unconventional oil and gas extraction techniques. In addition, the scope of the SAB study must be expanded to include not only the total harm that occurs through water resource contamination and depletion, but also through other types of harms caused by unconventional oil and gas extraction. The SAB must study the impact of how these techniques will increase oil and gas development overall. Finally, the SAB should consider and incorporate recent studies that appear to have been left out of the Progress Report.

Thank you for the opportunity to comment. We look forward to working with the SAB in the future.

Respectfully submitted,

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Hollin Kretzmann
Staff Attorney
Center for Biological Diversity
351 California Street, Suite 600
San Francisco, CA 94104

[10] See Center for Biological Diversity "Impacts of Fracking on Wildlife" (Sept. 30, 2013); see also Appendix A for list of references documenting impacts to wildlife.

Appendix A:
Oil and Gas Development Impacts on Wildlife

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Consideration of Radiation in Hazardous Waste Produced from Horizontal Hydrofracking

Report of E. Ivan White
Staff Scientist for the
National Council on Radiation Protection

Radioactivity in the environment, especially the presence of the known carcinogen radium, poses a potentially significant threat to human health. Therefore, any activity that has the potential to increase that exposure must be carefully analyzed prior to its commencement so that the risks can be fully understood. Horizontal hydrofracking for natural gas in the Marcellus Shale region of New York State has the potential to result in the production of large amounts of waste materials containing Radium-226 and Radium-228 in both solid and liquid mediums.

A complete and thorough analysis of the potential environmental pathways for exposure of people to these radioactive materials is a prerequisite to any regulatory approval of activities involving their extraction, handling, transportation and storage.

> The guiding principle for this work is that ***radioactivity should never be released into the environment in an uncontrolled manner*** because of the potential for exposure from the many potential pathways that exist.

Over the past fifty years, the Atomic Energy Commission (AEC) and the Nuclear Regulatory Commission (NRC) have spent millions of dollars on research that has resulted in computer models of the transport of radioactivity through the environment to humans. These environmental transport and human uptake models, known as "RESidual RADiation," or "RESRAD," are designed to be incorporated into governmental regulatory guidelines to ensure that people are not exposed to levels of radiation and radioactivity that would result in negative health impacts.

In April of 1999, the New York State Department of Environmental Conservation's Division of Solid and Hazardous Materials, assisted by representatives from sixteen oil and gas companies, conducted an internal investigation entitled *An Investigation of Naturally Occurring Radioactive Materials (NORM) in Oil and Gas Wells in New York State.* The report concluded that drill cuttings and wastewater from oil and gas drilling operations "do not constitute a health risk for the State's residents nor present a potential degradation of the State's environment."

A similarly cavalier attitude towards human exposure to radioactive material pervades the NYS DEC's 2011 Draft Revised Supplemental Generic Environmental Impact Statement (rSGEIS). The document's superficial characterization of radiation risks has prompted warnings from radiation experts, including those at the EPA whose public comments on the rSGEIS reflect deep concerns about the DEC's understanding and appreciation of the actual risks posed by radiation.

The National Council on Radiation Protection (NCRP) is a Congressionally-chartered agency charged with the authority and responsibilty to coordinate public information on radiation protection and radiation measurements. In its 2010 NCRP Report #169, *Design of Effective Radiological Effluent Monitoring and Environmental Surveillance Programs*, we describe the required radiation detection equipment and state-of-the-art modeling approaches for determining radionuclide transport pathways in the atmosphere, surface water, groundwater, and soil. Methods are presented for estimating potential radiation dose to the public and natural ecosystems resulting from releases of radionuclides into the environment.

Based on my experience in assessing potential transport pathways for radiation and a review of the DEC's internal report, I find two serious flaws that must be addressed and corrected prior to any final determination related to hydrofracking in New York State. The first is that the report examined a very different type of drilling than that which is being proposed. The second is that the authors used RESRAD in a limited way, resulting in faulty conclusions.

The 1999 DEC report examines vertically-drilled oil and gas wells in New York State that have been hydrofracked. This is very different from the ***horizontal*** hydrofracking currently being proposed for New York State. Vertical wells of the type measured by the NYSDEC are typically 1500-3000 feet deep with minimal penetration into the Marcellus shale formation. Horizontal slickwater hydrofracking wells, on the other hand, reach depths of 6,000 feet before turning horizontally for an additional mile or so. These deeper, longer wells have a much greater overall exposure to the Marcellus Shale formation and the radioactive materials contained within it, and thus an increased likelihood of bringing that radioactivity to the surface. (See Figure 1)

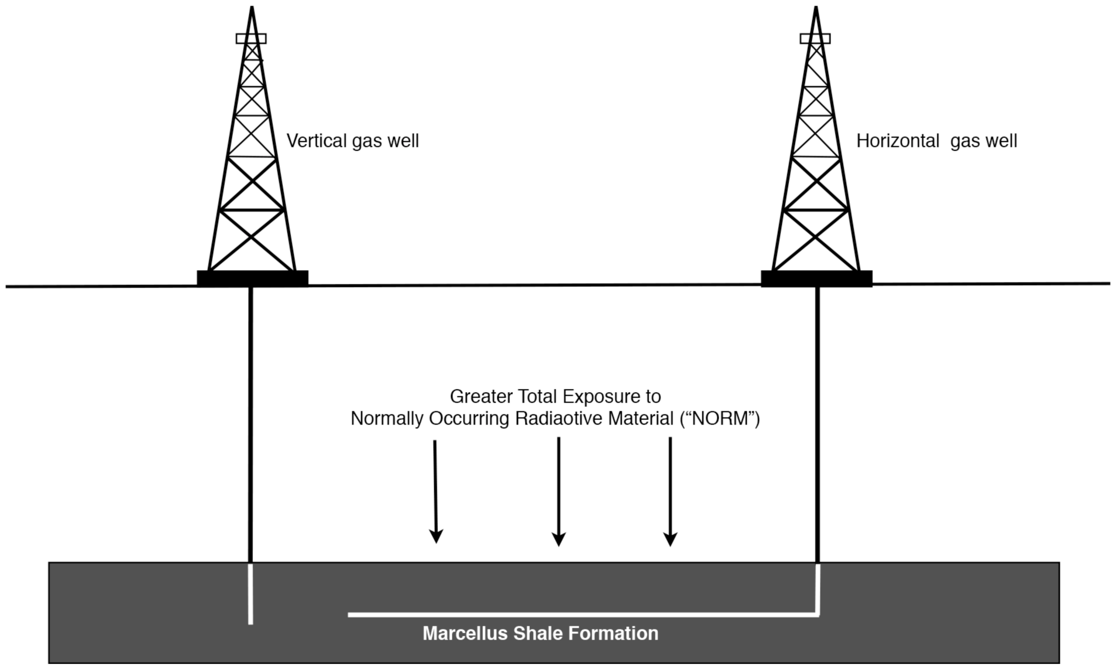


Figure 1: Comparison of Exposure to NORM in Marcellus Shale for Vertical Wells and Horizontal Wells

The second flaw is that RESRAD was not properly used to determine **all** of the potential pathways of the radiation. The following diagrams illustrate the potential pathways for radionuclides released into the environment in an uncontrolled manner, in air or in water.

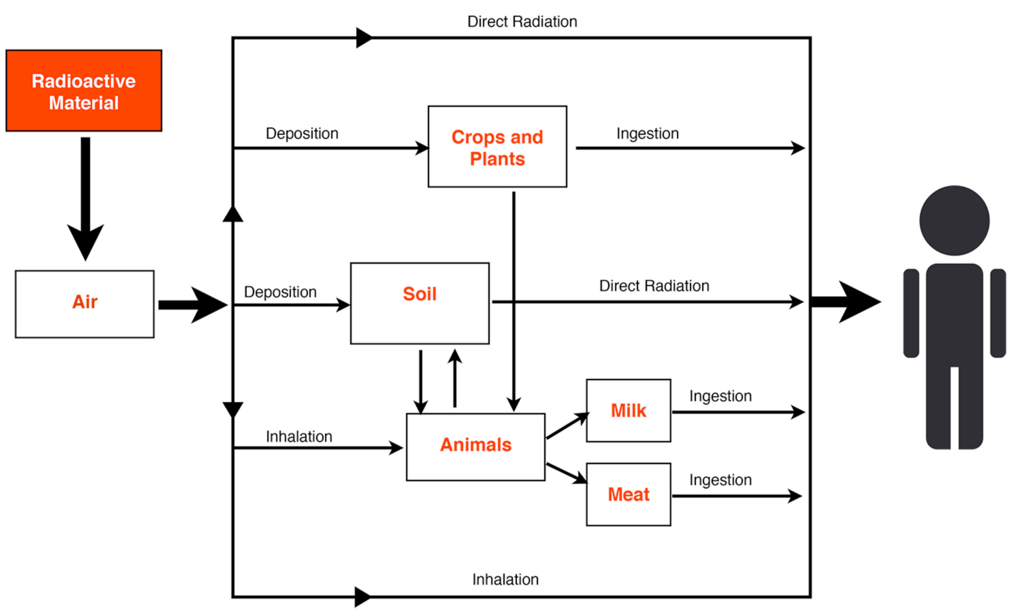


Figure 2: Pathways for Radiation Migration Through Air

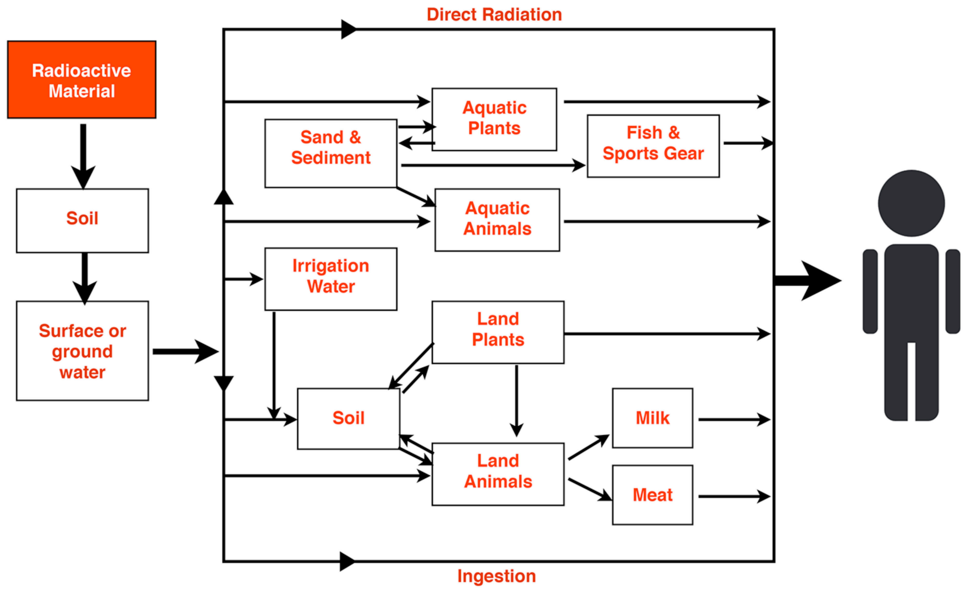


Figure 3: Pathways for Radiation Migration Through Soil and Water

For example, if radioactive wastewater from hydrofracking is spread on a road, there are two possible scenarios involving different pathways.

> In one, the radioactive waste is spread on a paved road with a crown. Some of the waste will inevitably run off the road and find its way into a waterway or onto grazing fields or crops with the resulting pathways. The radioactivity in the waste remaining on the road will be resuspended by the traffic into the air with the resulting direct exposure to humans or biota.
>
> In the second scenario, the waste spread on the dirt road is adsorbed by the dirt. When the dirt road dries out, the radioactive waste is resuspended in the dust from the road. The dust particle size and concentration is determined by the weight of a vehicle, the number of tires, and its speed. The dust is inhaled by humans and animals and deposited on the local vegetation, with the resulting pathways as illustrated above.
>
> In both cases the cumulative impact of the radioactive waste will be determined by the amount of radiation contained in the waste, the number of vehicles and humans travelling on the road over years, proximity to residential or commercial areas, the amount of radiation migrating off road into streams or lakes or blowing onto agricultural land, and finally, the total potential dose to affected humans over time.

The radiation dose from a single truck travelling 40 miles per hour on a dirt road in rural New York State may appear to be insignificant, but the cumulative dose from 30 to 40 years of trucks could very easily be significant and needs to be rigorously calculated. Although there is considerable concern for the general population, exposed populations also include those most vulnerable; the old, the young and the ill.

Importantly, the type of radioactive material found in the Marcellus Shale and brought to the surface by horizontal hydrofracking is the type that is particularly long-lived, and could easily bio-accumulate over time and deliver a dangerous radiation dose to potentially millions of people long after the drilling is over.

Under the linear-no threshold hypothesis used in radiation protection, the goal is to limit the total radiation dose to large populations because of the increased probability of health effects. In the current case, the uncontrolled release of hazardous waste could result in the exposure of millions of people over decades.

Moreover, this scenario does not include any analysis of exposures to other hazardous chemicals used in the fracking process, which could have an unknown synergistic effect on the population.

SUMMARY CONCLUSIONS

1. Radioactive materials and chemical wastes do not just go away when they are released into the environment. They remain active and potentially lethal, and can show up years later in unexpected places. They bio-accumulate in the food chain, eventually reaching humans. Under the proposal for horizontal hydrofracking in New York State, there are insufficient precautions for monitoring potential pathways or to even know what is being released into the environment.

2. The NYS DEC has not proposed sufficient regulations for tracking radioactive waste from horizontal hydrofracking. By way of comparison, the nuclear industry has to rigorously account for all releases of radioactivity. No radioactive material leaves a nuclear facility without being carefully tracked to its safe final destination. Neither New York State nor the Nuclear Regulatory Commission would permit a nuclear power plant to handle radioactive material in this manner. (It is important to note that tracking of radioactive materials cannot be accomplished retrospectively; accurate accounting *must* be incorporated from the very beginning to ensure public safety.)

3. RESRAD was made precisely for situations like this, but it must be used properly to produce valid conclusions. Picking and choosing isolated scenarios and ignoring downstream exposures, as was done in the Report, is not a proper use of RESRAD and renders the conclusions invalid. All of the potential pathways over a span of decades as the hazardous material accumulates and the public's body burden build up must be considered to produce a valid RESRAD conclusion. This applies to both radioactive and chemical waste.

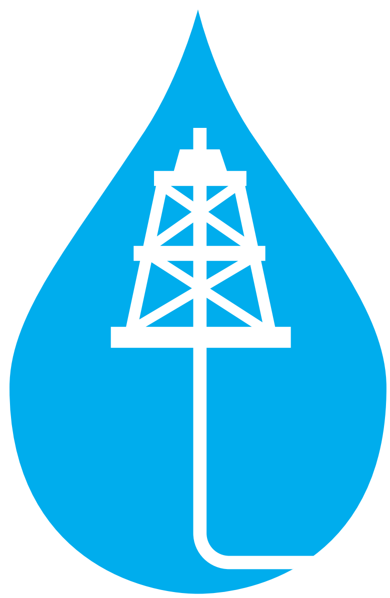
4. While this statement deals only with the radioactivity of waste produced by horizontal hydrofracking, the same principles of exposure pathways must be taken into account for all of the toxic chemicals used in the process. The EPA Pavillion Report demonstrates that there are hazardous chemicals in fracking fluid, and a recent review of the EPA report confirmed that it was valid.

E. Ivan White
October, 2012

This report was edited for public release by Grassroots Environmental Education, a non-profit organization.

Ceres

HYDRAULIC FRACTURING & WATER STRESS:
Growing Competitive Pressures for Water



May 2013

Authored by
Monika Freyman, Ceres
Ryan Salmon, Ceres

Ceres is a nonprofit organization mobilizing business leadership on sustainability challenges such as climate change and water scarcity. It directs the Investor Network on Climate Risk (INCR), a network of more than 100 investors with collective assets totaling more than $11 trillion.

Ceres provides tools and resources to advance corporate water stewardship including the *Ceres Aqua Gauge*, a roadmap that helps companies assess, improve and communicate their water risk management approach and that allows investors to evaluate how well companies are managing water-related risks and opportunities. For more details, see: www.ceres.org/aquagauge

AUTHORED BY

Monika Freyman, Ceres
Ryan Salmon, Ceres

ACKNOWLEDGEMENTS

Ceres wishes to thank World Resources Institute for its assistance in developing the water stress maps, as well as PacWest Consulting Partners for its assistance with the organization and interpretation of the FracFocus data. We would like to thank Jean-Philippe Nicot of the Jackson School of Geosciences at the University of Texas for providing feedback on the work.

We also wish to thank our colleagues who provided valuable insight and assistance: Sarah Betancourt, Brian Sant, Peyton Fleming, Andrew Logan and Brooke Barton.

Graphic design by Patricia Robinson Design.

FOR MORE INFORMATION, CONTACT:

Monika Freyman, CFA
Water Program Manager
Ceres
99 Chauncy Street
Boston, MA 02111
freyman@ceres.org

www.ceres.org

Summary

This Ceres research paper analyzes water use in hydraulic fracturing operations across the United States and the extent to which this activity is taking place in water stressed regions. It provides an overview of efforts underway, such as the use of recycled water and non-freshwater resources, to mitigate these impacts and suggests key questions that industry, water managers and investors should be asking. The research is based on well data available at FracFocus.org and water stress indicator maps developed by the World Resources Institute.

FracFocus data was collected for more than 25,000 tight oil (sometimes referred to as shale oil) and shale gas wells in operation from January 2011 through September 2012. The research shows that 65.8 billion gallons of water was used, representing the water use of 2.5 million Americans for a year. Nearly half (47 percent) of the wells were developed in water basins with high or extremely high water stress. In Colorado, 92 percent of the 3,862 wells were in extremely high water stress areas. In Texas, which accounts for nearly half of the total number of wells analyzed, 5,891 of its 11,634 wells (51 percent) were in high or extremely high water stress areas. Extremely high water stress means over 80 percent of available water is already being withdrawn for municipal, industrial and agricultural uses.

The research paper provides valuable insights about potential water use/water supply conflicts and risks, especially in basins with intense hydraulic fracturing activity and water supply constraints (due to water stress and/or drought). Given projected sharp increases in production in the coming years and the potentially intense nature of local water demands, competition and conflicts over water should be a growing concern for companies, policymakers and investors. Prolonged drought conditions in many parts of Texas and Colorado last summer created increased competition and conflict between farmers, communities and energy developers, which is only likely to continue.[1] In areas such as Colorado and North Dakota, industry has been able to secure water supplies by paying a higher premium for water than other users or by getting temporary permits. Neither of these practices can be guaranteed to work in the future, however. Even in wetter regions of the northeast United States, dozens of water permits granted to operators had to be withdrawn last summer due to low levels in environmentally vulnerable headwater streams.[2]

The bottom line: shale energy development cannot grow without water, but in order to do so the industry's water needs and impacts need to be better understood, measured and managed. A key question investors should be asking is whether water management planning is getting sufficient attention from both industry and regulators.

A key question investors should be asking is whether water management planning is getting sufficient attention from both industry and regulators.

1 Jack Healy, "For Farms in the West, Oil Wells Are Thirsty Rivals," *The New York Times*, September 5, 2012

2 Susquehanna River Basin Commission, Press Release, "64 Water Withdrawals for Natural Gas Drilling and Other Uses Suspended to Protect Streams," July 16, 2012

Research Background

FRACFOCUS

FracFocus.org was launched in 2011 to serve as a voluntary national hydraulic fracturing chemical registry and is managed by the Groundwater Protection Council and the Interstate Oil and Gas Compact Commission to provide the public with access to information about the chemicals used for hydraulic fracturing. The database provides the location of each well that was "fracked," the date it was fracked and the chemical additives and total volume of water injected down the well. However, information on the source and type of water used (e.g. freshwater, recycled, saline etc.) for each well is not disclosed and there are some structural issues with the database such as trade secret exemptions being claimed in supplying chemical information to the site.[3] Since being launched, 10 states and two Canadian provinces have opted to use FracFocus for regulatory reporting.

Since disclosure to FracFocus is often still voluntary, the number of wells and volume of water injected/used is underreported. Bloomberg estimated that FracFocus captured data on about 60 percent of wells fracked through the end of 2011, but disclosure is likely now even higher.[4] The data in Ceres' analysis represents wells drilled from Jan. 1, 2011 through Sept. 30, 2012 and captures information on 25,450 wells. It includes both oil and gas and horizontal and vertical wells that have been hydraulically fractured. PacWest Consulting Partners helped organize and interpret the data.[5]

WRI AQUEDUCT WATER RISK ATLAS

The World Resources Institute's (WRI) recently launched Aqueduct Water Risk Atlas (Aqueduct) provides companies, investors and governments with a comprehensive, high-resolution picture of water-related risks worldwide. The Aqueduct includes 12 global water indicators grouped into three categories: physical water quantity risk; physical water quality risk; and regulatory and reputational risk.[6] Our analysis focused on the baseline water stress indicator, which is indicative of the level of competition in a given region and measures total annual water withdrawals (municipal, industrial and agricultural) expressed as a percentage of water available.[7]

LINKING THE DATA

By linking the two datasets together through matching latitude and longitude coordinates, Ceres was able to study well locations and water volumes being injected against geographic water quantity indicators provided by the WRI maps. This allows us to study the extent and distribution of well locations in regions with water-sourcing challenges. By aggregating the total volume of water used in any region, we gain valuable insights into the water demand for hydraulic fracturing against water supply constraints such as drought severity and water stress. These indicators speak to the growing competitive pressure for water.

3 Kate Konschnik, with Margaret Holden and Alexa Shasteen, "Legal Fractures in Chemical Disclosure Laws," Harvard Law School, Environmental Law Program, Policy Initiative, April 2013

4 Benjamin Haas, Jim Polson, Phil Kuntz and Ben Elgin, "Fracking Hazards Obscured in Failure to Disclose Wells," Bloomberg News, August 14, 2012

5 PacWest Consulting Partners provides a database of the FracFocus source data developed through custom-built software that parses, cleans, analyzes and interprets the data in conjunction with human analysts.

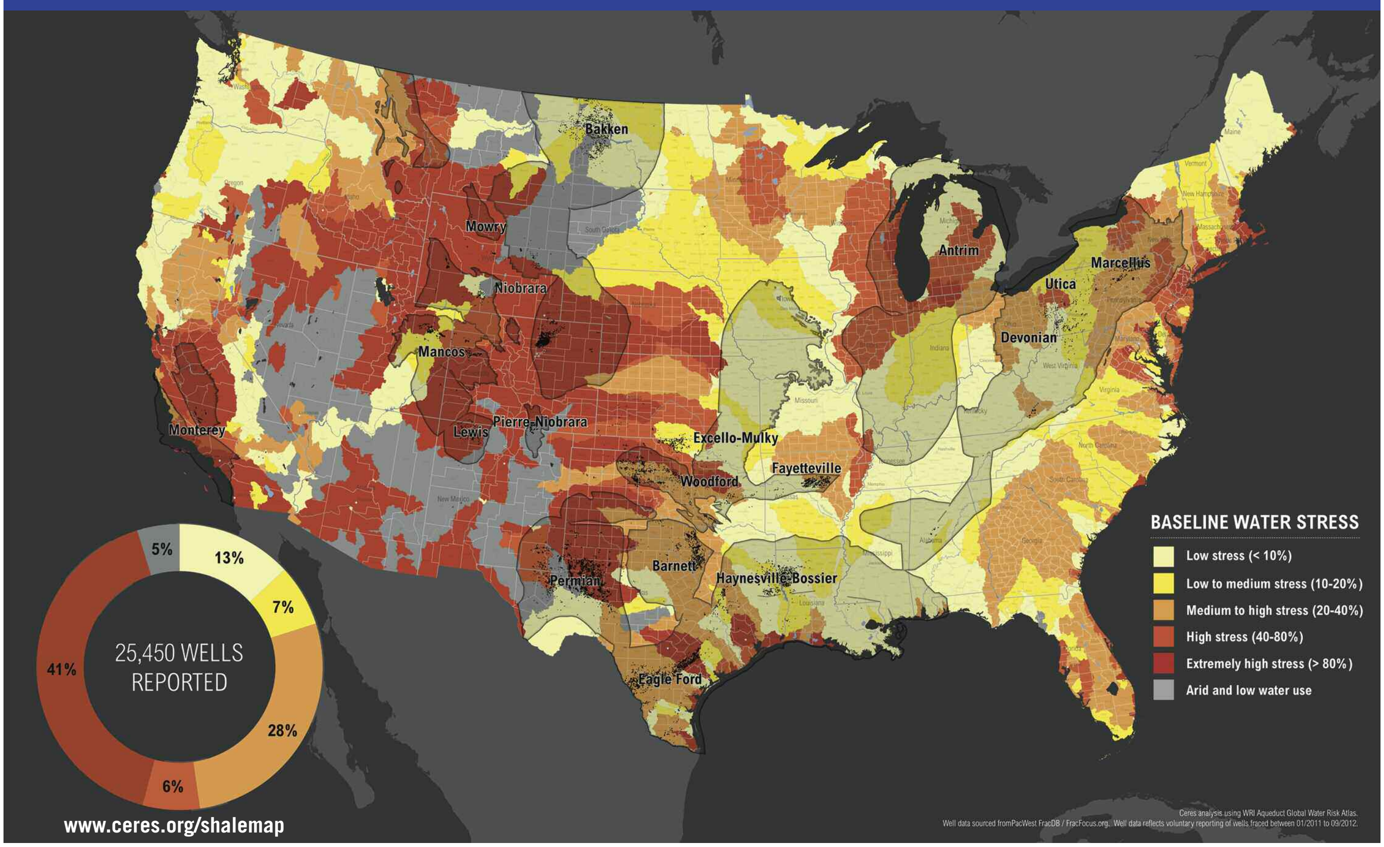
6 World Resources Institute, Release: "New Mapping Tool Provides Unprecedented Ability to Assess Water Risk," January 30, 2013

7 Water stress measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percent of the total annual available flow. Higher values indicate more competition among users. For details on methodology see white paper by Francis Gassert, Matt Landis, Matt Luck, Paul Reig and Tien Shiao, Aqueduct Metadata Document, Aqueduct Global Maps 2.0, January 2013

Key Findings

In the below map and in Figures 1 and 2 (p. 6) one can see that almost half (47 percent) of shale gas and tight oil wells are being developed in regions with high to extremely high water stress. This means that over 80 percent of the annual available water is being withdrawn by municipal, industrial and agricultural users in these regions. Overall 75 percent of wells are located in regions with medium or higher baseline water stress levels. Although water use for hydraulic fracturing is often less than one or two percent of a state's overall use, it can be much higher at the local level, increasing competition for scarce supplies. **Please click on the map to access an online map that allows you to zoom in on specific regions and well sets.**

COMPETITION FOR WATER IN U.S. SHALE ENERGY DEVELOPMENT



Map of hydraulically fractured well locations as overlaid onto the WRI's Aqueduct Water Risk Atlas using the baseline water risk indicator. Forty-seven percent of wells are found in regions with high or extremely high water risk indicating growing competitive pressure on water supplies for shale energy development. Well locations in the map above appear as black patches. The wells appear more clearly, as black circles, on the online map. Shale basins are represented by shaded areas. Click on map to access online map.

FIGURE 1: NUMBER & PERCENTAGE OF HYDRAULICALLY FRACTURED WELLS BY WATER STRESS

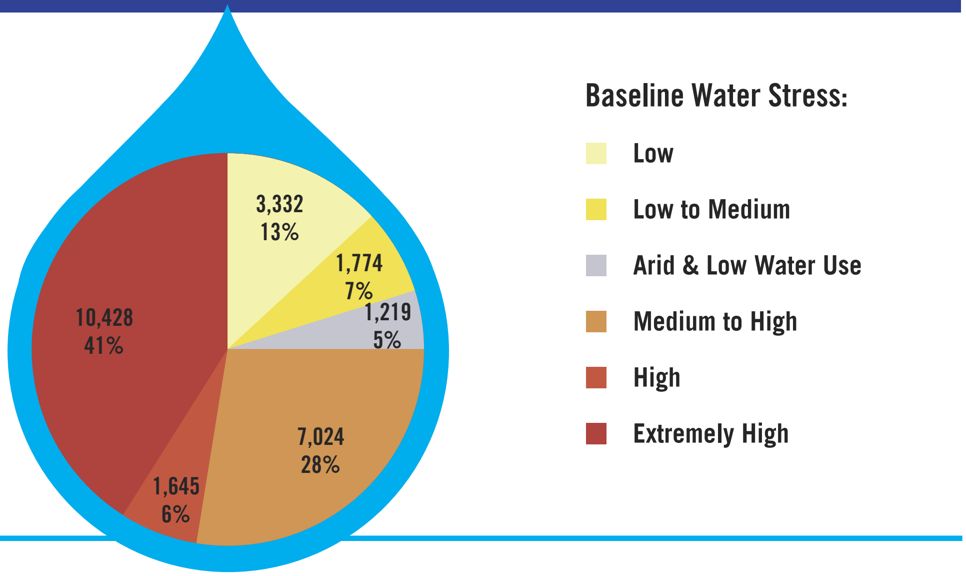
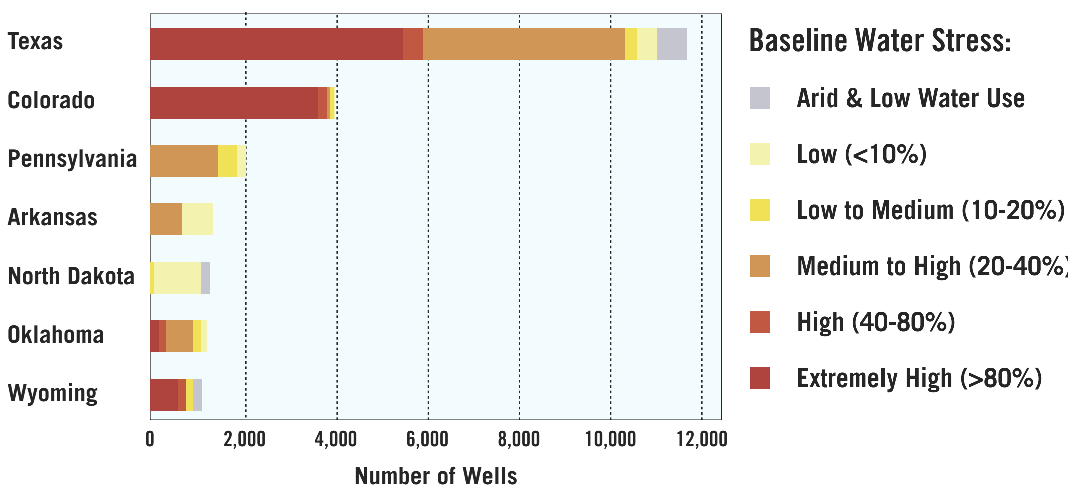


FIGURE 2: NUMBER OF HYDRAULICALLY FRACTURED WELLS BY STATE & WATER STRESS



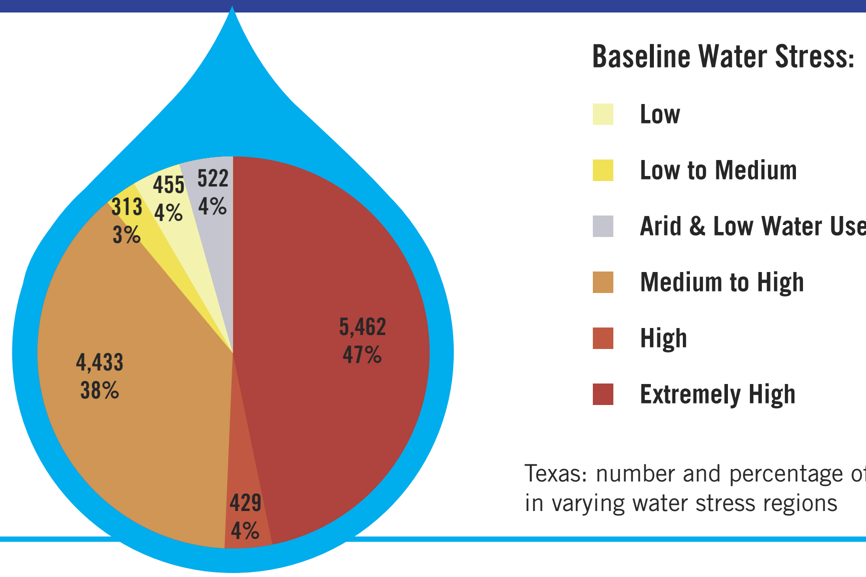
Numbers of wells in top seven shale energy producing states by water stress.

Figures 3 through 6 (pp. 7-8) graphically extrapolate from the maps the number of wells and the volume of water injected for hydraulic fracturing in the major energy development states. Wells in Texas make up just under half of the total wells reportedly drilled and water volumes injected. Just under half of the wells developed in Texas are in regions with high to extremely high water stress. In Colorado, 97 percent of wells are being developed in regions of high or extremely high water stress.

According to the data, from Jan. 2011 to Sept. 2012, 65.8 billions of gallons of water were used in hydraulic fracturing operations both for oil and gas development and in vertical and horizontal wells across the U.S. This amount represents roughly the water use of 2.5 million Americans for a year.[8]

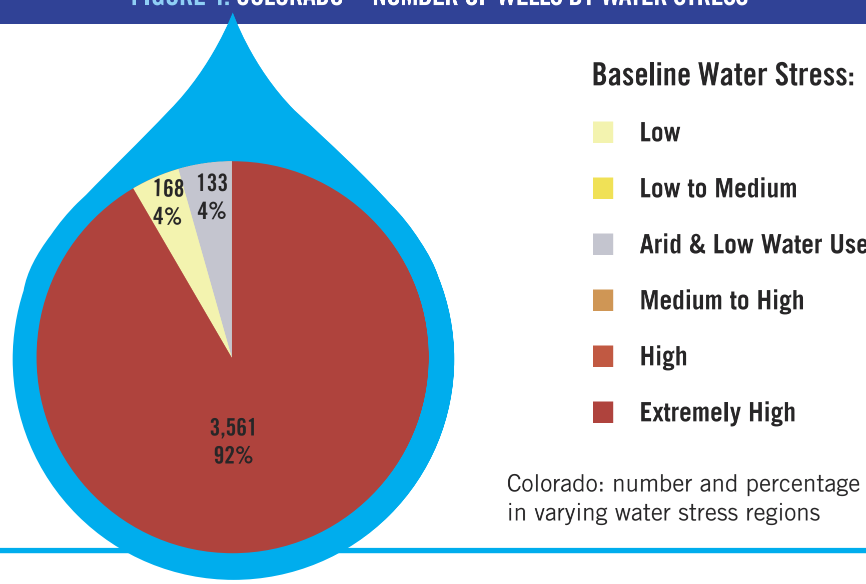
8 The EPA estimated that 70bn gallons represented the water use of one city with 2.5m inhabitants in its Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, February 2011

FIGURE 3: TEXAS—NUMBER OF WELLS BY WATER STRESS



Texas: number and percentage of wells in varying water stress regions

FIGURE 4: COLORADO—NUMBER OF WELLS BY WATER STRESS



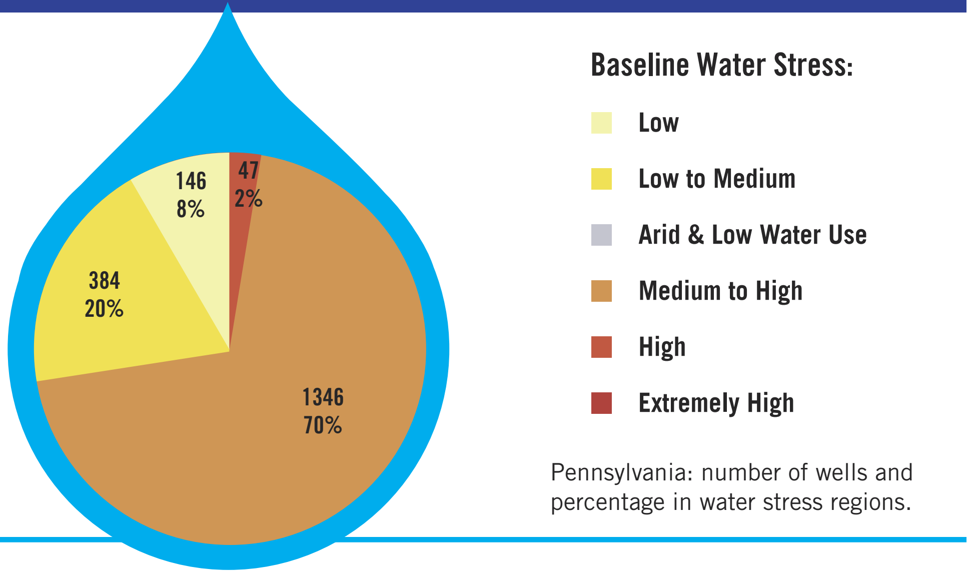
Colorado: number and percentage of wells in varying water stress regions

Texas, Pennsylvania and Arkansas were the three states with the highest water use for shale energy. Water use data for oil and gas development in Texas in another study was estimated to be about 26 billion gallons of water for 2011.[9] Our data reflects similar water use but from a longer period of time, thus supporting that FracFocus data under reports water use. Similarly the Colorado Oil and Gas Conservation Commission estimated water use in 2011 for hydraulic fracturing to be just under five billion gallons.[10] Our numbers for Colorado water use are similar, but again are from a longer period of time.

9 "Oil and Water Use in Texas: Update to the 2011 Mining Water Use Report," Jean-Philippe Nicot, P.E.,P.G., Robert C. Reedy, P.G., Ruth A. Costley, and Yun Huang, P.E., Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas, Austin, September 2012

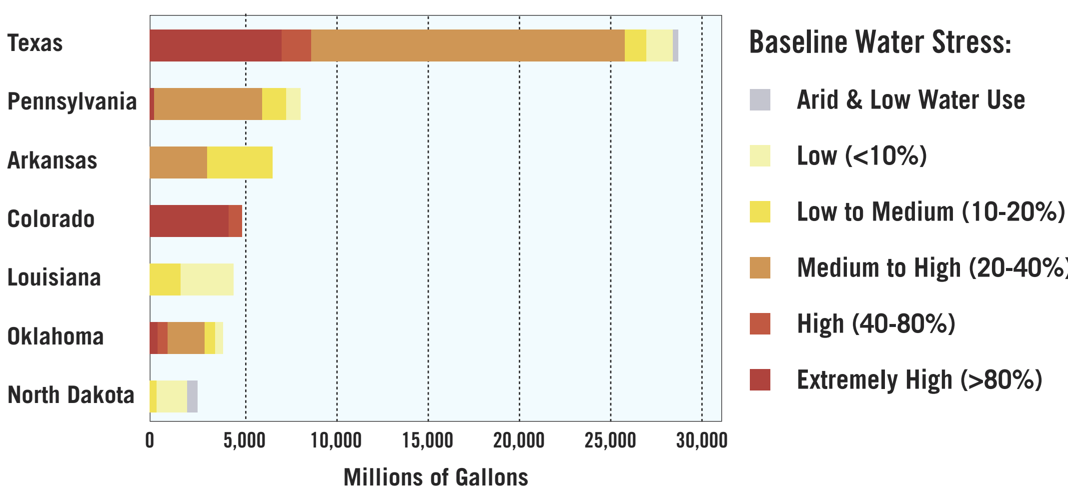
10 Estimates of 2011 Colorado water use for hydraulic fracturing were 14,900 acre feet with one acre foot being equivalent to ~326,000 gallons. From "Water Sources and Demand for Hydraulic Fracturing of Oil and Gas Wells in Colorado from 2010 through 2015," jointly prepared by the Colorado Division of Water Resources, the Colorado Water Conservation Board and the Colorado Oil and Gas Conservation Commission; http://cogcc.state.co.us/Library/Oil_and_Gas_Water_Sources_Fact_Sheet.pdf

FIGURE 5: PENNSYLVANIA—NUMBER OF WELLS BY BASELINE WATER STRESS



Pennsylvania: number of wells and percentage in water stress regions.

FIGURE 6: VOLUME OF WATER INJECTED FOR HYDRAULIC FRACTURING BY STATE & WATER STRESS REGIONS



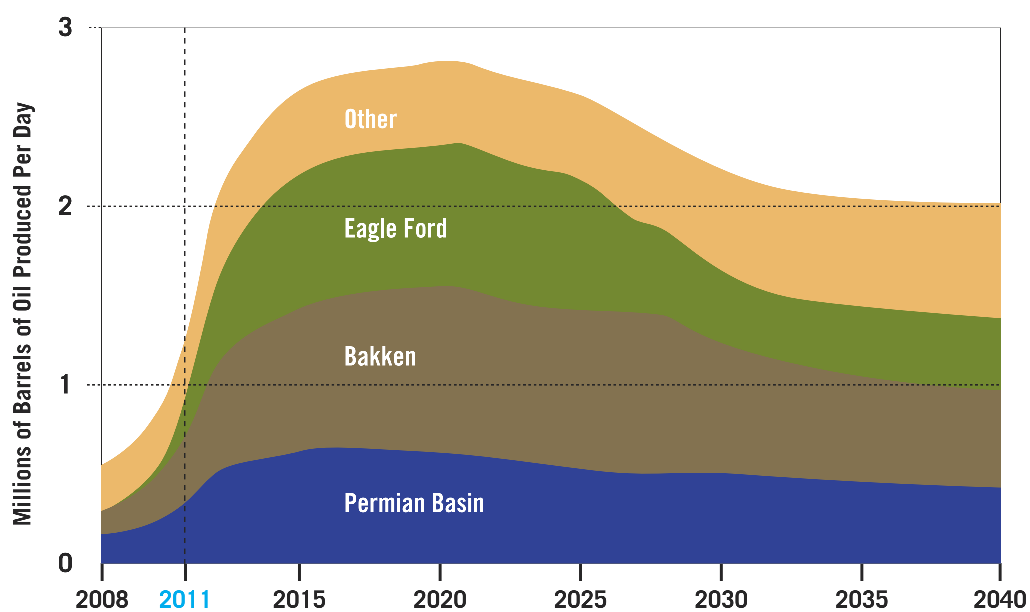
Water use by state and base line water stress level. Only states with one billion or more gallons of cumulative water use included.

Looking Toward Future Water Requirements

There needs to be across the board disclosure of the sources of water used for hydraulic fracturing, the amount withdrawn from each source, the amount used for each fracture and the amount of flowback water (initial flows) and produced water (later flows) returned to the surface.

Shale energy extraction is a thirsty business. The U.S. Energy Information Administration (EIA) predicts that shale gas production will rise from 23 percent of U.S. natural gas production in 2010 to 49 percent in 2035 and that tight oil production will rise from just over 1.2 million barrels per day in 2011 to 2.8 million by 2020.[11] Given these trends, investors should be asking if water management planning is getting sufficient attention from both industry and regulators. Shale development needs water to grow, but in order to do so, the industry's current and future water requirements need to be better understood, measured and managed. The adage, "what gets measured, gets managed," holds true. There needs to be across the board disclosure of the sources of water used for hydraulic fracturing, the amount withdrawn from each source, and the amount of flowback water (initial flows) and produced water (later flows) returned to the surface.

FIGURE 8: TOTAL & PROJECTED U.S. TIGHT OIL PRODUCTION BY GEOLOGIC FORMATION FROM 2008-2040



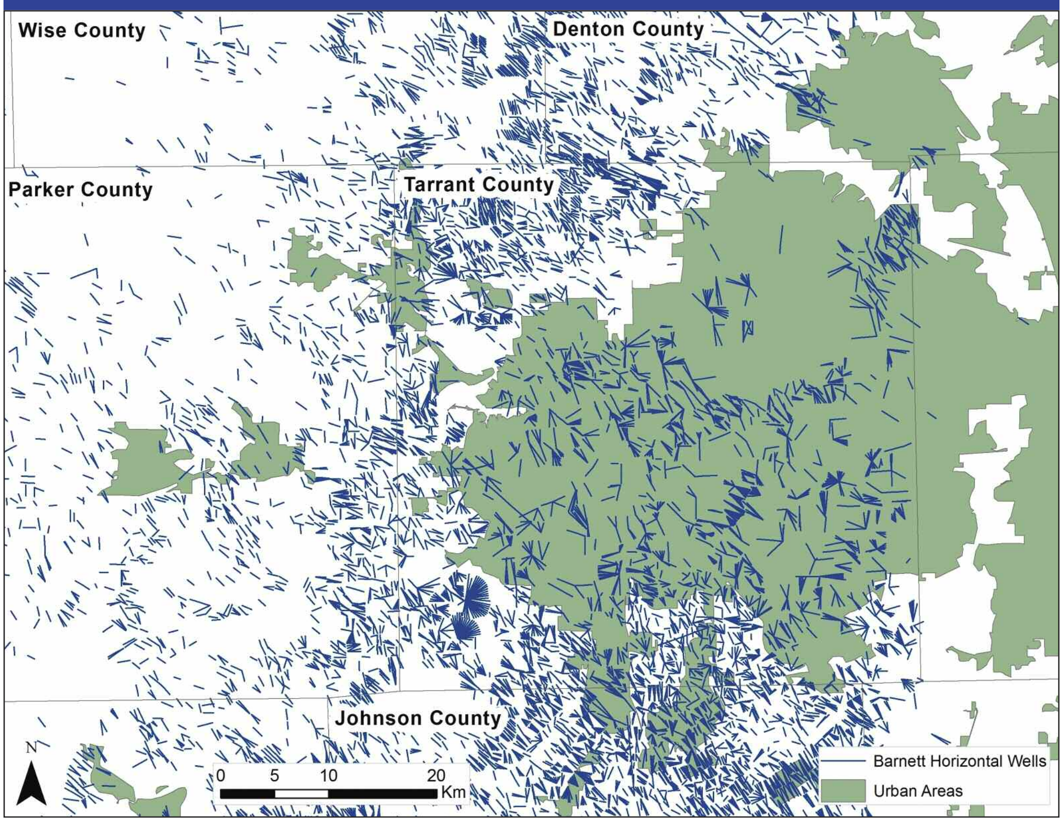
Source: EIA Annual Energy Outlook 2013

11 US Energy Information Administration, EIA Annual Energy Outlook 2013

Investors should ensure that companies have a local stakeholder engagement process in place on water issues.

Development of shale energy resources requires a large amount of water, with estimates ranging between two to 10 million gallons per well. The amount of water consumed per well depends on the geology of the shale, the number of fracturing stages and the amount of water that flows back to the surface (estimated between 20-80 percent). Although total water use for hydraulic fracturing is often less than 2 percent of a state's overall water use, requirements at the local level can be much higher.[12] The map of Tarrant County, Texas below highlights the potentially intense localized nature of shale energy development. The estimated water used for hydraulic fracturing in Tarrant County alone in 2011 was 2.8 billion gallons of water, which is equivalent to about 10 percent of the water used in all of Texas for hydraulic fracturing. Several other Texan counties such as Wise and Johnson experienced high water demands from hydraulic fracturing representing 19 and 29 percent of their overall county water use respectively.[13] Investors should ensure that companies have a local stakeholder engagement process in place on water issues.

FIGURE 9: HORIZONTAL WELLS IN THE BARNETT SHALE, TARRANT COUNTY, TEXAS — 2011



Map view of horizontal wells in the Barnett Shale centered on Tarrant County, 2011.

Source: "Oil and Water Use in Texas: Update to the 2011 Mining Water Use Report," Jean-Philippe Nicot, P.E.,P.G., Robert C. Reedy, P.G., Ruth A. Costley, and Yun Huang, P.E., Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas, Austin, September 2012

12 Note 9

13 Jean-Philippe Nicot and Bridget Scanlon, "Water Use for Shale-Gas Production in Texas," U.S., Environmental Science and Technology, 46, 3580-3586, 2012

Efforts To Mitigate Water Stress

Many important efforts and innovations are taking place to limit the use of freshwater. The use of recycled water and alternative sources such as wastewater, saline water, seawater or acid-mine drainage is growing. In some regions such as the Marcellus in Pennsylvania, recycling rates are estimated to reach 40 percent.[14] Although the Northeast is one of the "wetter'" regions, high water recycling rates are due to the lack of wastewater disposal infrastructure. Recycling rates in many other regions remain in the single digits.[15] However in some parts of Texas the use of saline water is increasing. For example, saline water use in the Eagle Ford in Texas is about 20 percent.[16] Overall water recycling and the use of non-freshwater sources must increase considerably to make a significant impact. Increasing use of saline ground water sources must be done in conjunction with increasing studies of the impacts of using these water resources and their relationship to freshwater aquifers.

The U.S. Environmental Protection Agency in its review of drinking water impacts from hydraulic fracturing is studying the problem of water sourcing and looks to release those results in 2014. However, some are choosing to act now. Efforts are underway by both industry and regulators to use non-freshwater sources such as saline groundwater, seawater or to use more recycled water.[17] The Texas Railroad Commission recently changed permitting requirements making it easier to recycle.[18] Other lawmakers in Texas are pursuing measures such as legislation that would introduce mandatory across-the-board water recycling requirements.[19] The recently launched Center for Sustainable Shale Development in Pennsylvania is calling for 90 percent recycle rates.[20] These steps are encouraging, but it is important to realize that recycling can only go so far in solving water sourcing problems since much of the water injected remains in the formation. Nevertheless companies should be disclosing their aggregated use of recycled and non-freshwater sources as well as a breakdown of these numbers by region of production. Quantifiable water recycling and non-freshwater use targets should be in place and on-going dialogue should be encouraged between industry and investors to better understand the roadmap, challenges and barriers (be it technical or regulatory) to reaching these targets.

Nevertheless companies should be disclosing their aggregated use of recycled and non-freshwater sources as well as a breakdown of these numbers by region of production. Quantifiable water recycling and non-freshwater use targets should be in place and on-going dialogue should be encouraged between industry and investors to better understand the roadmap, challenges and barriers (be it technical or regulatory) to reaching these targets.

14 Brian Lutz. Aurana Lewis and Martin Doyle, "Generation, transport, and disposal of wastewater associated with Marcellus Shale gas development," Water Resources Research, Feb. 8 2013

15 Note 9

16 Note 9

17 American Water Intelligence, "Finding a brackish alternative to fresh frac water," Vol 2. Issue 3, March 2011

18 The Railroad Commission of Texas, Press Release, "TRC Adopts New Hydraulic Fracturing Wastewater Rules," March 26, 2013

19 Karen Boman, "Legislation Targets Mandates for Water Recycling in Oil, Gas Industry," Rig Zone, April 15, 2013

20 Center for Sustainable Shale Development, Performance Standards (March 2013); http://037186e.netsolhost.com/site/wp-content/uploads/2013/03/CSSD-Performance-Standards-3-27-GPX.pdf

Conclusion

Advances in hydraulic fracturing and horizontal drilling and resulting extraction of energy in shale gas and tight oil formations has truly been a disruptive technology. First, this technology has enabled producers to achieve exponentially more hydrocarbons per well versus old technologies and techniques. Second, the resulting rapid development of shale energy needs to be put in context of already at-risk water resources. Growing economic and energy production pressures are putting added pressures on water supplies, especially in regions such as Texas and Colorado, which are already under severe strain due to recent droughts. Climate change will only exacerbate water supply and demand imbalances. Shale energy development highlights the fact that our water resources were already vulnerable before additional demands were introduced. Regulators, water managers and ultimately all significant economic players who rely on abundant supplies of water must double-down their efforts to better manage this limited and most precious resource.

ABOUT THIS RESEARCH

This white paper is part of a larger, more comprehensive study Ceres is undertaking to analyze the water risks across the entire hydraulic fracturing lifecycle—from water sourcing to final treatment and disposal of wastewater—across different regional basins in North America. Further analysis of well locations and water data compared to other WRI water indicators, such as seasonal variability of water supplies, ground water stress and drought severity, will also be included. The research is aimed principally at investors who have financial stakes in well operators and support services in these regions.

Ceres

Ceres
99 Chauncy Street
Boston, MA 02111
T: 617-247-0700
F: 617-267-5400
www.ceres.org

Impacts of Fracking on Wildlife: A Review
Center for Biological Diversity
Authors: Dipika Kadaba and Shaye Wolf
Updated September 6, 2013

Methods:
The primary sources of information included in this review are publications in scientific journals, and government, news and advocacy group reports. An internet search was performed using Web of Science and Google Scholar to locate scientific publications, and Google search to locate other reports. All searches used a combination of the keywords 'hydraulic fracturing,' 'fracking,' 'wildlife,' and 'animals.' These keywords primarily yielded publications about the impacts of fracking activity on the health, behavior, and habitat of wildlife and other animals. Accounts of livestock and pet animals were included along with wildlife as they are environmentally impacted in similar ways. The bibliographies of scientific papers and fracking summary reports by advocacy groups also served as sources of current information on the impacts of fracking on wildlife. An extensive Google search using the above mentioned keywords also yielded numerous news reports and a small amount of literature that was not included in the reviewed summary reports. This search method allowed the identification of literature specific drilling activity aided by hydraulic fracturing, as opposed to other kinds of oil and gas development.

Summary:
Our review found 25 accounts of the impacts of hydraulic fracturing on wildlife, in the following 3 areas:
[I] Impacts caused by exposure to fracking activity,
[II] Impacts caused by accidental contamination from fracking chemicals, and
[III] Population impacts caused by habitat loss and degradation

[I] Impacts caused by exposure to fracking activity
Regular drilling activity that utilizes hydraulic fracturing has been linked to number of negative impacts on wildlife, even when drilling is done in accordance with state rules and no accidents are reported. Proximity to fracking activity is associated with decreased richness of aquatic species and the spread of invasive species, death and deformities of wildlife and domestic animals, and an increased risk of the spread of wildlife disease.

[II] Impacts caused by accidental contamination
There have been numerous cases of spills, blowouts, and improper fencing that exposed fish and other wildlife to fracking chemicals. These accidents caused large scale fish kills, kills of threatened species, and a range of negative health effects to wildlife and domestic animals, from birth defects to death.

[III] Population impacts caused by habitat loss and degradation
Numerous studies found that sensitive bird species and other wildlife are affected by truck traffic, human presence, and edge effects from gas drilling infrastructure – one study found that a single drilling station can affect 30 acres of forest. These effects of habitat degradation on wildlife include interference with behavior, migration, and reproduction.

These accounts are also classified by **type of publication:**
News article, Video news report, Magazine article, Journal article, Peer-reviewed paper, Press release, State report, Advocacy group report, Non-profit association report, or Institutional report.

Impacts to wildlife that were not included in this review, but which are common to oil and gas development in general, include the effects of noise and light pollution and the spread of invasive species. Noise pollution from energy facilities has been linked to lower densities and reproductive success of birds. One study on noise pollution impacts found that songbirds that were found in areas near noiseless energy facilities had a total density 1.5 times higher than areas near noise-producing sites, indicating avoidance of noise producing infrastructure.[1] Another study showed that the reproductive success of ovenbirds was diminished by chronic background noise originating from wellpads.[2] The impacts of lighting of oil and gas infrastructure have been cited as a cause of concern for wildlife.[3] Effects include attracting night-flying insects to artificial light sources, thus depleting the prey of wildlife that depend on them.[4] Construction activity can affect air, soils, nutrient cycling, and wildlife habitat. The discharge of produced water into native streams affects water chemistry and water availability, thus disturbing native ecosystems.[5] Controlled studies have also shown that natural gas development activity and associated disturbance may facilitate the establishment of non-native plants.[6]

This review represents and incomplete overview of the full impacts of fracking activity on wildlife for several reasons: (1) studies and reports on the impacts of oil and gas development do not always specify whether hydraulic fracturing was employed; (2) there are significant research gaps on the effects of fracking on wildlife; and (3) many fracking impacts are likely never reported or even observed.

[I] Wildlife impacts caused by exposure to fracking activity

[Peer-reviewed paper]
1) Negative health impacts to wildlife, pets, and domestic animals caused by exposure to fracking activity
Animal owners and veterinarians were surveyed in six states (Colorado, Louisiana, New

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[1] Bayne E.M., Habib, L., and Boutin, S. 2008. Impacts of Chronic Anthropogenic Noise from Energy-sector Activity on the abundance of songbirds in the boreal forest. Conservation Biology 22(5):1186-93.
[2] Habib, L., Bayne E.M., and Boutin, S. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds Seiurus aurocapilla. Journal of Applied Ecology, 44(1):176-184.
[3] New York State Deparment Of Environmental Conservation. 2011. Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program. http://www.dec.ny.gov/energy/75370.htm.
[4] Kiviat, E. and Schneller-McDonald, K. 2011. Fracking and Biodiversity: Unaddressed issues in the New York debate. News from Hudsonia, 25(1&2).
[5] Bureau of Land Management (BLM): (2003). Final environmental impact statement and proposed plan amendment for the powder river basin oil and gas project. Volume 1 of 4.WY-070-02-065. US Department of the Interior, Bureau of Land Management, Buffalo Field Office.
[6] Bergquist, E., Evangelista, P., Stohlgren, T.J., and Alley, N. 2007. Invasive species and coal bed methane development in the Powder River Basin, Wyoming. Environ Monit Assess 128:381-394.

York, Ohio, Pennsylvania, Texas) affected by gas drilling. The following cases of negative health impacts related to exposure to fracking infrastructure or wastewater were reported:

- Among wildlife, fish experienced sudden death and dermatological abnormalities, and song birds and amphibians experienced sudden death as well.
- Pet dogs and cats experienced various systemic impacts, and also sudden death.
- Farm animals such as bovines, horses, poultry, and llamas suffered a range of impacts, from poor reproduction and systemic problems, to sudden death.

Some health impacts also resulted from accidental spills of fracking wastewater.

Bamberger, M. and Oswald, R.E. 2012. Impacts of gas drilling on human and animal health. New Solutions, 22(1):51-77.

[News article]
2) Decreased species richness and increased water pollution found in streams near natural gas drilling activity
A preliminary study investigating the effects of drilling for natural gas on stream life and water quality found reduced aquatic species richness in streams close to drilling activity. They reported, "as the density of well pads increased, the number of types of stream insects decreased." They also reported higher levels of water pollutants in areas with high density drilling. The results of the complete study will be published at the end of 2012.

Susan Phillips, "Researchers Wade Into Streams to Study Gas Drilling Impacts," State Impact, NPR, October 6, 2011, http://stateimpact.npr.org/pennsylvania/2011/10/06/researchers-wade-into-streams-to-study-gas-drilling-impacts/ (accessed June 26, 2012)

[Peer-reviewed Paper]
3) Bird mortality caused by oil field wastewater disposal facilities
Hydraulic fracturing fluids are sometimes disposed of in commercial and centralized oilfield wastewater disposal facilities (COWDFs), which are used in Colorado, New Mexico, Utah, and Wyoming. Birds are attracted to these large ponds which can potentially cause wildlife mortality. Field inspections in Wyoming found 269 bird carcasses – most commonly grebes and waterfowl. Sodium toxicity and surfactants – which are found in hydraulic fracturing fluids – were suspected to be the cause of death at three of the inspected COWDFs.

Ramirez, P. Jr. 2010. Bird Mortality in Oil Field Wastewater Disposal Facilities Environ Manage. 46(5):820-6

[Peer-reviewed paper]
4) Coalbed methane extraction, which commonly utilizes hydraulic fracturing, is linked to an increased risk of West Nile Virus to threatened Greater sage-grouse in Wyoming
The survival rate of the greater sage-grouse in Wyoming has declined by 25% in recent years. Coalbed Methane Development in the area causes large volumes of water to be discharged and impounded during natural gas extraction, which creates aquatic habitats that can support mosquito development. There was a 75% increase in potential habitat for mosquito larvae due to an increase in small discharge ponds in this region. The mosquito *Culex tarsalis,* which

is found in the area, spreads West Nile Virus to susceptible species. This implies the Greater Sage-grouse is at increased risk of exposure to West Nile Virus due to Coalbed Methane Development.

Zou, L., Miller, S.N., and Schmidtmann, E.T. 2006. Mosquito Larval Habitat Mapping Using Remote Sensing and GIS: Implications of Coalbed Methane Development and West Nile Virus. J Med Entomol, 43(5):1034:41

[News article and State report]

5) Fracking waste water suspected to be cause of fish abnormalities in Susquehanna River

There is intense natural gas drilling in the basin of the Susquehanna River, and over 15 water treatment plants in Pennsylvania had been accepting waste water from hydraulic fracturing activity, subsequently discharging it into streams.[1] Fish in the Susquehanna River have been exhibiting abnormalities — for example, 40% of adult small-bass within one river section had black spots and lesions[1], and in some cases, 90-100% of fish observed were cases of intersex, possibly due to endocrine disruption.[2]

1. Betsey Piette, "BP oil spill, fracking cause wildlife abnormalities," Workers World, April 27, 2012, http://www.workers.org/2012/us/bp_oil_spill_fracking_0503/ (accessed June 26, 2012).
2. Pennsylvania Fish & Boat Commission, "Ongoing problems with the Susquehanna River smallmouth bass, A case for impairment," May 23, 2012, www.fish.state.pa.us/newsreleases/2012press/senate_susq/SMB_ConservationIssuesForum_Lycoming.pdf (accessed June 26, 2012).

[Video news report]

6) Death and deformities in domestic animals in Garfield County, Colorado

In an interview with the New York Times, a family living near natural gas wells and storage tanks reported congenital abnormalities in goats born on their property, as well as the death of their poultry.

Erik Olsen, "Natural Gas and Polluted Air," The New York Times, February 2011, http://video.nytimes.com/video/2011/02/26/us/100000000650773/natgas.html (accessed June 26, 2012)

[Non-profit association report]

7) Mortality in pets and domestic animals, as reported by an individual, to the Monongahela Basin Watershed Group

An individual living near a seven-acre impoundment pool reported deaths of dogs and goats. An autopsy revealed arsenic in a dog, and a horse on the property also became sick. The Pennsylvania Department of Environmental Protection (PADEP) detected Ethyl glycol and arsenic in water samples on the property.

Upper Monongahela River Association, "WV/PA Monongahela Area Watersheds compacts, Minutes – Seventh Meeting," March 23, 2011, http://www.uppermon.org/Mon_Watershed_Group/minutes-23Mar11.html (accessed June 26, 2012)

[II] Impacts caused by accidental contamination from fracking chemicals

[Peer-Reviewed Paper and Government Report]

8) Unlawfully discharged fracking fluids kill aquatic invertebrates and fish, including Blackside Dace, a federally threatened species

A company in Kentucky illegally discharged fracking fluids into a stream, contaminating it with hydrochloric acid and other chemicals, and killing federally threatened Blackside Dace.

According to the U.S. Fish and Wildlife Service report, "the discharges killed virtually all aquatic wildlife in a significant portion of the fork, including fish and invertebrates." Among the aquatic wildlife killed, bodies of blackside dace - a fish species listed as threatened under federal law – were also recovered.

According to the 2013 Papoulias and Velasco study, in 2007, fracking fluids used during the development of four natural gas wells in Knox County, Kentucky, were released into Acorn Fork creek in the upper Columbia River basin; the fracking effluent overflowed the retention pits directly into Acorn Fork. The hydrochloric acid and dissolved metals from the fracking fluid significantly reduced stream pH from pH 7.5 to 5.6 and created a thick orange-red flocculent. Fish and aquatic invertebrates were killed or displaced for months in over 2.7 kilometers of the approximately 5 kilometers of affected waters in the stream. The federally threatened Blackside Dace was among the fish killed. It is not known how many dace were killed overall since peak mortality was likely missed before researchers arrived, but one dead, one moribund, and several living but distressed Blackside Dace were observed. An analysis of the water quality of Acorn Creek and fish tissues (analysis of Creek Chub and Green Sunfish tissues since Blackside Dace were not available) a month after fracking found that (1) fish exposed to affected Acorn Creek waters showed general signs of stress and had a higher incidence of gill lesions, and (2) the abrupt and persistent changes in post-fracking water quality resulted in toxic conditions.

Papoulias, D.M. and A.L. Velasco. 2013. Histopathological analysis of fish from Acorn Fork Creek, Kentucky, exposed to hydraulic fracturing fluid releases. Southwestern Naturalist 12 (Special Issue 4): 92-111.

Office of Law Enforcement, U.S. Fish and Wildlife Service, Case at a Glance: U.S. v. Nami Resources Company, LLC. www.fws.gov/home/feature/2009/pdf/NamiInvestigation.pdf (accessed on July 20, 2010).

[State Report]

9) Accidental release of wastewater causes death of fish and invertebrates

In Washington County, PA, a pipeline at Cross Creek Wells accidentally discharged an estimated 4,200 gallons of wastewater, as well as sediments. A report by the Oil and Gas Management Program of the Department of Environmental Protection concluded, "The creek was impacted by sediments all the way down to the lake and there was evidence of a fish kill as invertebrates and fish were observed lying dead in the creek.

Department of Environmental protection, Commonwealth of Pennsylvania, Inspection Report, May 27, 2009. www.marcellus-shale.us/pdf/CC-Spill_DEP-Insp-Rpt.pdf (accessed on June 26, 2012).

[Institutional report]

10) Wildlife mortality reported in incidents associated with natural gas drilling operations

Figure 1: Table of incidents of wildlife mortality associated with Natural Gas drilling operations

Location	State	Year	Main Issue Reported	Damage
Dimock	PA	2009	Spill of lubricant gel used in fracture fluid at the drilling site due to failed pipe connections	Contaminated wetland, caused fish kill
Hopewell Township	PA	2009	Broken transmission line led to spill of 7,750 barrels of diluted fracture fluids	Contaminated stream, killing over 100 fish in area rich in biodiversity

MIT Energy Initiative. 2011. "The future of Natural Gas, An Interdisciplinary MIT study." http://web.mit.edu/mitei/research/studies/natural-gas-2011.shtml (accessed June 26, 2012)

[Magazine Article]

11) Contaminated liquids cause cattle and wildlife mortality in Rosa Mesa, New Mexico

In Rosa Mesa, NM, contaminated groundwater (or "produced water") often leaks from storage tanks or is dumped, and antifreeze leaks from compressors used in gas production. This toxic standing liquid is consumed by cattle and wildlife. Ranchers frequently report death of their cattle, and observe carcasses of deer, elk, and other small mammals.

Ted Williams, "The Mad Gas Rush," March 2004, Audubon, http://archive.audubonmagazine.org/incite/incite0403.html (accessed June 26, 2012).

[News Article]

12) A truck runs off the road and spills fracking liquid, causing the death of minnows

In Washing County, PA, a tanker truck hauling fracking liquid ran off a road and spilled almost 5,000 gallons of liquid. The spill resulted in the contamination of a stream and the death of several minnows.

Kathie O. Warco, "Fracking truck runs off road; contents spill", The Observer-Reporter, October 21, 2010. http://www.observer-reporter.com/OR/Story/10-21-2010-fracking-truck-rolls (accessed July 20, 2012).

[Advocacy group report]

13) Accidental blowout contaminates high-quality fishery

In Clearfield County, PA, a blowout released nearly 1 million gallons of wastewater into nearby creeks. This accident led to the uncontrolled discharge of wastewater into a tributary of Little Laurel Run, a high-quality coldwater fishery.

Michaels, C., Simpson, J.L, and Wegner, W. 2010. "Fracture Communities, Case studies of the environmental impacts of industrial gas drilling," Riverkeeper, www.riverkeeper.org/wp-content/uploads/2010/09/Fractured-Communities-FINAL-September-2010.pdf (accesed June 26, 2012)

[Press release]

14) Natural gas drilling fluids spilled into wetland and coldwater fishery

A spill of used natural gas drilling fluids in Bradford County, PA, sent 4,200-6,300 gallons of fluids into a wetland and a tributary of Webier Creek, which drains into a coldwater fishery.

Department of Environmental protection, Commonwealth of Pennsylvania, "DEP Fines Talisman Energy USA for Bradford County Drilling Wastewater Spill, Polluting Nearby Water Resource," August 2, 2010, http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=13249&typeid=1 (accessed June 26, 2012).

[Advocacy group report]

15) Inadequate prevention of harm to wildlife by drilling operators

Industrial gas drilling operators in Colorado committed numerous violations including "failure to prevent unauthorized exploration and production waste discharges; …failure to install appropriate fencing to prevent significant adverse environmental impacts resulting from access to a pit by wildlife, migratory birds, domestic animals, or members of the general public…"

Michaels, C., Simpson, J.L, and Wegner, W. 2010. "Fracture Communities, Case studies of the environmental impacts of industrial gas drilling," Riverkeeper, www.riverkeeper.org/wp-content/uploads/2010/09/Fractured-Communities-FINAL-September-2010.pdf (accesed June 26, 2012)

[III] Population impacts caused by habitat loss and degradation

[Peer-reviewed paper]

16) Decline in habitat availability for pronghorn due to gas field development

The Jonah and PAPA (Pinedale Anticline Project Area) gas fields occur in the wintering home range of the pronghorn — the country's longest terrestrial migrant. The habitat choices of female pronghorn demonstrated a fivefold decrease in the use of high-quality habitat patches and the abandonment of areas with the greatest habitat loss and industrial footprint. These results indicate a decline in the availability of high-quality habitat for pronghorn due to the behavioral impacts of habitat alteration associated with gas field development.

Beckmann, J.P., Murray, K., Seidler, R.G., and Berger, J. 2012. Human-mediated shifts in animal habitat use: Sequential changes in pronghorn use of a natural gas field in Greater Yellowstone. Biological Conservation, 147(1):222-3

[Peer-reviewed paper]

17) Regional declines of some songbird species are exacerbated by increased energy development

This study on the responses of the sagebrush bird community to oil and natural gas development in Wyoming found that an increasing density of wells in an area was associated with decreased numbers of Brewer's sparrows, sage sparrows, and vesper sparrows. Interestingly, the abundance of several species was lowest in the oldest gas field, which suggests that the impacts of oil and gas development may compound over time, rather than showing signs of recovery or acclimation.

Gilbert, M.M, and Chalfoun, A.D. 2011. Energy Development Affects Populations of Sagebrush Songbirds in Wyoming. The Journal of Wildlife Management, 75(4):816-824

[Peer-reviewed paper]

18) Dense oil and gas infrastructure adversely impact greater sage-grouse and elk habitat

In the Big Piney-LaBarge field, Wyoming, the overall area of oil and gas infrastructure, including roads, pipelines, pads, and wastepits, covers 4% of the total area; however, the effect of that infrastructure on resident wildlife is much greater. 97% of the total area falls within one-quarter mile of infrastructure, thus impacting all the habitat of the greater sage-grouse in the area. The vast majority of the area also has road densities greater than two miles of road per square mile of the total area, which has adverse effects on elk.

Weller, C., Thomson, J., and Aplet, G. 2002. Fragmenting Our Lands: The Ecological Footprint from Oil and Gas Development. The Wilderness Society, 80221(303):1-30.

[Peer-reviewed paper]

19) Current natural gas development stipulations insufficient to prevent declines of Greater Sage-grouse populations in the Powder River basin

Current rules that prohibit development within a certain distance of sage-grouse mating areas (or "leks") are inadequate to ensure sage-grouse persistence, and may impact their population over larger areas. Seasonal restrictions on drilling and construction do not address impacts caused by loss of sagebrush and incursion of infrastructure that can affect populations over long periods of time. Other indirect effects, such increased livestock grazing due to newly available water or changes in predator abundance due to drilling infrastructure may also negatively impact sage-grouse populations.

Walker, B.L., Naugle, D.E., and Doherty, K.E. 2007. Greater Sage-Grouse Population Response to Energy. Journal of Wildlife Management, 71(8):2644-54.

[Peer-reviewed paper]

20) Young greater-sage grouse have lower reproductive success due to natural-gas infrastructure

Young greater-sage grouse avoid mating near infrastructure of natural-gas fields, and those that were reared near infrastructure had lower annual survival rates and were less successful at establishing breeding territories compared to those reared away from infrastructure.

Holloran, M.J., Kaiser, R.C., and Hubert, W.A. 2010. Yearling Greater Sage-Grouse Response to Energy Development in Wyoming. Journal of Wildlife Management, 74(1):65-72.

[Peer-reviewed paper]
21) Natural gas development leads to habitat degradation and loss for Mule Deer
Increased levels of natural gas exploration, development, and production across the Intermountain West have created a variety of concerns for mule deer (*Odocoileus hemionus*) populations, including direct habitat loss due to road and well-pad construction. Mule deer are less likely to occupy areas in close proximity to well pads than those farther away. There was no evidence of well-pad acclimation by mule deer; rather, they selected areas farther from well pads as development progressed. The distribution of deer shifted toward less-preferred and presumably less-suitable habitats.

Sawyer, H., Nielson, R.M., Lindzey, F., and McDonald, L.L. 2006. Winter Habitat Selection of Mule Deer Before and During Development of a Natural Gas Field. Journal of Wildlife Management, 70(2):396–403.

[Press release]
22) A drilling company illegally filled in an acre of exceptional wetland
"The Department of Environmental Protection inspected a Bloss Township, Tioga County, site in March and found that Seneca Resources Corp. of Brookville had filled nearly one acre of "exceptional value" wetland without authorization, improperly built an impoundment, and caused sediment runoff by failing to institute erosion control best management practices. The unauthorized fill in a wetland and sediment runoff were violations of the Pennsylvania Clean Streams Law and the Dam Safety and Encroachments Act."

Department of Environmental protection, Commonwealth of Pennsylvania, "DEP Fines Seneca Resources Corp. $40,000 for Violations at Marcellus Operation in Tioga County," July 10, 2010, http://www.portal.state.pa.us/portal/server.pt/community/newsroom/14287?id=14655&typeid=1 (accessed June 26, 2012).

[Advocacy group report]
23) Area affected by drilling pads are compounded by edge effects, negatively impacting area-sensitive forest birds
Almost 250 drilling pads on the Marcellus shale of Pennsylvania were studied; an average of 8.8 acres of forest had been cleared for each drilling pad, along with associated infrastructure. After accounting for ecological edge effects, it was found that each drilling station actually affected 30 acres of forest. The study predicted area-sensitive species such as the black-throated blue warbler and the scarlet tanager would be adversely affected by drilling infrastructure.

Johnson, N. 2010. "Pennsylvania energy impacts assessment: Report 1: Marcellus shale natural gas and wind," Nature Conservancy – Pennsylvania Chapter, http://www.tcgasmap.org/media/PA%20Assessment%20of%20Gas%20Impacts%20TNC.pdf, (accessed June 26, 2012)

[News article]

24) Fracking activity threatens fisheries by depleting water levels

"Where… fracking water comes from is one of the major threats to fisheries. Trucking water in is expensive; it's cheaper to run a fire hose to a local source. Because well sites are often in undeveloped highlands, these sources are often small trout streams. Regulations for drawing water vary among the states, and there are questions about how well current regulations protect waterways. There is also a question of enforcement. Four gas companies have already been caught withdrawing water from Pennsylvania trout streams without permission."

Anthony Licata, "Natural gas drilling threatens trout in Pennsylvania (and other Appalachian states)," July 24, 2009, Field and Stream, http://www.troutrageous.com/2009/08/field-stream-pa-natural-gas-drilling.html, (accessed June 27, 2012)

[Non-profit association report]

25) Potential impacts of shale gas development to bats in the northeastern US

A report by Bat Conservation International discusses the hazards posed by fracking to northeastern bat populations, which are already severely threatened by white-nose syndrome. Bat species of particular concern are the federally endangered Indiana Bat, the little brown bat, and two bat species that have been petitioned for Endangered Species Act protection—the northern long-eared bat and the eastern small-footed bat. Threats to bat from fracking include water withdrawal, water contamination and toxic exposure, habitat loss and degradation, and greenhouse gas emissions and associated climate change.

Hein, C. D. 2012. Potential impacts of shale gas development on bat populations in the northeastern United States. An unpublished report submit ted to the Delaware Riverkeeper Network, Bristol, Pennsylvania by Bat Conservation International, Austin, Texas