PHOTOGRAPH © WWW.GARTHLENZ.COM

Community Health and Shale Development Guidebook

VERSION 1.0
NOVEMBER 2015

DANA GOODSON   RESOLVE   KATHLEEN ARCURI

ACKNOWLEDGEMENTS

The authors would like to thank the members of the working group who dedicated their time, insight, and expertise to shape the guidebook into a useful document for readers:

- David Baker, Vice President, Environmental Affairs, Newmont Mining Corporation (retired)
- Stephen D'Esposito, President, RESOLVE
- David Dyjack, Executive Director, National Environmental Health Association
- Aaron Wernham, CEO and President, Montana Healthcare Foundation
- Shell staff also participated on the working group and provided input and feedback

Thank you to Shell Oil Company, Talisman Energy, and the National Association of County and City Health Officials (NACCHO) for providing initial funding and support for the project. RESOLVE also matched these contributions with its own resources.

We also wish to express our deep appreciation for our expert advisors who reviewed the drafts and contributed invaluable comments that improved the quality of the guidebook:

- George Blankenship, Blankenship Consulting LLC
- David R. Brown, ScD, Public Health Toxicologist, Southwest Pennsylvania Environmental Health Project
- John Corra, Director, Wyoming Department of Environmental Quality (retired)
- James Rada, Environmental Health Services Division Director, Jefferson County Public Health, Colorado

Thank you to the members of NACCHO and the participants in the June 11, 2015 review workshop at RESOLVE who took the time to review the draft and offer helpful comments and advice on making it a useful document. Many thanks to the NACCHO team who generously assisted with outreach, including Amy Chang, Jennifer Li, Katie Regan, and Andrew Roszak.

We greatly appreciate those who contributed to the guidebook by sharing advice and resources or by participating in interviews for the case studies: Karen Hacker, Allegheny County Health Department; Katrina Korfmacher, University of Rochester; Cat Lazaroff, Resource Media; Brett Martin, West Park Behavioral Health; Amy Mifflin, Global Collaborations, Inc.; Dennis Schmitz, PEC Safety; John Thorson, California Public Utilities Commission; Jack Ubinger, RESOLVE; and Bill Wren, University of Texas at Austin.

We are forever grateful to our talented and dedicated group of RESOLVE interns, volunteers, and staff, who made this project possible. Many thanks to Tunan Pan for her graphic design and formatting of the document and website; to Erica Bucki, Rachel Crow, Nicole Delcogliano, Brian Goodson, and Meg Perry for research and drafting case studies and other pieces of the guidebook; to Max Ciaglo, Sallie Dehler, Mariah Grubb, Nathan Hahn, Chrissie Juliano, David and Sharon Mason, Rachel Nelson, and Brendon Thomas for review, editing, formatting, and preparing the guidebook for release; to Maya Breitburg-Smith, Sallie Dehler, Kim Rustem, and Alisha Sunderji for assistance with outreach and the review workshop; and to Juliana Birkhoff, Andrew Krieger, and Matthew Mbasu for initial groundwork and research to set up the project.

As RESOLVE has gathered information and resources from a variety of sources and perspectives for this guidebook, the points made may not necessarily reflect the views of those supporting this project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF BOXES

LIST OF ACRONYMS

ANHE	Alliance of Nurses for Healthy Environments
ANRC	Arkansas Natural Resources Commission
APHA	American Public Health Association
API	American Petroleum Institute
ATV	all-terrain vehicle
BLM	Bureau of Land Management
BMP	best management practices
BTEX	benzene, toluene, ethyl benzene, xylene
CAA	Clean Air Act
CBI	confidential business information
CBPR	community-based participatory research
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COGCC	Colorado Oil and Gas Conservation Commission
CWA	Clean Water Act
DEP	Department of Environmental Protection
DOT	Department of Transportation
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GWPC	Ground Water Protection Council
HAP	hazardous air pollutants
HBACV	health-based air comparison values
HIA	health impact assessment
HRQOL	health-related quality of life
IOGCC	Interstate Oil and Gas Compact Commission
IPIECA	International Petroleum Industry Environmental Conservation Association
MSDS	material safety data sheet
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NISA	National Industrial Sand Association
NORM	naturally occurring radioactive materials

NTSB	National Transportation Safety Board
OGP	International Association of Oil and Gas Producers
OPS	Office of Pipeline Safety
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIPA	Pipelines and Informed Planning Alliance
POTW	publicly owned treatment works
RCRA	Resource Conservation and Recovery Act
RFF	Resources for the Future
SDWA	Safe Drinking Water Act
SWPA-EHP	Southwest Pennsylvania Environmental Health Project
TDS	Total Dissolved Solids
TENORM	technologically enhanced, naturally occurring radioactive material
TRB	Transportation Research Board
UIC	Underground Injection Control
USDW	underground sources of drinking water
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTSA	University of Texas—San Antonio
VOCs	volatile organic compounds
WHO	World Health Organization

INTRODUCTION

The Need and Goals for the Guidebook

With the recent boom in shale energy development in the United States, local public health officials and other stakeholders are often seeking information and guidance on the health issues that could accompany development in their communities. In response to that need, RESOLVE's Solutions Network consulted with a multi-stakeholder working group to create this guidebook on the community health issues that can arise as a result of shale energy development.

Our goal is for health officials, community members, and industry representatives to use this guidebook to 1) gain a basic factual understanding of the potential health issues, 2) easily access in-depth resources from a variety of perspectives,[1] and 3) learn about some options for responding to challenges. We hope that the guidebook will become a valued resource that provides a basis for stakeholders to engage in productive conversations around how to address the impacts and manage the benefits of development. To that end, we have included case examples in which companies and communities have worked together to find solutions to community concerns. This is a dynamic guidebook, to be updated as new information and case studies emerge (see the website version at http://solutions-network.org/site-communityhealthguidebook).

1 With the goal of presenting a variety of perspectives, RESOLVE has included information and references from perspectives that may not reflect the perspectives of other stakeholders involved in this project. Therefore, support for or participation in the development of the guidebook does not constitute a blanket endorsement of all resources cited herein.

RESOLVE Approach

As an independent organization with a 30-year history of bringing those with different perspectives together to solve environmental, social, and health problems, RESOLVE took a collaborative approach to this guidebook, soliciting input from local health officials, companies, and nongovernmental organizations (NGOs). We drew on a variety of different perspectives when pulling together the resources for this guide, which you can see in the bibliography organized by source type.

We recognize that some of the health issues associated with shale energy development (such as truck traffic, communicable diseases, impacts on municipal services, and managing revenues in a way that benefits community health) are common to many forms of natural resource development, including mining and conventional oil and gas development. These sectors have long confronted such health challenges; consequently, there is an existing body of information and resources for responding to them. While shale development has some unique characteristics—such as bringing oil and gas development in closer proximity to communities and residences than has been common in the past—this project draws upon these resources where they can be useful in the shale development context.

Project Background & Participants

In 2012, RESOLVE hosted a series of multi-stakeholder conversations around the process of shale development for oil and gas resources. The goal was to learn whether there could be a role for collaborative dialogue and action to address concerns and foster solutions to the challenges involved. One recommendation for useful action emerging from those conversations was the concept of creating a guidebook as a resource for local health officials.

Shell Oil Company and Talisman Energy provided initial funding for the creation of the guidebook. RESOLVE matched these resources with general support funding and has also received support from the National Association of County and City Health Officials (NACCHO).

RESOLVE asked a variety of stakeholders for input on the composition of a working group to guide the project. The working group's mandate was to give guidance and advice to RESOLVE on the development of the guidebook. For a list of working group members and their short biographies, see Appendix B. In addition to the working group, RESOLVE recruited a group of expert advisors to give feedback on particular elements of the guidebook, drawing on their expertise in the fields of public and/or environmental health and their experience with shale development operations.

A team of RESOLVE staff, interns, and volunteers participated in and led the working group; collected the resources for the guidebook; and drafted the guidebook text. We shared the drafts with the working group and the expert advisors for feedback. We also delivered a webinar presentation to NACCHO members and invited their feedback on the draft via an online survey. After revising the document based on the NACCHO comments, we held another feedback workshop for all stakeholders and invited written comments on the draft. We made a concerted effort to take the feedback we received into account in preparing the final version.

Guidebook Organization: How to Use This Guide

The guidebook is organized both by project stage and the typical questions that community stakeholders might have. The six project stages described are initial assessment; leasing and permitting; exploratory drilling; development; production; and project closure and land restoration. Other summaries of the shale development process may differ somewhat in their organization of the project phases. We have described the project steps in this way to highlight aspects of the process that are relevant to local communities and are amenable to community-company engagement and to the implementation of certain management options, such as early planning.

The entry for each stage includes a brief description of what the company does at that stage; what the community might experience; health concerns the community might have; options for managing health-related issues, including case studies describing what others have done; and a set of selected resources. The options for addressing health concerns are organized according to those who could carry them out, including local officials, company representatives, and community leaders. Some options are often-implemented or recommended practices; others have been undertaken at some sites or by some operators; and others are suggestions for stakeholders to consider. These are not, therefore, a standardized set of best practices, but rather a menu of options to give local decision-makers a range of alternatives that might suit their particular community.

Although we have organized the guide by project stage, we recognize that some communities may be host to multiple well sites that can all be in different stages of development. We have therefore included a chart of the entire process with icons indicating the major health issues that are discussed at each stage to facilitate searching for particular topics (see Figure 1). You can also refer to the table of contents for a topic listing. Finally, the icons corresponding to each health issue are highlighted at the beginning of the section where that issue is addressed; they also appear throughout the text whenever the topic is mentioned. In the electronic version of the document, you may click on the icon to move to the next place in the text where that issue arises.

Additional Resources

Have we missed an important document? The resources provided in this guidebook are not intended to constitute a comprehensive list, but rather a starting point that we can build upon as new resources emerge. If you know of useful resources or case studies that are not listed here, please let us know by contacting RESOLVE at communityhealthguide@resolv.org.

Health Considerations of Shale Development

WHAT IS SHALE DEVELOPMENT?

First, a word on terminology. We are using the term "shale development" to refer to the entire process of seeking and extracting oil and/or natural gas reserves from shale deposits using a combination of horizontal drilling and high-volume hydraulic fracturing techniques, often known as "fracking." The combination of these techniques allows oil and gas operators to reach previously inaccessible "tight," or low-permeability, geologic formations like shale deposits, allowing the trapped resources to flow into the well and up to the surface for capture.

While these techniques have been in use in the oil and gas industry for decades, they have only recently improved to the point where the exploitation of shale formations has become feasible for the industry. Originally used for natural gas, operators have adopted horizontal drilling and hydraulic fracturing techniques in oil fields, allowing both oil and natural gas production in the United States to skyrocket.[2] After becoming the world's largest producer of natural gas in 2010, the United States took the lead in petroleum production in 2013.[3]

This new oil and gas boom has also brought development to regions where extensive shale deposits—known as *shale plays*—are present. A 2013 *Wall Street Journal* analysis determined that over 15 million Americans now live within a mile of a shale well drilled since 2000.[4] Many of these communities are unfamiliar with the implications of shale development, with its potential challenges and benefits—an information gap that this guidebook aims to help fill.

A PUBLIC HEALTH APPROACH TO SHALE DEVELOPMENT

According to the American Public Health Association (APHA), "Public health promotes and protects the health of people and the communities where they live, learn, work and play."[5] The focus of public health professionals is on prevention and wellness, anticipating and avoiding risks to keep people healthy. Public health practitioners hail from a range of fields, including not only government public health officials and public health physicians and nurses, but also first responders, researchers, community planners, and public policymakers.

To determine potential population health risks, practitioners and/or researchers take into account both the health effects of a particular ***stressor***, such as air pollution or psychosocial stress, and the potential exposure of the population to that stressor. They consider possible ***exposure pathways***, or the means through which people can be exposed to a stressor. In the case of air pollution and shale development, for example, exposure pathways include fugitive emissions of pollutants from wells and other project infrastructure or emissions from increased truck traffic, such as road dust and diesel exhaust. Furthermore, public health practitioners are concerned with impacts on vulnerable subpopulations, such as the elderly, pregnant women, children, and people with existing respiratory conditions like asthma. Finally, they might also consider the cumulative effects of a number of different stressors on a population.

When attempting to determine if there is a link between possible environmental exposures and public health risks, researchers can

2 Geological Society of America, "GSA Critical Issue: Hydraulic Fracturing," 8, accessed December 10, 2014, http://geosociety.org/criticalissues/hydraulicFracturing/documents/GSA-HydroFracking.pdf

3 Grant Smith, "U.S. Seen as Biggest Oil Producer After Overtaking Saudi Arabia," ***Bloomberg News*** (July 4, 2014), http://www.bloomberg.com/news/2014-07-04/u-s-seen-as-biggest-oil-producer-after-overtaking-saudi.html

4 Russell Gold and Tom McGinty, "Energy Boom Puts Wells in America's Backyards," ***The Wall Street Journal.com*** (October 25, 2013), http://www.wsj.com/articles/SB10001424052702303672404579149432365326304

5 American Public Health Association, "What Is Public Health?" accessed December 8, 2014, https://www.apha.org/what-is-public-health

draw on several types of investigative methods, each with different strengths and limitations in terms of answering questions from a public health standpoint. These different study types are described below:

- **Environmental epidemiologic** studies are generally observational in nature and investigate the possible links between environmental stressors and health outcomes. Environmental epidemiologic studies can be **descriptive**—such as case reports or studies of a disease cluster—or **analytic**, which involve more individually detailed data and control populations. Descriptive studies are generally considered most useful for generating hypotheses and analytic studies for testing hypotheses. Typical examples of analytic studies are **cohort studies**, which follow a group of people with a particular exposure over the long term to determine the consequences, and **case-control studies**, which study past exposures of two groups of people—those who have a particular health outcome (or case, such as breast cancer) and those who do not (control group).[6] Limitations of environmental epidemiologic studies include the difficulty of ascertaining the relationship of a health outcome to a particular exposure given the multiplicity of factors in real-world situations. In addition, given the potentially long period between exposure to a toxicant and the development of certain diseases, it can be difficult to identify and measure exposure during the most critical time periods.[7]
- **Toxicology studies** involve experiments using animal alternatives and animals to evaluate potential hazards of a chemical or other stressor. These studies provide indicators of potential hazards, and are used by regulatory authorities, industry, and others to assess potential hazards to humans and the environment.
- **Exposure assessments** quantify the magnitude, frequency, and duration of human exposure to a contaminant in the environment. It is step 3 of the 4-step process of risk assessment and attempts to answer these questions: "How much of the stressor are people exposed to during a specific time period? How many people are exposed?"[8] According to the U.S. Environmental Protection Agency (EPA), "Exposure assessment considers both the *exposure pathway* (the course an agent takes from its source to the person(s) being contacted) as well as the *exposure route* (means of entry of the agent into the body)."[9]

In addition to these investigative methods, **surveys and self-reports** describe the health status of residents in areas where environmental changes are taking place. While subjective reports cannot provide reliable evidence of impacts or causality, they can serve as a useful indicator of issues for further research.[10]

6 National Research Council, *Environmental Epidemiology, Volume 2: Use of the Gray Literature and Other Data in Environmental Epidemiology* (Washington, DC: National Academies Press, 1997), 13–19, http://www.nap.edu/openbook.php?record_id=5804&page=13.

7 The Breast Cancer Fund, "Environmental Epidemiological Studies," http://www.breastcancerfund.org/clear-science/research-methods/enviro-epidemiological.html (accessed 8/15/15).

8 U.S. Environmental Protection Agency, "Step 3: Exposure Assessment," last updated 7/31/12, http://www.epa.gov/risk_assessment/exposure.htm.

9 U.S. Environmental Protection Agency, "Step 3: Exposure Assessment," last updated 7/31/12, http://www.epa.gov/risk_assessment/exposure.htm.

10 Vera Bonnet, *Shale Extraction and Public Health: A Resource Guide* (2013), Shale and Public Health Committee, League of Women Voters of Pennsylvania, pp. 2-3, http://shale.palwv.org/wp-content/uploads/2013/12/846114-League-of-Women-Voters-Shale-Resource-Guide.pdf.

RECENT LITERATURE ON PUBLIC HEALTH RISKS & SHALE DEVELOPMENT

In three recent reviews of the existing research on the public health risks of shale development, researchers concluded that there is a "compelling need" for more research with regard to the human health impacts of drilling operations and the level of human exposure to potential stressors.[11, 12, 13] In a December 2014 review of the scientific literature published in *Reviews on Environmental Health*, the authors found that the chemicals used in shale development and found near well sites can present risks to human reproduction and development and there is an urgent need for studies to determine actual exposures. The Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations, funded by the National Institute of Environmental Health Sciences (NIEHS), recommended that research be conducted on a number of topics, including on potential local air and water quality impacts (see Stage 3 for a discussion of potential air and water quality impacts). The Working Group also urged that affected communities be engaged in the design and implementation of the studies (community-based participatory research, or CBPR). The authors of the three reviews emphasized the need for 1) gathering baseline data before shale development activities begin and 2) conducting comprehensive epidemiologic studies in order to answer key questions on potential public health impacts.

Natural Gas Well Fracking. Photo by Daniel Foster under Creative Commons BY-NC-SA 2.0.

11 John L. Adgate, Bernard D. Goldstein, and Lisa M. McKenzie, "Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development," Environmental *Science and Technology* (February 10, 2014), http://www.r-cause.net/uploads/8/0/2/5/8025484/adgate_et_al_2014_ph_risks.pdf.

12 Trevor M. Penning, Patrick N. Breysse, Kathleen Gray, Marilyn Howarth, and Beizhan Yan, "Environmental Health Research Recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Uncon ventional Natural Gas Drilling Operations," *Environmental Health Perspectives* (July 18, 2014), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4216169/.

13 Ellen Webb et al., "Developmental and Reproductive Effects of Chemicals Associated with Unconventional Oil and Natural Gas Operations," *Reviews on Environmental Health*, Volume 29, Issue 4, Pages 307–318, December 5, 2014, http://www.degruyter.com/view/j/reveh.2014.29.issue-4/reveh-2014-0057/reveh-2014-0057.xml?format=INT.

Health Issues Addressed in This Guidebook

This guidebook is focused on the potential health effects of shale development for local communities. We have made an effort to be comprehensive in our discussion of the relevant health issues, including both the positive and negative impacts. The icons below represent the following topic areas covered in the guidebook:

AIR QUALITY—including health effects of potential air contaminants and the potential exposure pathways of fugitive emissions; diesel-powered trucks and machinery; venting and flaring; evaporation pits; dehydration units; compressor stations; silica sand; and road dust

WATER QUALITY—including the composition of fracturing fluids; the components of produced water; and the potential exposure pathways of seismic testing, spills, leaks, groundwater contamination, wastewater disposal, and orphaned wells

DISEASES—including communicable diseases and mental health impacts

WATER QUANTITY—including sourcing, U.S. water law, and regulation and permitting

SAFETY ISSUES—for local communities—meaning threats to physical safety, such as injuries and death—including the potential for blowouts (i.e., sudden, uncontrolled releases of gases or fluids), explosions, chemical spills, fires, exposure to high levels of airborne chemicals, vehicular accidents, and induced seismicity

HEALTH-RELATED QUALITY OF LIFE—including the effects of economic and social changes; impacts on local infrastructure and services; and changes in the physical environment such as noise, lighting, and the viewshed (see Box 1)

BOX 1. HEALTH-RELATED QUALITY OF LIFE

Some of the impacts of shale development that are most salient to local communities are those in the area of **health-related quality of life** (HRQOL or, for the purposes of this guidebook, "quality of life"). The World Health Organization (WHO) defines health as "a state of complete physical, mental, and social well-being, not merely the absence of disease..."[14] Well-being and quality of life must therefore be considered in a discussion of individual and community health. According to the U.S. Centers for Disease Control and Prevention (CDC), HRQOL is "an individual's or group's perceived physical and mental health over time." This multidimensional concept has been shown to be an important predictor of health outcomes. HRQOL data can be used to determine health needs and guide interventions.[15]

In order to measure quality of life, the WHO has identified the six domains in the table on the right as important to assess.[16] Shale development projects have the potential to affect many, if not all, of these domains. Given the potential impacts on the economy, infrastructure, and physical environment of a community, these projects can influence the "environment" domain in particular. The aspects of HRQOL that we have focused on in this guidebook are social relationships; financial resources and opportunities for acquiring new information and skills (economic impacts); and the physical environment, including pollution, noise, traffic, lighting, and viewshed alterations. In this guidebook, the HRQOL concept is used as a framework for organizing these types of positive and negative community impacts and considering their potential relation to health.

14 Programme on Mental Health, World Health Organization Division of Mental Health and Prevention of Substance Abuse, ***WHOQOL Measuring Quality of Life*** (WHO/MSA/MNH/PSF/97.4, 1997), 1, http://www.who.int/mental_health/media/68.pdf.

15 Centers for Disease Control and Prevention, "Health-Related Quality of Life: HRQOL Concepts," last modified March 17, 2011, http://www.cdc.gov/hrqol/concept.html.

16 Programme on Mental Health, World Health Organization Division of Mental Health and Prevention of Substance Abuse, ***WHOQOL Measuring Quality of Life*** (WHO/MSA/MNH/PSF/97.4, 1997), 3-4, http://www.who.int/mental_health/media/68.pdf.

TABLE 1. DOMAINS OF HEALTH-RELATED QUALITY OF LIFE

Domain	**Facets incorporated within domains** Overall Quality of Life and General Health
1. Physical health	Energy and fatigue Pain and discomfort Sleep and rest
2. Psychological	Bodily image and appearance Negative feelings Positive feelings Self-esteem Thinking, learning, memory and concentration
3. Level of Independence	Mobility Activities of daily living Dependence on medicinal substances and medical aids Work capacity
4. Social relationships	Personal relationships Social support Sexual activity
5. Environment	Financial resources Freedom, physical safety and security Health and social care: accessibility and quality Home environment Opportunities for acquiring new information and skills Participation in and opportunities for recreation/leisure Physical environment (pollution/noise/traffic/climate) Transport
6. Spirituality / Religion / Personal Beliefs	Spirituality / Religion / Personal Beliefs

Limitations in Scope

Given our focus on local communities and health officials, we have mentioned—but not detailed—health concerns for workers at shale development sites, as worker-related health and safety issues fall under the purview of the federal Occupational Safety and Health Administration (OSHA) and the National Institute for Safety and Health (NIOSH) at the Centers for Disease Control and Prevention (CDC). We have also not addressed issues that are national or international in scope, such as energy policy and climate change.

Finally, we have reviewed many different types of sources with the goal of conveying the health considerations that may arise with shale development. These health issues will not occur in every case and will depend on a variety of factors, including—but not limited to—the size and character of the community; the geography of the site; the stage and scale of development; and the relationship between the community, the industry, and local officials. We have therefore not attempted to describe the likelihood of the occurrence of a particular health effect, but rather to describe the range of possible effects to allow readers to take them into account when considering potential impacts in their own communities.

General Resources on Community Health & Shale Development

SHALE DEVELOPMENT

- Frackmap (http://worldmap.harvard.edu/maps/FrackMap) is a mapping tool hosted by Harvard University that includes the locations of U.S. shale plays and permitted wells. Other data layers, such as the principal aquifers in the U.S., can be displayed and/or uploaded into the tool.
- The Geological Society of America website (http://www.geosociety.org/criticalissues/hydraulicFracturing/index.asp) has "critical issue" pages dedicated to an overview of the shale development process, its history, and some potential environmental issues, including water quality, water use, and induced seismicity.
- National Energy Technology Laboratory, "Modern Shale Gas Development in the United States: An Update" (September 2013), prepared for the U.S. Department of Energy, http://www.netl.doe.gov/File%20Library/Research/Oil-Gas/shale-gas-primer-update-2013.pdf. This update to the 2009 "Modern Shale Gas Development in the United States: A Primer," contains an overview of U.S. natural gas resources, the technology used to develop shale gas, and the existing regulatory framework; it also describes some potential environmental and community impacts, including water quality, water quantity, air quality, and induced seismicity.

PUBLIC HEALTH

- John L. Adgate, Bernard D. Goldstein, and Lisa M. McKenzie, "Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development," *Environmental*

Science and Technology (February 10, 2014), http://www.r-cause.net/uploads/8/0/2/5/8025484/adgate_et_al_2014_ph_risks.pdf. This article reviews the existing literature on public health and shale development, concluding that significant gaps exist and more research is needed. It also describes potential exposure pathways and health effects from the chemicals used in shale operations.

- International Association of Oil and Gas Producers (OGP), "Strategic Health Management: Principles and Guidelines for the Oil and Gas Industry" (June 2000), http://www.ogp.org.uk/pubs/307.pdf. OGP is an organization intended to give oil and gas producers a place to share best practices with others in the industry. OGP has developed guidance on planning for health throughout the stages of oil and gas operations.
- National Association of County and City Health Officials (NACCHO), "Hydraulic Fracturing: What Local Health Departments Need to Know," Issue Brief (Washington, DC: November 2014), http://eweb.naccho.org/eweb/DynamicPage.aspx?WebCode=proddetailadd&ivd_qty=1&ivd_prc_prd_key=3a169831-6bc6-4605-a89f-a61b76a7c573&Action=Add&site=naccho&ObjectKeyFrom=1A83491A-9853-4C87-86A4-F7D95601C2E2&DoNotSave=yes&ParentObject=CentralizedOrderEntry&ParentDataObject=Invoice%20Detail. This issue brief presents a general overview of shale development and the ways that local health departments can mitigate potential harm from the process.
- Trevor M. Penning, Patrick N. Breysse, Kathleen Gray, Marilyn Howarth, and Beizhan Yan, "Environmental Health Research Recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations," *Environmental Health Perspectives* (July 18, 2014), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4216169. This article summarizes the working group's recommendations for research on the public health impacts of shale development, including on water quality, air quality, epidemiologic research, and CBPR methods.
- Ellen Webb, Sheila Bushkin-Bedient, Amanda Cheng, Christopher D. Kassotis, Victoria Balise and Susan C. Nagel, "Developmental and Reproductive Effects of Chemicals Associated with Unconventional Oil and Natural Gas Operations," *Reviews on Environmental Health* 29, no. 4 (December 2014): 307–318, http://www.degruyter.com/view/j/reveh.2014.29.issue-4/reveh-2014-0057/reveh-2014-0057.xml?format=INT. This review discusses the chemicals used in shale development, their health effects, and potential routes of exposure. It also covers potential reproductive and developmental impacts, particularly during vulnerable periods of pre-natal and post-natal development. It concludes there is an urgent and compelling need for more research, including biomonitoring of humans and animals and epidemiological studies.

FIGURE 1. SHALE DEVELOPMENT TIMELINE AND LISTING OF TOPICS DISCUSSED

initial assessment 1

The company is assessing the resource potential of the area.
Estimated timeframe (varies): Several weeks to months

leasing & permitting 2

The company is working to obtain mineral leases and permits to begin the drilling process.
Estimated timeframe (varies): Months to 2 years

exploratory drilling 3

The company has completed preliminary testing and is drilling a well to determine whether to fully develop the site.
Estimated timeframe (varies): 2–3 years

development & production 4

The company has decided to develop the site, builds more wells, and produces oil or gas for market.
Estimated timeframe (varies): 3–5 years for development; 10–50 years for production

project closure & land restoration 5

The wells are past production, so the company begins to plug the wells and restore the area.
Estimated timeframe (varies): Months to 2 years

STAGE 1
INITIAL ASSESSMENT

HEALTH ISSUES
IN THIS SECTION

What is the company doing at this stage?[1]

In the early stages of shale development, a company—or possibly several companies—determines whether or not to develop potential oil and gas reserves in your area. Before making the decision to pursue development at a site, companies first take the time and invest resources in studying and understanding the area.

In an area where potential oil and gas reserves have not yet been exploited, a variety of oil and gas operators, ranging from small companies to multinational corporations, might be seeking to assess the resources. At this stage, the identity of the operator is often not apparent because companies do not wish to alert their competitors to their possible interest in the area. Operators therefore hire a third-party surveyor to conduct early exploration activities on their behalf. The third-party survey company might be providing information to one company, several different companies, or conducting their own exploratory surveys in the hope of later selling the information to an oil and gas operator.

Oil and gas reserves are found almost exclusively in sedimentary rocks contained within certain geologic structures. To determine whether such structures are present, the survey company may undertake the following geophysical exploration activities:

- reviewing the historical records of the area under investigation
- reviewing geologic field maps, previous well drilling data, and coring information
- conducting field work to examine the geologic properties on the surface
- performing subsurface remote sensing, using photography, LiDAR, and infrared images to locate the target geologic structures
- conducting seismic testing

The most common geophysical exploration method is seismic testing. If sufficient geologic and/or geophysical data is already available in your area, however, the operator may forgo additional seismic testing. This test does not confirm the presence of oil or gas deposits, but rather indicates a rock type that is likely to contain them.

Seismic tests artificially generate sound waves picked up by receivers (geophones) to create a 2- or 3-dimensional subsurface map. To create the sound waves, the company can 1) employ *thumper trucks* (which drop heavy weights on roads or other surfaces), 2) detonate explosive charges (a specialized form of dynamite) deep underground, or 3) use a ground-shaking device.

Depending on state and local requirements, the seismic survey company may be required to obtain a U.S. Department of Transportation (DOT) permit for the transport of heavy loads. Additionally, the company might need to post a bond to hedge against any damages to roads or other public infrastructure. Other possible requirements include employing traffic officers, posting safety signage, and notifying nearby residents of the planned seismic survey work.

1 The sections on company practice were based on descriptions in several documents, including Ground Water Protection Council and ALL Consulting, ***Modern Shale Gas in the United States: A Primer***; National Energy Technology Laboratory, ***Modern Shale Gas Development in the United States: An Update***; United States Government Accountability Office, ***Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks***; Shell Oil Company, "Life of an Onshore Well" (graphic animation); Geological Society of America website "GSA Critical Issue: Hydraulic Fracturing"; and Earthworks, ***Oil and Gas at Your Door? A Landowner's Guide to Oil and Gas Development***. These sections were then refined through interactions with industry representatives and consultants via document edits, Work Group guidance, and input in the June 11, 2015 multi-stakeholder workshop.

If the company wishes to survey on private land, it is often necessary to obtain permission from the property owner. In some cases, the company provides nominal compensation to those who sign permission slips for seismic survey work on their property. Not all jurisdictions require companies to obtain landowner permission, however.[2] For information on the regulations in your state governing exploration, contact the relevant state agency (see Table 2 for a list of agencies).

What might my community experience?

In the beginning, some of the initial assessment activities might not be noticeable to residents. It is common to spot a team of geologists taking pictures and making field observations. Seismic tests, on the other hand, are likely to draw attention. If using thumper or vibrator trucks, the survey team may employ as many as 5–6 trucks[3] accompanied by personal vehicles. Depending on the size of the sample area, the testing takes place over a period of days to months. A seismic survey team can cover several miles a day on average, and the surveys typically cover 50–100 square miles or more.[4]

If the survey company plans to conduct seismic tests on private property, the company will contact landowners to notify them when it will take place and/or request their permission. Company personnel will first survey the property to stake out the exploration area and to mark areas for the survey team to avoid. Depending on the type of survey, they might temporarily place geophones (a receiver for the sound waves generated by the testing), data boxes, or cables on the property. The company might cut narrow lanes through forested areas or brush for the survey equipment. If using explosive charges, the company drills small diameter *shot holes* that can be up to150 feet deep (although they are not usually more than 80 feet deep).[5]

During seismic testing, approximately 40 members of the survey team will set up the seismic recording equipment, generate the sound waves—either by moving a thumper or vibrator truck through the area or detonating the charges—and record the data. After testing is complete, the company should remove all the equipment and materials and plug any shot holes. Depending on the type of test, the equipment might be present on the property for a few days to 3–4 weeks.

WILL SEISMIC EXPLORATION ACTIVITIES CAUSE ANY DAMAGE? IF SO, WHO WILL COVER REPAIRS?

Due to their weight, seismic survey trucks can damage roads and bridges or cause surface disturbance if the infrastructure is not well-maintained or cannot accommodate heavy loads (even DOT-permitted ones). Such disturbance could possibly lead to erosion and sedimentation of surface waters.[6]

If the surveyor uses underground dynamite charges instead of

2 "Can You Conduct a Seismic Survey without a Landowner's Permission?" Courthousedirect.com, http://info.courthousedirect.com/blog/bid/315123/Can-You-Conduct-A-Seismic-Survey-Without-the-Landowner-s-Permission (August 14, 2013).

3 Rigzone, "Training: How Does Land Seismic Work?", accessed September 20, 2015, http://www.rigzone.com/training/insight.asp?insight_id=301&c_id=18.

4 John B. McFarland, "How Do Seismic Surveys Work?" Oil and Gas Lawyer Blog (April 15, 2009), http://www.oilandgaslawyerblog.com/2009/04/how-do-seismic-surveys-work.html.

5 Mark R. Milligan, "What Are Seismic Surveys and How Much 'Shaking' Do They Create?" Utah Geological Survey website, http://geology.utah.gov/map-pub/survey-notes/glad-you-asked/what-are-seismic-surveys (July 3, 2004).

6 *Earthworks, Oil and Gas at Your Door? A Landowner's Guide to Oil and Gas Development* (Durango, Colorado: Oil and Gas Accountability Project, 2005), 6–13, http://www.earthworksaction.org/library/detail/oil_and_gas_at_your_door_2005_edition#.UxjPSj9dWSo.

trucks, the detonations take place far enough underground that they do not impact the surface. Company ATVs and other vehicles can also cause surface disturbance or leave track marks.

Companies must comply with state regulations covering exploration activities, which often include requirements to post a bond for any damages and to plug shot holes, among other provisions. Companies are required to compensate public or private property owners for any damages or the impacts of "non-normal" use that takes place during seismic surveying.[7] If landowners sign a permit to access their property, there may be provisions pertaining to any damages sustained. For information on the regulations in your state, contact the state oil and gas regulatory agency (see Table 2).

COULD SEISMIC TESTING CAUSE EARTHQUAKES?

Seismic testing has long been a feature of traditional oil and gas exploration, preceding the recent boom in shale development, and this aspect of the process has not been linked to earthquakes. The amount of explosives used in seismic surveying (approximately 10–20 pounds), is much less than would be needed to generate seismic waves similar to a 1.5 earthquake on the Richter scale (320 pounds).[8] Vibrator trucks generate even less energy than explosives.[9] For more on the topic of seismicity, see the safety section in Stage 4.

What health considerations are there?

WATER QUALITY

There could be some localized water quality impacts as a result of seismic exploration activities. As mentioned above, the creation of survey lines or vehicle track marks can cause surface disturbance. If not restored, they can lead to erosion and runoff into waterways. Earthworks, a nonprofit advocacy organization working to protect communities and the environment from the adverse impacts of mineral and energy development, indicates a few considerations for private well owners with regard to seismic testing. For example, private well water could be affected if the shot holes reach the water table and are not properly plugged.[10] In this case, the shot holes could provide a pathway for contaminants to the groundwater supplying the wells. Earthworks also notes that underground seismic explosions could impact subsurface water flow and pressure, potentially reducing well water supply.[11]

7 "Can You Conduct a Seismic Survey without a Landowner's Permission?" Courthousedirect.com, http://info.courthousedirect.com/blog/bid/315123/Can-You-Conduct-A-Seismic-Survey-Without-the-Landowner-s-Permission (August 14, 2013).

8 Mark R. Milligan, "What Are Seismic Surveys and How Much 'Shaking' Do They Create?" Utah Geological Survey website, http://geology.utah.gov/map-pub/survey-notes/glad-you-asked/what-are-seismic-surveys (July 3, 2004). Earthquakes of magnitude 1.5 to 2 on the Richter scale are rarely felt.

9 Mark R. Milligan, "What Are Seismic Surveys?"

10 Earthworks, ***Oil and Gas at Your Door?*** pp. I-7.

11 Earthworks, ***Oil and Gas at Your Door?*** pp. I-7.

QUALITY OF LIFE

Initial exploration activities can begin to affect the physical environment of your community, particularly if you live in a rural area unaccustomed to traffic. During the few weeks that these activities take place, heavy trucks and convoys of other vehicles could be present on local roads, and the accompanying traffic and noise, although temporary, could affect residents' quality of life.

When people in your community become aware of the potential for shale development in the area, they might begin to form expectations in anticipation of both the costs and benefits of that development. At this stage of early exploration, however, companies are still highly uncertain as to whether they will find sufficient mineral deposits to make development worthwhile.

What can be done to address health concerns? What have others done?

LOCAL OFFICIALS

Once exploration activities start to become apparent, community members will likely start to form expectations around potential shale development. It can be useful at that point to put the activities in context. Local officials, operators, and seismic survey company representatives can assist by notifying residents and community leaders that surveying will take place, providing information on what to expect, and clarifying the likelihood that initial exploration activities will lead to next steps—and if so, on what timeframe. These topics could be addressed at local town or county board meetings, local planning or zoning hearings, or an informational open house.

Given that there can be a number of operators and seismic survey companies exploring an area, it is important to make an effort to include all of them in the planning and execution of community outreach activities.

INDUSTRY REPRESENTATIVES

The American Petroleum Institute (API), an industry association, has produced a set of guidelines for oil and gas operators on how to communicate with and engage local stakeholders around their projects. The document notes that many operators are already following practices similar to those described in the guidelines, and that its recommendations are "typical and reasonable" under normal operating circumstances.[12] The guidelines offer engagement options for all phases of the project development cycle, including the initial entry phase. Acknowledging that different operators can be exploring the same area, the guidelines suggest that companies coordinate with each other when reaching out to local stakeholders.

The guidelines emphasize early two-way communication and proactive outreach to stakeholders, which companies should maintain throughout the life of the project. Other key

12 American Petroleum Institute (API), Community Engagement Guidelines, ANSI/API Bulletin 100-3, first edition (July 2014), http://www.api.org/globalitems/~/media/Files/Policy/Exploration/100-3_e1.pdf

recommendations for this phase include setting professional standards for both contractors and employees, providing training, and conveying company guidelines for safety, environmental, and health practices. It is also important to manage the expectations of stakeholders and contractors, especially given that the project often does not proceed past this stage. Companies should therefore develop a strategy for withdrawal and communicating to stakeholders about that scenario, even in this initial phase.

The seismic survey company can undertake a number of actions to reduce community impact. The API guidelines encourage operators to work with their contractors as well as local agencies and officials to promote road safety and good traffic management.[13] To avoid interfering with regular traffic patterns, for example, the seismic survey team often meets with local officials to learn about peak travel times in the area, school bus routes, and the optimal areas for parking. They also meet with the official in charge of local infrastructure to learn which roads and bridges to avoid or to upgrade prior to seismic survey work.

Some survey companies use the following methods to reduce the impacts of their activities:

- obtaining permission from landowners before conducting seismic tests on private property
- establishing a safe buffer zone between seismic testing activities and potentially sensitive structures or objects
- when clearing paths (lines) for seismic equipment, cutting narrow lanes, including slight bends to prevent predators having an easy view of their prey; avoiding valuable trees; and avoiding the creation of ruts
- plugging shot holes on both ends
- removing all equipment, materials, stakes and waste after testing is done
- repairing any rutting or surface disturbance that may have occurred

Finally, companies might also discuss their survey plans with landowners to help them avoid sensitive or valuable areas. The surveyor might seek to conduct seismic tests as far from surface waters as possible to reduce the potential for erosion and runoff into bodies of water.

LANDOWNERS

Earthworks has developed a handbook for landowners in areas where oil and gas development is taking place. Among other recommendations, Earthworks suggests that landowners discuss the placement of the equipment or the location of the seismic testing activities with the company before the tests take place to minimize any surface disturbance. If property owners are using a well for drinking water, Earthworks advises landowners to consider testing the water before and after seismic exploration on their property to establish a baseline and allow them to note any changes that take place. For more on potential impacts and tips for landowners, see the resources section below.

13 API, Community Engagement, pp. 6.

What resources can provide further information?

STAKEHOLDER ENGAGEMENT

- American Petroleum Institute, "Community Engagement Guidelines," ANSI/API Bulletin 100-3, first edition (July 2014), http://www.api.org/news-and-media/news/newsitems/2014/july-2014/~/media/Files/Policy/Exploration/100-3_e1.pdf. The industry association has released a set of recommendations for oil and gas companies on communication and stakeholder engagement activities around oil and gas development projects.
- International Council on Mining and Metals, "Community Development Toolkit," (July 20, 2012), http://www.icmm.com/news-and-events/news/articles/icmm-presents-updated-community-development-toolkit. The toolkit contains guidance and tools for community development, relationship-building, planning, assessment, management, and monitoring and evaluation. Developed for the mining industry, these tools may be adapted to the oil and gas sector.

WATER QUALITY MONITORING

- Garfield County, Colorado, Department of Public Health, "Water Treatment Decision Guide," http://www.garfield-county.com/public-health/documents/WaterTreatmentGuide_MECH.pdf. This guide gives guidance to well owners on how to interpret the results of well water quality laboratory reports and gives guidance on what actions to take in light of the results.
- Penn State Extension, Penn State College of Agricultural Sciences website, "Drinking Water," http://extension.psu.edu/natural-resources/water/marcellus-shale/drinking-water. The Penn State Extension website contains information, recorded webinars, and resources on how to test private well water and interpret the results.
- Southwest Pennsylvania Environmental Health Project website, "Water," http://www.environmentalhealthproject.org/health/water. The Southwest Pennsylvania Environmental Health Project (SWP-EHP) is a nonprofit environmental health organization that offers support to Southwestern Pennsylvania residents who are concerned about the health impacts of gas drilling. The website contains guidelines, step-by-step guidance, and tips for testing private well water.

QUALITY OF LIFE

- Canadian Association of Petroleum Producers, "What to Expect When You're Expecting a Well" (June 2014) http://www.capp.ca/publications-and-statistics/publications/250098. This brochure for landowners gives an overview of the lifecycle of a typical well and answers questions that landowners may have. The regulations and agencies mentioned are Canadian.
- Earthworks, ***Oil and Gas at Your Door? A Landowner's Guide to Oil and Gas Development*** (Durango, Colorado: Oil and Gas Accountability Project, 2005), http://www.earthworksaction.org/library/detail/oil_and_gas_at_your_door_2005_edition#.UxjPSj9dWSo. Earthworks is an advocacy organization working on natural resource extraction issues. This handbook describes the stages of oil and gas development; potential impacts of oil and gas development on health, safety, and quality of life; alternative technologies and practices; the legal and regulatory issues; tips for landowners; and landowner stories. For more details on seismic exploration and tips for landowners, see pp. I-6 – I-7.

TABLE 2. STATE OIL AND GAS REGULATORY AGENCIES

Note: States that are not listed do not have a regulatory agency specific to oil and gas. In some states, other agencies, such as geological survey agencies, could be useful sources of scientific information related to shale development.

State	Oil and Gas Regulatory Agencies	Contact Information
Alabama	State Oil and Gas Board	http://www.ogb.state.al.us Phone: 205-349-2852
Alaska	Alaska Oil & Gas Conservation Commission	http://doa.alaska.gov/ogc/Regulations/RegIndex.html Phone: 907-279-1433
	Department of Natural Resources, Division of Oil and Gas	http://dog.dnr.alaska.gov Phone: 907-269-8800
Arizona	Oil and Gas Conservation Commission	http://www.azogcc.az.gov Phone: 520-770-3500
Arkansas	Oil and Gas Commission	http://www.aogc.state.ar.us Phone: 479-646-6611
California	Department of Conservation, Division of Oil, Gas and Geothermal Resources	http://www.consrv.ca.gov/dog/Pages/Index.aspx Phone: 916-445-9686
Colorado	Colorado Oil and Gas Conservation Commission	http://cogcc.state.co.us Phone: 303-894-2100

Florida	Department of Environmental Protection	http://www.dep.state.fl.us/water/mines/oil_gas/index.htm Phone: 850-245-8336
Georgia	Department of Natural Resource, Environmental Protection Division	http://epd.georgia.gov Phone: 888-373-5947
Idaho	Idaho Department of Lands	http://www.idl.idaho.gov/oil-gas/index.html Phone: 208-334-0200
Illinois	Department of Natural Resources, Oil and Gas Resource Management	http://www.dnr.illinois.gov/oilandgas/Pages/default.aspx Phone: 217-782-7756
Indiana	Department of Natural Resources, Division of Oil and Gas	http://www.in.gov/dnr/dnroil Phone: 317-232-4055
Kansas	Kansas Corporation Commission, Conservation Division	http://www.kcc.state.ks.us/conservation/index.htm Phone: 785-271-3100
Kentucky	Department of Natural Resources, Division of Oil and Gas	http://oilandgas.ky.gov/Pages/Welcome.aspx Phone: 502-573-0147
Louisiana	Department of Natural Resources, Office of Conservation	http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=301&ngid=1 Phone: 225-342-5540
Maryland	Maryland Department of the Environment	http://www.mde.maryland.gov/PROGRAMS/LAND/Pages/index.aspx Phone: 410-537-3000

Michigan	Department of Environmental Quality, Office of Oil, Gas and Minerals	http://www.michigan.gov/deq/0,4561,7-135-3306_57064---,00.html Phone: 517-284-6823
Mississippi	Mississippi Oil and Gas Board	http://www.ogb.state.ms.us Phone: 601-576-4900
Missouri	Department of Natural Resources, Geological Survey	http://www.dnr.mo.gov/geology/geosrv/ogc/index.html Phone: 573-368-2143
Montana	Board of Oil and Gas	http://www.bogc.dnrc.mt.gov Phone: 406-656-0040
Nebraska	Nebraska Oil & Gas Conservation Commission	http://www.nogcc.ne.gov Phone: 308-254-6919
Nevada	Division of Minerals	http://minerals.nv.gov/Programs/OandG Phone: 775-684-7040
New Mexico	Energy, Minerals and Natural Resources Department, Oil Conservation Division	http://www.emnrd.state.nm.us/OCD Phone: 505-476-3458
New York	Department of Environmental Conservation, Division of Mineral Resources	http://www.dec.ny.gov/about/636.html Phone: 518-402-8056
North Carolina	Division of Energy, Mineral and Land Resources	http://portal.ncdenr.org/web/lr/oilgas Phone: 919-707-9234

North Dakota	Industrial Commission, Department of Mineral Resources, Oil and Gas Division	https://www.dmr.nd.gov/oilgas Phone: 701-328-8020
Ohio	Department of Natural Resources, Division of Oil and Gas	http://oilandgas.ohiodnr.gov Phone: 614-265-6565
Oklahoma	Oklahoma Corporation Commission, Oil and Gas Division	http://www.occeweb.com/og/oghome.htm Phone: 405-521-2240
Oregon	Department of Geology and Mineral Industries	http://www.oregongeology.org/mlrr/oilgas.htm Phone: 541-967-2039
	Department of Environmental Protection, Bureau of Oil and Gas Management	http://www.portal.state.pa.us/portal/server.pt/community/office_of_oil_and_gas_management/20291 Phone: 717-783-2300
South Carolina	Department of Health and Environmental Control	http://www.scdhec.gov/environment Phone: 803-898-3432
South Dakota	Department of Natural Resources, Geological Survey	http://www.sdgs.usd.edu Phone: 605-677-5227
Tennessee	Department of Environment and Conservation	http://www.tn.gov/environment/article/oil-gas Phone: 615-687-7120
Texas	Railroad Commission of Texas	http://www.rrc.state.tx.us/oil-gas Phone: 512-463-6838

Utah	Department of Natural Resources, Division of Oil, Gas and Mining	http://oilgas.ogm.utah.gov/index.htm Phone: 801-538-5340
Virginia	Department of Mines, Minerals and Energy, Division of Gas and Oil	http://www.dmme.virginia.gov/DGO/DgoLandingPage.shtml Phone: 804-692-3200
Washington	Department of Natural Resources, Division of Energy, Mining and Minerals	http://www.dnr.wa.gov/programs-and-services/geology/energy-mining-and-minerals/oil-and-gas-resources Phone: 360-902-1450
West Virginia	Department of Environmental Protection, Office of Oil and Gas	http://www.dep.wv.gov/oil-and-gas/Pages/default.aspx Phone: 304-926-0450
Wyoming	Wyoming Oil and Gas Conservation Commission	http://wogcc.state.wy.us Phone: 307-234-7147

STAGE 2
LEASING & PERMITTING

HEALTH ISSUES IN THIS SECTION

What is the company doing at this stage?

LEASING

Only exploratory drilling can confirm the presence of viable oil or gas deposits. Prior to drilling, however, the company must obtain the rights to develop the subsurface minerals. If early exploration has indicated promising geologic structures, the company will attempt to purchase or negotiate lease contracts with the mineral owners, who could be individuals, trusts, governments, or other companies.

Where conditions are suitable for oil and gas development, state regulators create a system for efficiently extracting the resources. This process includes determining ***well spacing***, or the permissible proximity of wells within one geological formation. A ***drilling unit*** is the area designated by state governments that can contain a single oil or gas well, and the allotted acreage can vary widely by state.

The company typically needs to lease a certain portion of a drilling unit before drilling can take place. If the company does not obtain control of the necessary acreage, then production in that area might not proceed; in that case, the company might sell its interests in the leases it has obtained.

PERMITTING

Once the leases are in hand, the company must secure the necessary permits before it can proceed with drilling a well. Depending on the location, there can be local, state, tribal, and federal government agencies involved in the permitting process.

Who has authority over the permitting process?

Federal Government

There are several federal statutes, including the Clean Air Act and the Clean Water Act, that apply to shale energy development (for a summary of federal laws and regulations pertaining to shale development, see Appendix C). Federal agencies may delegate the implementation of federal laws to the states under federal oversight. States may adopt their own standards on these issues, although they must be at least as protective as the federal statutes—and can be more so. Federal agencies also directly regulate oil and gas development occurring on federal lands.

Tribal Government

Native American lands are often held in trust by the federal government, and therefore potential energy development on or near tribal lands involves coordination and negotiation with both the tribal government and relevant federal government agencies. There can also be unique laws and regulations pertaining to energy development on tribal lands.

State Government

States regulate shale gas development and production on their territory and may be the primary administrators of relevant federal laws. It is possible for several different state agencies to play a role in regulating shale development. The agency with primary authority varies from state to state; there may be a designated oil and gas commission, or the primary agency may be housed in the state's department of natural resources or environmental protection agency (for the agency with primary authority in your state, see Table 2). The recent boom in shale energy development has resulted in many states finding that they have insufficient resources and staffing to meet the demands of administering the necessary regulations.

Local Government

County and municipal governments often play a regulatory role in or near populated areas, where they may manage issues such as noise levels, lighting, traffic flow, and the required distance that the operation must maintain from residences or other sensitive areas (or *setbacks*). Zoning laws are the primary tool for local governments to manage shale development in their area. In some cases, local governments have attempted to impose limits or bans on shale development in their area, bringing them into conflict with the state's authority over the development of natural resources. State courts are currently adjudicating some of these state preemption cases with varying outcomes (see Appendix C).

What must the operator do to obtain the necessary permits?

Once the company has gathered the leases in an established production unit, it must secure state and local permits prior to drilling an oil or gas well. In order to file for the permits, operators must prepare for a number of aspects of the development process, which vary from state to state. For example, the Colorado Oil and Gas Conservation Commission (COGCC) drilling permit application[1] includes the following elements:

- **Financial assurance**—in most states, the company must post a bond that guarantees the funding for proper well abandonment and site restoration.
- **Leases and agreements**—the operator must have acquired the mineral rights where it intends to drill. In Colorado it must also *stake* the site by surveying the land, mapping out the area where it intends to locate the well pad, and marking it with stakes to create a plot. The survey details are required in the permit application. In the case of a *split estate* (see Box 2), the operator must make arrangements with the surface owner for access, either by signing a surface use agreement or by posting a bond.
- **Setbacks**— to comply with setback regulations, operators must indicate the distance to the nearest public infrastructure. In a review of regulations in 31 states with existing or potential shale development, the nonprofit organization Resources for the Future (RFF) found that most states require setbacks from buildings and other sensitive structures. Setback distances range from 100 to 1,000 feet from the well.[2] Fewer than half of the states (12 of 31) require setbacks from water sources; Colorado is among them.
- **Groundwater monitoring**—operators must conduct pre- and post-drilling groundwater monitoring and post the results on the COGCC website. As of May 2013, a limited number of states require baseline water well testing (8 of 31 surveyed).[3]
- **Waste and wastewater disposal plan**—operators must indicate how they plan to handle wastes from the drilling operation in a manner that meets the applicable regulations.

In addition to the drilling permit, the operator must obtain federal Department of Transportation (DOT) permits for the transport of heavy loads. Some states or localities may require operators to work with local agencies to designate which roads it intends to use or construct. The operator might also need to obtain a permit to construct temporary housing facilities for workers or to identify the source of water that it will draw on for its operations.

During this phase, the operator will typically bring in a small team of experts to begin the necessary assessments and prepare the plans. It might also hire a few additional local workers. Once the state approves the permits, the operator typically has a 1–2 year timeframe in which to construct the well pad site.

1 Colorado Oil and Gas Conservation Commission, "Application for Permit to Drill – Form 2," video (8:26) on website, accessed December 10, 2014, https://cogcc.state.co.us/COGIS/DrillingPermits.asp.

2 Resources for the Future, "A Review of Shale Gas Regulations by State: Setback Restrictions from Buildings," updated May 22, 2013, http://www.rff.org/centers/energy_and_climate_economics/Pages/Shale_Maps.aspx.

3 Resources for the Future, "Shale Gas Regulations."

What might my community experience?

To identify the owners of the mineral rights in your community, third party contractors will conduct extensive research at the local office of deeds and records, often resulting in a noticeable increase in activity and demands on that office.

As in the previous stage, there can be a number of different industry representatives operating in your area. In addition to the oil and gas companies and their contractors, there are agents, often known as *landmen*, who negotiate mineral leases with property owners. They might work on behalf of a particular company or work independently as a speculator to put together acreage that they can later resell to oil and gas operators.

BOX 2. SPLIT ESTATE

A *split estate* is a property whose subsurface minerals do not belong to the surface owner, but have been previously separated, sold, or allotted to another owner (sometimes the federal government). In this case, the oil and gas operator is not required to obtain the consent of the surface owner in order to explore or to develop the minerals. In some states, however, companies must attempt to negotiate access and impact compensation with surface owners. Compensation provisions include damages; any losses suffered due to the interruption of crops or the grazing of cattle; and the costs of replanting native grasses.

For local property owners who hold the mineral rights to their land (see Box 2), landmen may approach them to lease the mineral rights. These owners can negotiate leasing terms and additional agreements for use of their surface property to access the minerals. Depending on the stage at which mineral owners are contacted, the price offered per acre can vary significantly.

For surface owners who do not own the mineral rights, some states require companies to make a good faith effort to negotiate surface use agreements with them. Some companies will negotiate such agreements even in the absence of a requirement.

There are 58 million acres of land nationwide where the federal Bureau of Land Management (BLM) owns the mineral rights, but private citizens own the surface property.[4] The agency has established standards and guidelines for interacting with landowners that oil and gas operators must follow ("the Gold Book"). According to these guidelines, the operator must make a good faith effort to come to an agreement with the surface owner regarding access to the lands. If these efforts should fail, then the operator is required to post a bond for any damages or losses incurred by the surface owner.[5]

What do landowners who are approached about signing shale development leases need to know?

Landowners who own the mineral rights to their land stand to benefit from lease payments and royalties for the extraction of oil and gas. It is important to consider, however, the anticipated activities and potential impacts to your lands or property when negotiating a surface use agreement.[6] There are also potential liability and mortgage risks for owners to consider.[7] Several organizations offer guidance for landowners considering signing oil or gas leases or surface use

4 Bureau of Land Management, "Split Estate: Rights, Responsibilities, and Opportunities" (2007), agency brochure, http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/bmps.Par.57486.File.dat/SplitEstate07.pdf.

5 API recommends that operators consult the Gold Book for guidance and best practices on communication and addressing the concerns of surface owners. American Petroleum Institute, "Environmental Protection for Onshore Oil and Gas Production Operations and Leases," API Recommended Practice 51R (July 2009), 6, http://www.api.org/~/media/Files/Policy/Exploration/API_RP_51R.pdf.

6 See Earthworks, "Oil and Gas at Your Door?" III-5–III-8 for a checklist of concerns and surface use agreement provisions to consider.

7 Elisabeth N. Radow, "Homeowners and Gas Drilling Leases: Boon or Bust?" *New York State Bar Association Journal* 83, no. 9 (November/December 2011), reprinted at http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/NYSBA%20Journal%20nov-dec2011.pdf.

agreements (see the resources section below).

With regard to property values in your community, the effect of energy development can be mixed. If you own the mineral rights on your property, the property values can be expected to increase. Studies suggest that regional property values tend to rise with development due to an influx of project workers and the economic boom, although this effect declines over time.[8] According to one study, whether properties in proximity to drilling sites increase or decrease in value depends on several factors, including their distance to the drilling site, whether they rely on well water or piped water, and if they are located in an area that has been previously permitted but not drilled. The value of homes in proximity to shale development sites has tended to increase overall, unless the home relied on well water, which indicates a perceived risk to the local water quality.[9, 10]

What are the implications of forced pooling laws?

Thirty-nine states have laws allowing for compulsory integration into a drilling unit, or *forced pooling*.[11] If a company controls a certain percentage of the acreage within a drilling unit, forced pooling allows the state to draw the remaining unleased properties into the unit, allocating a share of the royalties to the owners.[12] These laws were initially developed to promote efficient development of the mineral resources and prevent the drilling of too many wells in close proximity. They were also intended to keep a mineral owner's resources from being extracted through a well on a neighboring property without compensation.[13]

If owners within a drilling unit do not wish to sign a lease, the operator can file a forced pooling application with the state. If approved by the state, mineral owners are then given a choice: participate as a stakeholder in the development of the well or simply receive bonus and royalty payments. The operator usually accesses the minerals through horizontal drilling from a neighboring property. Forced pooling laws have most often been used in the longstanding oil and gas lands in the West; their usage in states in the newer shale plays is still to be determined.[14, 15]

What bonding and compensation requirements are there to protect landowner property and community infrastructure?

If the landowner and company negotiate a surface use agreement, this contractual agreement includes provisions for compensation of any damages.[16] Shale energy development is primarily regulated under state laws, which vary considerably. Some states have statutes requiring companies to attempt to negotiate compensation for potential damage with surface owners, as well as provisions incentivizing the companies to minimize damages. If no agreement is reached and property damages are not repaired, property owners might be able to

---

8 Lucija Muehlenbachs, Elisheba Spiller, and Christopher Timmins, "The Housing Market Impacts of Shale Gas Development" Resources for the Future Discussion Paper 13–39 (Washington, DC: December 2013), 1, http://www.rff.org/RFF/Documents/RFF-DP-13-39.pdf.

9 Muehlenbachs, Spiller, and Timmins, "Housing Market Impacts," 1.

10 New York State Department of Environmental Conservation, ***High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement (SGEIS) Documents*** (Albany, New York: April 2015), 6-253–6-254, http://www.dec.ny.gov/energy/75370.html.

11 Marie C. Baca, "Forced Pooling: When Landowners Can't Say No to Drilling," ***ProPublica*** (May 18, 2011), http://www.propublica.org/article/forced-pooling-when-landowners-cant-say-no-to-drilling.

12 Baca, "Forced Pooling."

13 Mike Lee, "Nuns and Other Landowners Watching as Pa. Reschedules 'Forced Pooling' Case," ***E&E News*** (July 23, 2014), reprinted at https://www.facebook.com/permalink.php?id=605152649568407&story_fbid=672103962873275.

14 Lee, "Nuns and Other Landowners."

15 For a compilation of state laws on forced pooling, see Marie C Baca, "State Laws Can Compel Landowners to Accept Gas and Oil Drilling," ***ProPublica*** (May 19, 2011), http://projects.propublica.org/tables/forced-pooling.

16 For landowner tips, a checklist of issues to consider when negotiating an agreement, and a sample agreement, see ***Oil and Gas at Your Door?*** III-3–III-23: http://www.earthworksaction.org/files/publications/LOguide2005book.pdf.

take a complaint before the state agency or oil and gas commission, depending on the state. Alternatively, they can seek compensation through the court system.

Most states require companies to post a bond, or a form of financial assurance, prior to drilling to cover the cost of plugging the well and reclaiming the site. This is done to ensure that there is funding to cover the costs if, for example, the company goes bankrupt before decommissioning the site.

With regard to community infrastructure, some municipalities and counties also have regulations relating to shale development. These regulations require companies to post bonds to cover any damages to local infrastructure; have permit and/or fee requirements; or have zoning ordinances restricting areas for development. In some states, local governments can require operators to enter road use agreements that specify conditions for local road and bridge improvements and maintenance, leading to improvements in local infrastructure. Costs can be shared or paid fully by the operator.

What health considerations are there?

Health considerations at this stage continue to be focused in the quality of life domain, with the introduction of possible impacts on social relationships in your community. As discussed in Box 1 on health-related quality of life, an individual or group's perceptions of their position in life in the context of their environment can have an important role to play in their overall health and well-being. The quality of life concept includes economic, social, and psychological aspects, among others.

QUALITY OF LIFE—ECONOMIC IMPACTS

Some landowners may financially benefit from the project by signing lease agreements with the operator, which can result in an improvement in quality of life by providing them greater financial resources and opportunities.

QUALITY OF LIFE—SOCIAL IMPACTS

Many communities where shale development occurs are small, cohesive rural communities with a place-based identity. With the introduction of lease offers to some residents—but not others—in the community, residents can begin to perceive the potential benefits of the project as unequally distributed, creating a new source of community tension and disagreement. These changes, as well as those that take place in future stages, could result in the loss of a sense of community identity and cohesion. Furthermore, the prospect of shale development can cause some residents to start moving out of the area, either because of increased activity driving up costs (see Economic Impacts under Stage 3), or because they are concerned about the potential environmental and social impacts.

In communities that are economically depressed, the prospect of economic benefits accompanying shale development can be a source of optimism. As mentioned above, the project might lead to improvements in local infrastructure, and might offer increased job opportunities if the project proceeds to exploratory drilling (see Economic Impacts under Stage 3). At this stage, however, it can be important to temper such optimism with an awareness of the possibility that the project will not move forward, to prevent the community making premature investments based on expected income.

QUALITY OF LIFE—PSYCHOLOGICAL IMPACTS

According to the World Health Organization, health is "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."[17] Psychological stress and the perception of negative impacts can play a significant role in an individual's overall health. Chronic stress can result in physical health impacts and initiate a self-reinforcing cycle—i.e., in response to a psychological or physical stressor, an individual's perception of health impacts may increase, which in turn increases his or her ***allostatic load***, or the "wear and tear on the body" resulting from the accumulation of repeated or chronic stress.[18]

In this stage of shale development, landowners who do not control the mineral rights on their property, or those who may not wish to sign agreements but could be subject to forced pooling laws, might experience psychological stress related to uncertainty and a sense of lost control over a valuable financial asset and their home environment. Landowners concerned about property values or possible damages to their estate could also experience such stress and a decline in quality of life. In addition, uncertainty surrounding the potential project and its impacts, as well as a fear of change, can have negative psychological effects on some community members.

In a 2013 study published in the *International Journal of Occupational and Environmental Health*, researchers interviewed a small set of residents in areas of shale development in the Marcellus Shale play who were reporting health impacts.[19] The goal was to identify the physical and mental stressors that participants attributed to shale development. The most commonly reported stressors involved the perception of negative interactions with and a lack of trust in company representatives and government officials. The top concerns identified were the following:

- having their concerns denied or being provided with false information (79%)
- corruption (61%)
- having their concerns/complaints ignored (58%)
- being taken advantage of (52%)[20]

The authors observed that these stressful feelings likely reinforced participants' concerns for their health, which increased over the three sessions of the study. As the authors note, there are relationship-building steps that local officials and company representatives can begin taking during the early stages of shale development to help alleviate concerns around trust and credibility. The activities listed in the "What Can Be Done?" sections of this guidebook , as well as those suggested in the American Petroleum Institute's (API) "Community Engagement Guidelines,"[21] could be helpful in establishing relationships with communities.

17 Kyle J. Ferrar, Jill Kriesky, Charles L. Christen, Lynn P. Marshall, Samantha L. Malone, Ravi K. Sharma, Drew R. Michanowicz, Bernard D. Goldstein, "Assessment and Longitudinal Analysis of Health Impacts and Stressors Perceived to Result from Unconventional Shale Gas Development in the Marcellus Shale Region," International Journal of Occupational and Environmental Health 19, no. 2 (2013): 104–12.

18 Ferrar et al., "Health Impacts," 110–111.

19 Ferrar et al., "Health Impacts."

20 Ferrar et al., "Health Impacts," 109.

21 American Petroleum Institute (API), "Community Engagement Guidelines," ANSI/API Bulletin 100-3, first edition (July 2014), http://www.api.org/globalitems/~/media/Files/Policy/Exploration/100-3_e1.pdf.

What can be done to address health concerns? What have others done?

COLLABORATIVE ACTIVITIES

Stakeholder Engagement, Communication, and Planning

This early stage is an opportune time to initiate communication channels and information sharing between the company and the community. Regardless of the company's plans, it is important for company representatives to work with local governments to plan for the eventual closure of the project from the outset. Anticipating the company's withdrawal from the area helps to reduce the risks and maximize the benefits to the community.[22]

How can I identify an industry partner?

Given that there can be a number of oil and gas operators and their contractors working in a particular area, it can be difficult for local stakeholders to identify appropriate industry partners. The API Community Engagement Guidelines urge operators to coordinate among themselves to engage with community stakeholders.[23] Some oil and gas companies regularly engage with communities as a part of their operations. Local officials or community leaders seeking to engage the industry could first contact the state regulator to obtain contact information for a particular company's regulatory manager (company contact information is also available on the regulatory permit). The manager has the ability to help identify the appropriate point of contact internally—for larger companies, it could be the communications representative or community liaison, and for smaller ones it could be an operations or exploration manager.

What topics are useful to discuss at this stage?

If local officials and company representatives meet to discuss the company's anticipated needs and potential community impacts, possible topics to cover include:

the likelihood that the project will proceed to production

- the length of time the operator anticipates conducting activities in the community
- the typical number of outside workers the project will require and how the company plans to accommodate them
- the number of families and children who could accompany project workers, which can help local officials determine whether more educational resources are needed
- the profile of the local labor pool and whether the company plans to hire locally; if so, what job skills and training might be necessary
- the company's emergency response plans and potential demands on emergency and fire department services, including any training needs and any specialized emergency response equipment that should be acquired (e.g., personal protective equipment)
- amount and timing of anticipated vehicle traffic; which local roads/bridges to avoid or are in need of an upgrade

22 API, "Community Engagement Guidelines," 5.
23 API, "Community Engagement Guidelines," 3.

- method for responding to any impacts to local infrastructure and services
- the company's plans for water sourcing; air, water, and noise monitoring; waste disposal; and erosion control
- approach to responding to community concerns about light, noise, and dust from traffic
- any plans to conduct flaring at the site
- the company's approach to engaging local community stakeholders

Depending on the outcome of these discussions, potential areas for collaborative planning or joint initiatives could emerge. For example, local officials can potentially work with the company and other regional stakeholders to coordinate the construction of water pipelines or common waste disposal facilities. These stakeholders may work together to establish educational programs in the region to train local workers in the skills needed at project sites (for example programs, see Box 10).

Local officials could also work with company representatives to hold an informational session or open house about the potential for shale development in the community. Many of the above topics should also be covered in an open house—in particular, it can be helpful to discuss the likelihood that the project will proceed and the length of time operations would last.

Water Quantity

The issue of water availability is covered in detail in Stage 4—Development and Production when regular withdrawals of large quantities of water come into play. As many of the impacts can be alleviated or avoided by appropriate planning, it is worth considering water management options at this stage of development. Furthermore, operators are sometimes required to submit their plans for water sourcing as part of the permitting process. It can be helpful for the company to develop a water-sourcing plan whether or not it is required, in order to understand existing water sources and demands and how the company's needs will interact with them.

To find out how water withdrawals and uses are regulated in your state, you can consult with the water quality state engineer at the state's department of water resources. As part of the information-sharing sessions between local officials and company representatives mentioned above, questions to discuss could include:

- What are the sources of water (ground or surface) in your community and how are they used (drinking, recreation, agriculture, livelihoods, energy generation)?
- What water source will the project use? If relevant, how might it impact other important uses of water in the community?
- When will the water withdrawals for the project take place?
- Will the project provide infrastructure that increases access to water? If so, will the community be able to use that water?
- What will happen to the wastewater? Will it be treated and returned to the water cycle, injected into rock formations, or reused for operations?

LOCAL OFFICIALS

From the outset, local officials could consider conducting—or encouraging their state or federal counterparts to conduct—a **Health Impact Assessment** (HIA) on potential shale development in their area, usually performed as part of an environmental or social impact assessment. The National Research Council of the National Academies of Sciences defines HIA as follows:

> "HIA is a systematic process that uses an array of data sources and analytic methods and considers input from stakeholders to determine the potential effects of a proposed policy, plan, program, or project on the health of a population and the distribution of those effects within the population. HIA provides recommendations on monitoring and managing those effects." [24]

HIAs often contain components of environmental health as well as socioeconomic risk assessment. They encompass a wide range of possible health effects that extend beyond toxicological effects, including[25]:

- air quality
- water quality
- noise
- agricultural uses
- demographic changes
- socioeconomic changes
- traffic changes
- employment and workforce impacts

An HIA is intended to assess both the risks and benefits of the proposed project in terms of overall community health. In doing so, it helps identify at-risk populations and provides recommendations for how to reduce possible negative impacts.

Quality of Life—Economic Impacts

It is important to note that local governments may experience a shortfall in funding in the early stages of development due to new demands upon local infrastructure and services, while the

BOX 3. CASE STUDY: HEALTH IMPACT ASSESSMENT

Oil drilling has taken place in Alaska since 1967. With the expansion of the industry in recent decades, some development activities began to occur near rural Alaskan native communities in the North Slope region, where some residents began expressing health concerns. In 2006, local tribal leaders and the borough government responded with a decision to jointly conduct the region's first HIA. The project's goals were to address community concerns and bring a more systematic, evidence-based approach to integrating public health data into the oil and gas planning and regulatory process. The Bureau of Land Management (BLM) agreed to integrate the HIA into an existing environmental impact statement (EIS) process for proposed oil and gas leasing near several local villages.

The study produced some significant findings. The HIA highlighted potential impacts on regional fish and wildlife populations, which would have consequences for local diet and nutrition. It also recognized potential social changes that the anticipated large increase in population would bring to the region. Finally, the HIA acknowledged the potential benefits for local communities, such as increased revenues to support police and emergency services, education, and public health programming.

As a result of the HIA's identification of specific risks to the community, preventative measures were taken to prepare the community for the expected changes, including:

- new BLM requirements for monitoring contaminants in locally-harvested fish and game
- air quality modelling for large industry facilities located near villages
- water quality monitoring
- worker education programs on drug and alcohol use and sexually transmitted diseases

The HIA process also led to a new level of collaboration between state and tribal public health authorities; state and federal regulators; and industry. The state subsequently established an HIA program and now conducts HIAs for large projects throughout Alaska.

Sources: Aaron Wernham, "Inupiat Health and Proposed Alaskan Oil Development: Results of the First Integrated Health Impact Assessment/ Environmental Impact Statement for Proposed Oil Development on Alaska's North Slope," EcoHealth 4 (2007), 500–513; The Pew Charitable Trusts, "Case Study: Oil Development, North Slope of Alaska" (December 30, 2006), http://www.pewtrusts.org/en/research-and-analysis/analysis/hip/hip-case-study-oil-development-north-slope-of-alaska

24 National Research Council, "Improving Health in the United States: The Role of Health Impact Assessment" (Washington, DC: 2011): 5, http://www.nap.edu/catalog/13229/improving-health-in-the-united-states-the-role-of-health.

25 Note that these impacts largely arise beginning in Stage 3 and are addressed there.

government might not receive additional income from production taxes for 2–5 years.[26] Local officials could therefore begin discussions with state legislative and executive branches during the early stages of shale development on how to design a tax structure that allows local governments to receive funding in a manner that meets their communities' infrastructure and service needs.

The economic impacts of shale development begin to materialize in Stage 3—Exploratory Drilling and are addressed in detail there.

Quality of Life—Noise Impacts

The permitting stage is a good time to consider how to avoid or mitigate many potential impacts, given that siting is a critical aspect of managing the impacts of noise. Some states require a noise mitigation plan as part of the permitting process. Truck traffic to and from the site is another major source of noise that stakeholders can seek to mitigate in this early phase. Local officials can therefore play a role in establishing speed limits for truck traffic, as well as designating appropriate truck routes.

The health impacts of noise are addressed under Quality of Life—Noise Impacts in Stage 3 when sound levels from the project could begin affecting residents.

Quality of Life—Visual Impacts

As with noise, the permitting phase - when plans are reviewed regarding siting and design of the project - is an important time for addressing visual impacts (see Quality of Life—Visual Impacts in Stage 3 for an overview). There are statutory requirements to protect significant scenic, historic, and recreational locations, including at state and federally owned sites. State regulators might conduct environmental impact assessments (EIAs) at this stage, and they could seek the input of municipal authorities on topics such as potential visual impacts.

For local officials, particularly those in tourist areas with high-value scenery, it can be useful to 1) conduct an early assessment to identify area resources of high visual sensitivity; 2) gather input from residents on their concerns regarding siting; and 3) review local land use ordinances. When there are significant cultural, historic, or natural resources near the planned development site, it may be helpful to conduct modeling or computer simulation of the *viewshed*, or the landscape/scenery visible to the eye from a fixed vantage point.[27]

INDUSTRY REPRESENTATIVES

Stakeholder Engagement

In addition to the above activities, the API Community Engagement Guidelines suggest that operators provide community members with access to a feedback mechanism. For example, some operators have provided an 800 number, which helps them respond to issues as they arise.

This is also a good time to conduct monitoring activities to establish a baseline for air and water quality, as well as ambient noise levels. Having a baseline will be an essential reference point for later monitoring efforts and will help determine the potential impacts of shale development in the community. Some state regulations call on

26 Headwaters Economics, "Oil and Natural Gas Fiscal Best Practices: Lessons for State and Local Governments," (November 2012), 3, http://headwaterseconomics.org/wphw/wp-content/uploads/Energy_Fiscal_Best_Practices.pdf.

27 See Cornell University study of modeling for the Cayuga Heights and Ithaca overlooks: Sarita Rose Upadhyay and Min Bu, "Visual Impacts of Natural Gas Drilling in the Marcellus Shale Region," Cornell University (Fall 2010), 33-34, http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Visual%20Impact_Final%20Report.pdf.

operators to conduct baseline monitoring, particularly for water quality, within a certain distance of the planned site. As outlined in the case study in Box 4, one option is for the company and the community to undertake a joint effort in water quality monitoring.

Quality of Life—Noise Impacts

The best way to alleviate the effects of noise at the well site is by increasing the distance between the source and the person hearing it (*the receptor*). With multi-well pad shale development operations, one pad can drain a larger basin than in conventional oil and gas development, allowing more flexibility with regard to pad location. State requirements for setbacks of well pads from residences vary significantly. In an RFF survey, 20 states were found to have building setback restrictions for natural gas wellheads, ranging from 100 feet to 1,000 feet, with an average restriction of 308 feet.[32] After examining composite noise levels for various activities involved in shale development, the New York State Department of Environmental Conservation recommended noise modeling and additional mitigation measures for well pads located within 1,000 feet of occupied structures or places of assembly.[33]

BOX 4. CASE STUDY FROM THE MINING INDUSTRY: THE GOOD NEIGHBOR AGREEMENT

In 2000, when Stillwater Mining Company began making plans to expand their mining operations in two Montana counties, several environmental NGOs saw an opportunity to engage with the company about protecting the area's natural resources. During the hearing on the initial draft of the expansion permit, NGO representatives raised questions about its environmental implications. The groups subsequently entered into negotiations with the mining company on how to resolve these issues before the permit was finalized. The result of their negotiations was the creation of the 2000 Good Neighbor Agreement,[28] a legally binding document. The purpose of the agreement is to protect the area's quality of life while providing for responsible economic development.

Designed to avoid triggering state government regulatory action on water quality, the Good Neighbor Agreement (GNA) establishes water quality requirements that exceed those required by the state. Three citizens' committees and a set of projects were established to implement the objectives outlined in the agreement. As part of the agreement, an independent third-party consultant provides the citizen councils with technical assistance. The consultant costs, as well as other expenses of implementing the agreement, are covered by Stillwater.

One citizen committee focuses on engaging local residents in water quality monitoring for the agreement in the Stillwater, Boulder, and East Boulder Rivers.[29] Other initiatives of the GNA have increased public safety and decreased air pollution by establishing traffic restrictions and providing for carpooling, as well as a busing program for miners. On an annual basis, the technology committee considers any emerging best practices in the mining industry that could be applied to either of the mines.

The company's transparency about its operations, along with citizen participation in monitoring activities, has fostered an environment of trust.[30] Maintaining an ongoing relationship has been important for stakeholders in the GNA because it has allowed for open dialogue and development of amendments to the agreement as needed. For example, the busing agreement originally stated that Stillwater was permitted only 35 private vehicles on the road per day. Nine years later, stakeholders renegotiated the traffic provisions to accommodate the changing operational needs of the mine while keeping traffic to a minimum.

In its newsletter commemorating the tenth anniversary of the GNA, the Northern Plains Resource Council, one of the original NGO parties to the agreement, stated that the GNA "has become a template for resolving disputes and promoting positive interaction in the permitting and development of natural resources."[31]

For more information, contact the Northern Plains Resource Council, (406) 248 1154, info@northernplains.org.

28 Good Neighbor Agreement Between Stillwater Mining Company and Northern Plains Resource Council, Cottonwood Resource Council, and Stillwater Protective Association (originally signed May 8, 2000; amended November 11, 2009), https://www.northernplains.org/wp-content/uploads/2013/06/2009AmendedGNA.pdf.

29 Northern Plains Resource Council, "Good Neighbor Agreement: A Unique Solution for Local Protection," accessed December 9, 2014, https://www.northernplains.org/wp-content/uploads/2013/06/GNA_Citizens_Guide.pdf.

30 Northern Plains Resource Council, "10th Anniversary Good Neighbor Agreement Newsletter," 1, accessed December 9, 2014, https://www.northernplains.org/wp-content/uploads/2013/06/2010GNAjoint-newsletter.pdf.

31 Northern Plains Resource Council, "10th Anniversary," 1.

32 Richardson, Nathan, Madeline Gottlieb, Alan Krupnick, and Hannah Wiseman. "The State of State Shale Gas Regulation." Resources for the Future (June 2013), 24–28, http://www.rff.org/rff/documents/RFF-Rpt-StateofStateRegs_Report.pdf.

33 New York State Department of Environmental Conservation, "High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement (SGEIS) Documents" (April 2015), 7–134, http://www.dec.ny.gov/energy/75370.html.

In addition to following setback restrictions, The operator could undertake the following activities in the permitting phase:

- conducting a noise impact assessment that accounts for the presence of vulnerable populations or individuals in the vicinity
- siting access roads as far away from homes, schools, and other sensitive buildings as possible
- selecting a site that allows the topography or vegetation to act as sound barriers
- piping in water and/or recycling it on site to reduce truck traffic to the site (it is worth noting that pipelines have their own impacts, discussed in Appendix E)

Quality of Life—Visual Impacts

As with noise, the operator could seek to avoid visual impacts by siting well pads and access roads away from visually sensitive areas. Mitigation measures toconsider during the permitting phase include:

- minimizing the footprint of the well pad
- reducing the size of fluid retention ponds or replacing them with storage tanks
- using topography or vegetation to screen the site from view
- seeking to reduce the visual impact of structures such as compressor stations through design considerations (for example, by emulating the area's existing agricultural structures)[34]

What resources can provide further information?

LEGISLATION, REGULATION, AND PERMITTING

- The Intermountain Oil and BMP Gas Project website is maintained by the Getches-Wilkinson Center for Energy, Natural Resources, and the Environment at the University of Colorado Law School. For information on laws and policies pertaining to the oil and gas industry in Western intermountain states, see http://www.oilandgasbmps.org/laws/index.php. For a review of state laws in shale regions regarding water quality, water quantity, and air quality, see http://www.lawatlas.org/oilandgas.
- The Interstate Oil and Gas Compact Commission (IOGCC), is an organization representing the governors of member states on the responsible development of oil and gas resources. On its website, the IOGCC has a page with links to summaries of state statutes regarding oil and gas development (http://iogcc.publishpath.com/state-statutes). There is also a table with information on state oil and gas taxes.
- Ohio Department of Natural Resources (ODNR), Division of Oil & Gas Resources, shale drilling animation (4:12), http://oilandgas.ohiodnr.gov/shale#GEN. ODNR's graphic animation describes the state's regulatory and permitting activities at each stage of shale development.
- See Table 2 for a list of state oil and gas regulatory agencies.

34 Earthworks, "Oil and Gas at Your Door?" I-71.

HEALTH IMPACT ASSESSMENTS

- Colorado School of Public Health, Health Impact Assessment for Battlement Mesa, Garfield County, Colorado (Denver: 2010), http://www.garfield-county.com/public-health/documents/1%20%20%20Complete%20HIA%20without%20Appendix%20D.pdf. This draft document created by the Colorado School of Public Health, requested by the town of Battlement Mesa, is an example of a community health impact assessment in the context of a potential natural gas development project.
- International Association of Oil and Gas Producers (OGP), "A Guide to Health Impact Assessments in the Oil and Gas Industry" (2005), http://www.ogp.org.uk/pubs/380.pdf. OGP is an organization that aims to give oil and gas producers a place to share best practices with others in the industry.
- Pew Charitable Trusts, "The Health Impact Project," http://www.pewtrusts.org/en/projects/health-impact-project. The project aims to promote the use of HIAs as a decision-making tool for policymakers. The website contains information on the HIA process, case studies, and HIA research and analysis.
- World Health Organization, "Health Impact Assessment (HIA)," http://www.who.int/hia/en. WHO website has tools and guidance on conducting HIAs and a database of example HIAs in a variety of subject areas, including energy.

WATER QUALITY

- LawAtlas, "Water Quality: Permitting, Design, and Construction Map," (updated April 30, 2014), http://www.lawatlas.org/query?dataset=water-quality-permitting-design-construction#.U908JuNdWSo. This interactive map displays information on the laws and regulations relating to water quality and shale development in a set of states within the major shale formations. The map is curated by the Intermountain Oil and Gas BMP Project, which is housed at the University of Colorado Law School. It contains information on water quality laws for the following aspects of development: permitting, design, and construction; well drilling; well completion; production and operation; and reclamation.

QUALITY OF LIFE—ECONOMIC IMPACTS

- Bureau of Land Management, "Split Estate: Rights, Responsibilities, Opportunities" (2007), agency pamphlet, http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/bmps.Par.57486.File.dat/SplitEstate07.pdf. This pamphlet for operators and landowners gives an overview of the rights and responsibilities of each party when the federal government owns the mineral rights to the land.
- Cornell University Cooperative Extension (CCE), "Things to Consider When You Consider Leasing" (2014), http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Pages/Landowners.aspx. CCE's mission is to solve problems through education and by providing university-based resources to citizens. The website contains information on financial and legal implications of signing oil and gas leases, as well as tips for landowners. See also "Gas Exploration and Leasing on Private Land: Tips and Guidance for New York Landowners" (updated July 2008), http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/Gas%20Leasing%20on%20Private%20Land%20Tips.pdf.

- Earthworks, "Oil and Gas at Your Door? A Landowner's Guide to Oil and Gas Development" (Durango, Colorado: Oil and Gas Accountability Project, 2005), http://www.earthworksaction.org/library/detail/oil_and_gas_at_your_door_2005_edition#.UxjPSj9dWSo. This handbook contains guidance and tools for landowners during the leasing and permitting phase, including a checklist of concerns and an example surface use agreement.
- The Look before You Lease website (http://lookbeforeyoulease.org/about) provides information and a toolkit for landowners in Ohio, including a sample lease, checklists for negotiating a lease, royalty calculator, and water sampling resources. The website was created by the Rural Action, Ohio State University Extension in Athens County, Athens County Farm Bureau, and Appalachia Ohio Alliance (AOA) with the goal of providing landowners the information they need to make an informed decision about property rights and oil and gas leases.
- National Conference of State Legislatures (NCSL), "Compulsory Pooling Laws: Protecting the Conflicting Rights of Neighboring Landowners," October 24, 2014, http://www.ncsl.org/research/energy/compulsory-pooling-laws-protecting-the-conflicting-rights-of-neighboring-landowners.aspx. This NCSL webpage describes forced or compulsory pooling, gives definitions of relevant terms, and describes the different state approaches to compulsory pooling. It also has a map and table of state compulsory pooling laws.
- Elizabeth N. Radow, "Homeowners and Gas Drilling Leases: Boon or Bust?" *New York State Bar Association Journal* 83, no. 9 (November/December 2011), reprinted at http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/NYSBA%20Journal%20nov-dec2011.pdf. Law association journal article describes some of the issues involved in signing gas leases for New York landowners, including mortgage and insurance considerations.

CLOSURE PLANNING

- International Council on Mining and Metals, "Planning for Integrated Mine Closure: Toolkit" (London, UK: 2008), http://www.icmm.com/document/310. The International Council on Mining and Metals is an organization dedicated to improving the sustainability of the mining and metals industry. They use collaborative measures to address sustainable development. This toolkit offers tools and guidance for planning for project closure in collaboration with communities from the initial stages of a project. It was developed for the mining industry, but the tools are useful guides and could be adapted to the oil and gas sector.

BOX 5. WHO TO CONTACT ABOUT WHAT

With many state, federal, and local agencies playing roles in different aspects of shale development, it can be difficult to know who to contact. We have provided links to resources below on some of the main issues that may arise for local stakeholders.

Oil and Gas Drilling Regulations
See Table 2 for links to state oil & gas regulatory agencies

Information on Oil and Gas Leases
For information:
See Table 2 for links to state oil & gas regulatory agencies
For complaints:
Private Attorney or State Attorney General
http://consumerfraudreporting.org/stateattorneygenerallist.php

Oil and Gas Lease Contract Provisions
Qualified private attorney (personal referral or web/telephone book search)
National Conference of State Legislatures, compilation of state statutes on forced pooling:
http://www.ncsl.org/research/energy/compulsory-pooling-laws-protecting-the-conflicting-rights-of-neighboring-landowners.aspx

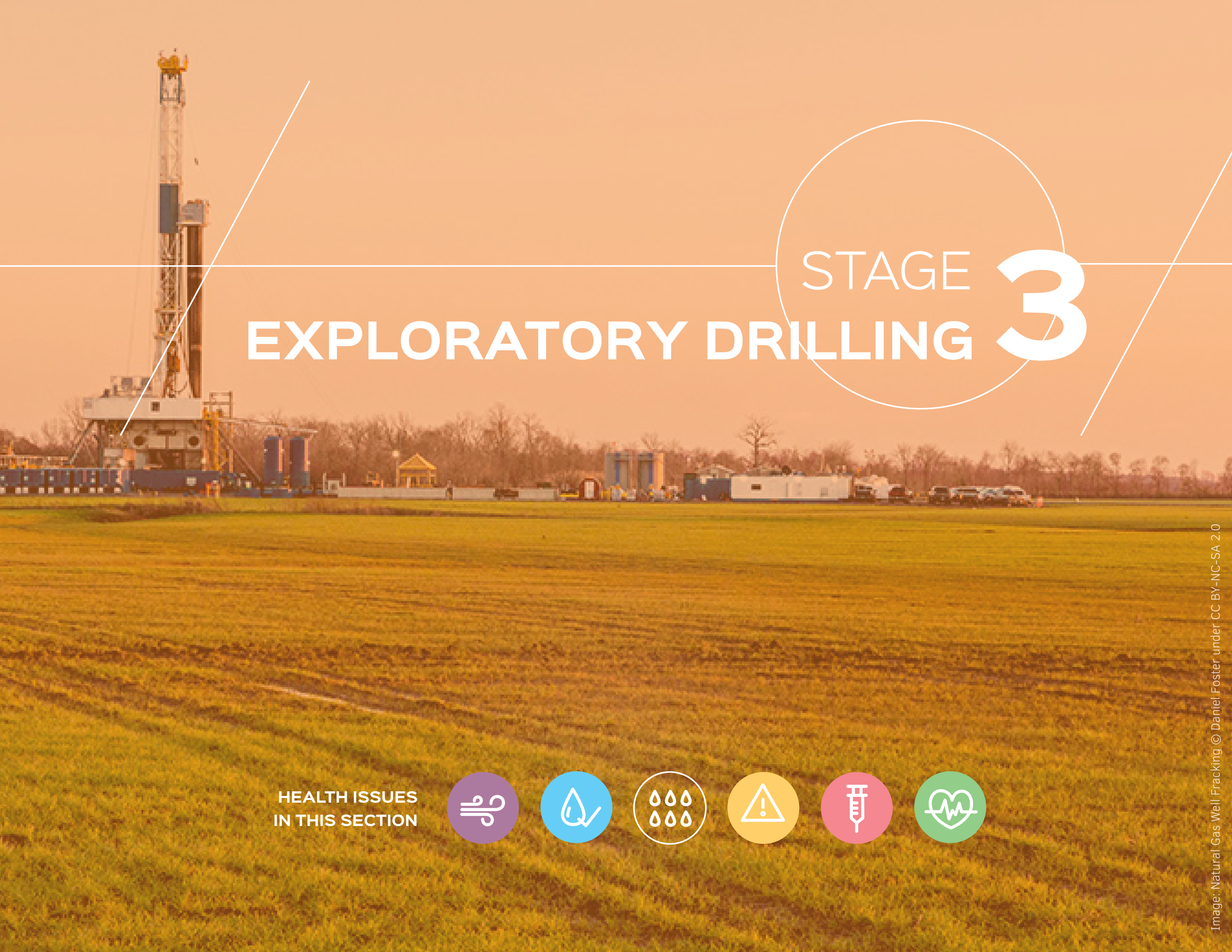
Water-Related Issues
Groundwater Protection Council, list of resources:
http://www.gwpc.org/resources/links

Environmental Conservation Law
U.S. Environmental Protection Agency, list of health and environmental agencies of U.S. states and territories:
http://www2.epa.gov/home/health-and-environmental-agencies-us-states-and-territories

Land Resource and Conservation Management
National Association of Conservation Districts, state directory of county-specific websites:
http://www.nacdnet.org/about/districts/directory

Mitigation Planning for Pipeline Crossing or Well Site Regulation Affecting Agriculture
National Association of State Departments of Agriculture, state directory:
http://www.nasda.org/9383/States.aspx

Pipeline Safety
U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration, list of state pages:
http://primis.phmsa.dot.gov/comm/States.htm?nocache=9789



STAGE 3
EXPLORATORY DRILLING

HEALTH ISSUES IN THIS SECTION

What is the company doing at this stage?

While geophysical prospecting is the initial method used to evaluate potential hydrocarbon sources, the only definitive way to indicate oil and gas presence is by drilling an exploratory well. At first, one exploratory well is typically drilled on a particular pad (although a number of exploratory wells may be drilled in a geographic area to estimate the extent of the resource), but once the company hones in on the best spots for the resource, then multiple wells may be drilled on the pad during the subsequent development phase. It is important to note, however, that many exploratory wells are not successful and thus are never fully developed. The process for well construction and drilling is described below.

The operator often first works with the landowner to select a well pad site and determine the need for access roads. After upgrading local roads or constructing new ones, the operator clears and levels the land and builds the pad. Construction of a well pad can take several weeks to months, depending on the characteristics of the site, the target formation, and the company's exploration and development approach.[1] As part of the well pad infrastructure, the operator installs facilities for storing drilling fluids and disposing of wastewater in either pits or tanks. Pipelines may also be built for the transport of water to and from the site (for more information on pipelines, see Appendix E). Companies may also construct temporary residences for their workers. In doing so, they are required to follow local and state health department regulations for housing and waste disposal.[2]

Over the construction period, heavy trucks move earth and transport equipment and supplies to and from the site, including the drilling rig, storage containers, temporary worker housing, and office trailers. The amount of traffic can vary substantially depending on the activity at the site, peaking in the days before and after the drilling and completion of each well. According to one estimate, there can be a total of 1,148 one-way heavy truck trips and 831 one-way light truck trips during the early phase of well development.[3]

Throughout the exploratory drilling phase, trucks will continue to provision the site with water, food, and fuel. The operator must follow the U.S. Department of Transportation's regulations for planning and permitting the transport of heavy loads.

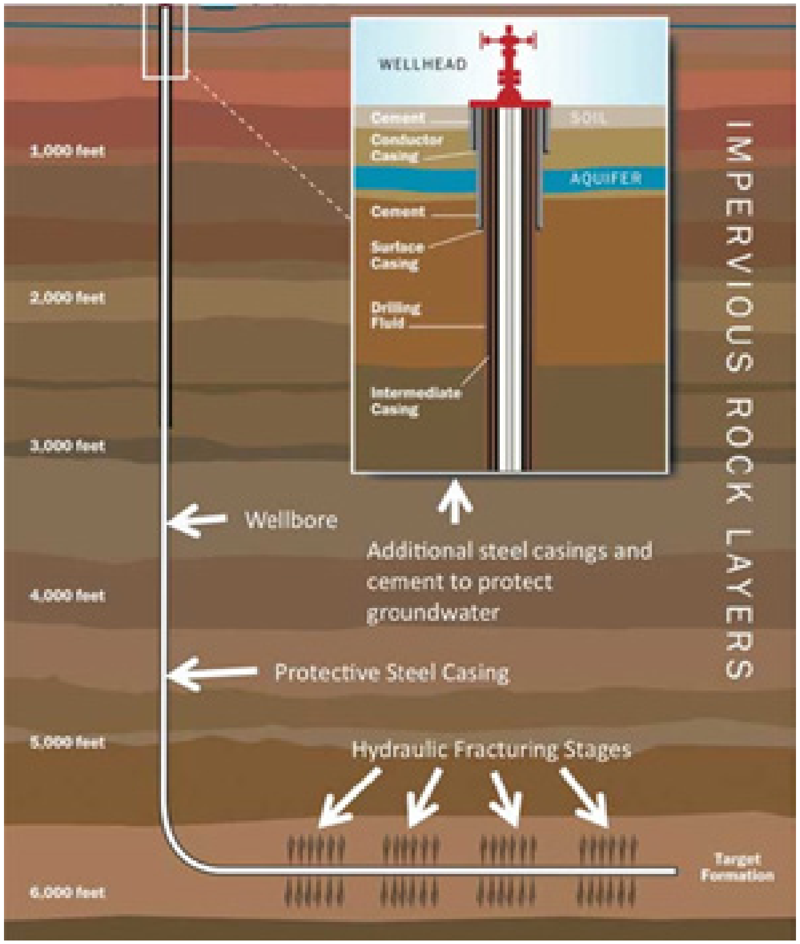
Rig in operation (currently drilling) in WV. By Samantha Malone.

1 George Blankenship, Blankenship Consulting LLC, personal communication on August 2, 2014.
2 For an example of state guidelines for temporary housing, see Ohio Environmental Protection Agency, ***Guidance for Temporary Housing Associated with Oil and Natural Gas Drilling Operations*** (May 2012), http://www.epa.state.oh.us/Portals/0/general%20pdfs/Guidance%20for%20Temporary%20Housing.pdf
3 New York State Department of Environmental Conservation, ***High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement (SGEIS) Documents*** (April 2015), 6-305, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch6b.pdf.

At this exploratory stage, companies typically bring in experienced contract workers to work on the drilling rigs. As an example of the workforce that can be required, the consultancy IHS Energy estimates that the drilling and fracturing of a typical oil well in the Bakken Shale requires 50 full-time employees.[4] During the drilling phase, employees might work 12-hour shifts on a rig that operates 24 hours a day. At other times, the crew working on a rig might be much smaller. Some workers might be present on a site for only a matter of hours to perform a specific task, or could rotate among multiple wells on the same day.[5]

Once the equipment, infrastructure, and drilling rig are in place, the operator prepares to drill the well. A blowout prevention device is installed for safety purposes, in case a high-pressure zone is encountered. Then the operator begins drilling a hole in the earth called a ***wellbore***. ***Drilling fluid***, also known as ***drilling mud***, is pumped into the wellbore to lubricate the drill and maintain the proper balance of pressure in the uncased wellbore. At selected depths in the underlying geology, the bit is removed from the wellbore and layers of steel casing and cement are installed to seal the well off from the surrounding rock, both to stabilize the wellbore and protect underground water sources (see Figure 2). Each casing is pressure-tested after cement is installed and has set. Depending on the well location and geology of the site, the well is then drilled vertically to a median depth of 8,100 feet[6] typically thousands of feet below groundwater resources, and gradually angled to a horizontal drilling position as it reaches the shale formation.

FIGURE 2. HORIZONTAL WELL CONSTRUCTION



Source: The Geological Society of America, http://www.geosociety.org/criticalissues/hydraulicFracturing/waterQuality.asp.

4 Ken Cohen, "What Does It Mean to Frack a Well? Part 1," ExxonMobil Perspectives (June 15, 2015), http://www.exxonmobilperspectives.com/2015/06/15/what-does-it-mean-to-frack-a-well-part-1.

5 George Blankenship, personal communication on August 2, 2014.

6 Based on an EPA analysis of operator disclosures to FracFocus. Well depths ranged from 2,900–13,000 feet (5th to 95th percentile). U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD), "Analysis of Hydraulic Fracturing Fluid Data from the FracFocus Chemical Disclosure Registry 1.0" (Washington, DC: U.S. EPA, March 2015), 63, www.epa.gov/hfstudy.

During drilling, measurements will be taken in the well to characterize the subsurface thickness and depth of formations, the mineralogy, and the types of fluids present. *Drill cuttings*—rock fragments generated by the drill bit—are examined to help determine if oil and gas are present and if so, in what quantity. Models based on this combined data can help establish a reliable prediction for hydrocarbon presence on a basin-wide scale. If the resource appears promising, the operator will proceed with *completing* and flow testing the well, and will likely drill, complete, and flow test additional exploratory wells to evaluate a particular geographic area.

After casing the wellbore, the operator begins the *completion* process, preparing it to produce oil or gas by removing the drilling rig and replacing it with a *workover* or *completion rig*. The well is first tested for integrity. Then the process of hydraulic fracturing begins. To fracture the shale, the operator inserts a perforating tool into the wellbore at the depth of the shale formation, which creates holes in the well casing. This is done in stages. High volumes of *fracturing fluid*—a mixture typically composed predominantly of water, along with sand and chemicals—are injected into the well at high pressure so that the fluid can flow through new or existing fractures in the shale rock. The sand holds these fractures open, allowing the oil or gas to flow back towards the wellbore. During the exploration phase, the natural gas produced by the well (or co-produced, in the case of a shale oil well) might be released into the atmosphere (*vented*), burned off (*flared*), or captured and sent to market. For more information on venting and flaring, see the Air Quality section below.

According to the American Petroleum Institute, oil and gas exploration and production generated 149 million barrels of drilling waste in 1995 (the last time an analysis was conducted), which is primarily composed of drill cuttings and mud.[7] Most of the waste is buried onsite or temporarily stored and then transported to landfills.[8] As with produced water, solid wastes may also be disposed of in Underground Injection Control (UIC) wells, which are regulated under the Safe Drinking Water Act (see Appendix C for more information on UIC wells). In some cases, the drill cuttings may be reused—for example, applied to roads for dust suppression purposes. Although such waste applications are regulated in many states, concerns have been raised about potential soil and water contamination from re-purposing the waste in this way[9] (see Box 8).

After the exploratory wells are completed and flow tested, the company studies the data collected to determine whether operations in the area are financially viable, a calculation that includes production potential, the acreage under the company's control, and the current value of the resource. A site could remain dormant for several years while the company weighs the costs and benefits and waits for the right economic conditions to materialize. The time for deliberation is limited by states, however, which require the operator to either put a well into production within a certain timeframe—which varies by state—or temporarily or permanently abandon the site.

7 U.S. Environmental Protection Agency (EPA), "Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations," (Washington, DC: October 2002), 2.

8 Ground Water Protection Council, "State Oil and Gas Regulations Designed to Protect Water Resources" (2014), 12, http://www.gwpc.org/sites/default/files/files/Oil%20and%20Gas%20Regulation%20Report%20Hyperlinked%20Version%20Final-rfs.pdf.

9 Maryland Institute for Applied Environmental Health (School of Public Health, University of Maryland), "Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland" Prepared for the Maryland Department of the Environment and the Maryland Department of Health and Mental Hygiene (July 2014), 47, 93, http://www.marcellushealth.org/uploads/2/4/0/8/24086586/final_report_08.15.2014.pdf.

What might my community experience?

With the installation of project infrastructure, drilling of a well, and the arrival of out-of-town workers, many of the impacts that communities experience due to shale development begin at this stage, although they may differ in intensity in later phases of the process. Your community might see an increase in traffic, road dust, and noise—and perhaps experience a change in the viewshed—as project infrastructure is installed. One of the most dramatic effects in many communities, particularly in small towns and rural areas, is the arrival of outside contract workers, who can bring changes to the economy, social structure, and health profile of the local community over the life cycle of the project.

POPULATION INFLUX AND BOOM-AND-BUST EFFECTS

In extractive sector industries such as mining or conventional oil and gas development, it has long been recognized that the establishment of a project—or even the prospect of one—can lead to a population increase in local communities as non-residents move to the area for jobs and other benefits afforded by the project (a phenomenon also known as *in-migration*). While there are economic benefits to be gained from this population growth, depending on the profile of the community and the level of in-migration, it can strain local infrastructure, services, and government capacity to respond to changes.

Moreover, when the project ends and benefits dwindle, the trend can be reversed as the local economy declines and people leave the area. As described under Quality of Life—Economic Impacts below, if not planned for and managed appropriately, this *boom-and-bust* cycle can leave the community in a worse economic situation than at the outset. Early planning to manage and mitigate population influx is essential, as is planning for the effective management of tax revenues and royalties to help communities prepare for the long term and the end of the project life cycle.

While many health issues associated with natural resource extraction in the exploration stage are related to population influx, others are tied to the presence of project infrastructure. Both types of impacts are discussed below.

What health considerations are there?

The activities that take place during the exploratory drilling stage can introduce a range of health concerns. The project has the potential to affect the community's air quality, water quality, safety, disease burden, and health-related quality of life (including changes to the local economy, society, noise level, and viewshed).

AIR QUALITY

Shale development can introduce a broad range of local air quality concerns, some of which appear later in the development and production phases. Many of them begin with the drilling of exploratory wells and carry on through the later phases of development and production. The major sources of potential air quality impacts include venting and flaring of natural gas from wells, and fugitive emissions from oil and natural gas processing equipment; diesel-powered trucks and machinery; road dust; evaporation from storage pits; and dust from silica sand (see Box 6 on silica dust). Depending on the people affected and the exposure levels and pathways, these emissions can potentially provoke a variety of health effects, ranging from a nuisance, to acute to chronic respiratory problems, to psychological stress caused by the perception of worsened air quality. For a summary of the potential health effects of air pollutants from shale development, see Table 3.

While there are few studies of air quality in the vicinity of shale development sites, there are numerous documented community complaints of odors and other symptoms consistent with exposure to contaminants from oil and gas operations, such as upper respiratory ailments and skin irritation.[10] One Colorado study measured air samples near well pads during the well completion phase and found that volatile organic compounds (VOCs), an ozone precursor, were present more frequently and at higher concentrations than in regional ambient air samples.[11] Residents nearest to the well pads were found to be at higher risk of acute and sub-chronic respiratory, neurological, and reproductive effects.[12]

In another study in the Barnett Shale region of Texas, researchers established a regional air monitoring network to monitor for VOCs near Dallas-Fort Worth, an area of high-density shale development.[13] They compared the monitoring data to a variety of regulatory health-based air comparison values (HBACVs) and found that none of the VOCs measured exceeded the HBACVs, concluding that the community was not being exposed to VOCs at a level that would cause a health concern.[14] Given that this was a community-scale study, the authors noted that individual property owners could potentially be exposed at higher or lower levels than those measured.[15]

In addition to monitoring location, the variability of air emissions at shale development sites (due to the intermittent use of equipment; the varying composition of shale formations and fracturing fluids; and the influence of weather patterns and terrain, among other factors) could be responsible for differing outcomes between the Texas and Colorado studies.[16]

10 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development," Environmental Science and Technology (2014), 8310–11.

11 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards," 8310.

12 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards," 8314.

13 Several previous air quality studies in the Dallas-Fort Worth area indicated that VOC emissions did not exceed air quality standards and that shale development is not the largest source of emissions (motor vehicles are). See B. Zielinska, D. Campbell, V. Samburova, "Impact of Emissions from Natural Gas Production Facilities on Ambient Air Quality in the Barnett Shale Area: A Pilot Study," Journal of the Air Waste Management Association 64 (December 2014), 1369-1383, http://www.ncbi.nlm.nih.gov/pubmed/25562933; Rachel Rawlins, "Planning for Fracking on the Barnett Shale: Urban Air Pollution, Improving Health Based Regulation, and the Role of Local Governments," Virginia Environmental Law Journal 31 (2013), 226-306, http://lib.law.virginia.edu/lawjournals/sites/lawjournals/files/2.%20Rawlins%20-%20Barnett%20Shale.pdf; Charles G. Groat and Thomas W. Grimshaw, Fact-Based Regulation for Environmental Protection in Shale Development, report by the Energy Institute (University of Texas-Austin: February 2012), http://www.velaw.com/UploadedFiles/VEsite/Resources/ei_shale_gas_reg_summary1202%5B1%5D.pdf. The 2014 Bunch et al. study aimed to build on previous shorter-term studies.

14 A.G. Bunch, C.S. Perry, L. Abraham, D.S. Wikoff, J.A. Tachovsky, J.G. Hixon, J.D. Urban, M.A. Harris, L.C. Haws, "Evaluation of Impact of Shale Gas Operations in the Barnett Shale Region on Volatile Organic Compounds in Air and Potential Human Health Risks," Science of the Total Environment 468–469 (2014), 832–833, http://www.sciencedirect.com/science/article/pii/S0048969713010073.

15 Bunch et al., "Evaluation of Impact of Shale Gas Operations," 841.

16 Gregg P Macey, Ruth Breech, Mark Chernaik, Caroline Cox, Denny Larson, Deb Thomas, and David O Carpenter, "Air Concentrations of Volatile Compounds near Oil and Gas Production: A Community-Based Exploratory Study," Environmental Health 13 (2014), 3, http://www.ehjournal.net/content/13/1/82#B21.

Some researchers have concluded that further study—including community-based research—is needed in order to account for the potential cumulative impacts of the various sources of air pollution over time at shale development sites.[17, 18]

Venting and flaring

Prior to the installation of equipment for collecting natural gas at an oil or gas well site, operators historically ***vented*** or ***flared*** the natural gas produced by the exploratory well. Venting has the effect of releasing methane, the primary component of natural gas—along with VOCs like benzene, toluene, ethyl benzene, and xylene (the BTEX chemicals)—directly into the atmosphere. Methane itself is principally a safety hazard if it accumulates in closed spaces; it can cause asphyxiation or explosions at high concentrations. VOCs can cause health issues such as respiratory problems and eye and skin irritation and, under certain conditions, can combine with other hydrocarbons to produce ground-level ozone, which might cause lung damage at high exposure levels. Chronic and prolonged exposure to ozone can result in asthma, lung disease, and cardiovascular effects.

As an alternative, flaring can take place in a closed incinerator box or, more commonly, at the top of a tall flare stack. The operator may also flare the gas when testing well flow or in emergency situations to prevent explosions or fires. Flares have a destruction efficiency of at least 98%,[19] thus significantly reducing methane and VOC emissions. Natural gas flaring principally forms carbon dioxide and water, but also results in some residual emissions of combustion byproducts, such as carbon monoxide and nitrogen oxides.[20] Flaring typically lasts between three and ten days and can create loud noise and heat, often requiring companies to notify local communities and fire departments before the burn takes place.

To avoid the environmental and health issues associated with venting, incinerating, or flaring the gaseous materials during a well completion, many companies now capture the marketable gas in a process referred to as a ***green completion***. Effective January 2015, new EPA regulations under the Clean Air Act (Amendment of New Source Performance Standards[21]) require 95% of VOCs from natural gas wells to be captured by green completions[22] as the well is prepared for production. Under the EPA rules, venting, incinerating, or flaring may still occur under certain circumstances; for example, during periodic maintenance and emergencies.

In August 2015, the EPA issued additional proposed rules that apply green completion requirements to shale oil wells.[23] The rules will apply only to sources newly constructed or modified after the date of proposed rule publication in the Federal Register (September 18, 2015). The agency intends to have

17 Charles W. Schmidt, "Blind Rush? Shale Gas Boom Proceeds Amid Human Health Questions," ***Environmental Health Perspectives*** 119, no.8 (August 2011), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3237379.

18 Macey et al., "Air Concentrations of Volatile Compounds," 1.

19 Dana R. Caulton et al., "Methane Destruction Efficiency of Natural Gas Flares Associated with Shale Formation Wells," Environmental Science and Technology 48, no. 16 (July 30, 2014), 9548-9554, http://pubs.acs.org/doi/abs/10.1021/es500511w.

20 U.S. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors," AP-42, Fifth Edition (1995), 13.5-1 – 13.5-3, http://www3.epa.gov/ttnchie1/ap42/ch13/final/c13s05.pdf.

21 U.S. Environmental Protection Agency, "EPA's Air Rules for the Oil and Natural Gas Industry: Summary of Key Changes to the New Source Performance Standards," accessed November 21, 2014, http://www.epa.gov/airquality/oilandgas/pdfs/20120417changes.pdf.

22 Green completion technologies vary by basin type.

23 U.S. EPA, "Proposed Climate, Air Quality and Permitting Rules for the Oil and Natural Gas Industry: Fact Sheet," 1, http://www3.epa.gov/airquality/oilandgas/pdfs/og_fs_081815.pdf.

the final rules in place in 2016. (For more information on laws and regulations, see Appendix C.)

Fugitive emissions

Local air quality might not only be impacted through operational releases of gases, but also through fugitive emissions of methane and VOCs due to leakage at wellheads, pipelines, storage tanks, compressors, and other equipment. There is uncertainty about how much leakage occurs and studies have drawn varying conclusions, depending on the method used to calculate emissions. In light of the new EPA requirements for green completions and the reduction of fugitive emissions from equipment and infrastructure, fugitive emissions from shale development should be significantly reduced.[24, 25] EPA's August 2015 proposed rules require operators to locate and plug leaks from pneumatic pumps, pneumatic controllers, and compressor stations, among other sources.

Diesel-powered trucks and machinery

The estimated 1,148 one-way heavy truck trips during the early phase of well development[26] can result in significant emissions from diesel fuel combustion. The preparation of drilling sites and construction of rigs and other industrial infrastructure require operation of heavy machinery, which is often diesel-powered. Once well drilling operations begin, diesel-powered generators usually power the drills as well as the pumps and compressors that force hydraulic fracturing fluid down wells and funnel natural gas through pipelines.

Diesel fuel contains $PM_{2.5}$, or fine particulate matter, that can penetrate deep into the lungs if inhaled. Exposure to diesel fuel exhaust and its components (such as arsenic, benzene, formaldehyde, and nickel) can cause immediate health effects such as cough, headaches, lightheadedness, and irritation of the eyes, nose, and throat. It can exacerbate respiratory illnesses, and studies have indicated that long-term exposure can lead to the increased risk of lung cancer.[27] For vulnerable populations, such as the elderly or those with respiratory conditions, exposure to high levels of fine-particle pollution is linked to increases in hospital admissions, emergency room visits, asthma attacks, and even premature deaths.[28]

The many diesel-powered engines used in shale development also result in emissions of carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and volatile organic compounds (VOCs). Under certain conditions, NO_x and VOCs can combine to form ground-level ozone, which brings its own health concerns (see Table 3).

In 2007, EPA issued the "Highway Diesel Rule," which set new emissions standards for heavy-duty vehicles. This new rule is expected to reduce harmful emissions from diesel fuel by 90%. The NIEHS Working Group on Unconventional Natural Gas Drilling Operations indicated that the impact of this rule on diesel fuel emissions from shale development operations is unknown and an important subject for further study.[29]

---

24 U.S. Environmental Protection Agency, ***EPA's Air Rules for the Oil and Natural Gas Industry: Summary of Key Changes to the New Source Performance Standards***, accessed November 21, 2014, http://www.epa.gov/airquality/oilandgas/pdfs/20120417changes.pdf.

25 U.S. EPA, "Proposed Climate, Air Quality and Permitting Rules for the Oil and Natural Gas Industry: Fact Sheet," 1, http://www3.epa.gov/airquality/oilandgas/pdfs/og_fs_081815.pdf.

26 New York State Department of Environmental Conservation, ***High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement (SGEIS)*** (April 2015), 6-305, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch6b.pdf.

27 California Office of Environmental Health Hazard Assessment, "Health Effects of Diesel Exhaust," accessed December 6, 2014, http://oehha.ca.gov/public_info/facts/dieselfacts.html.

28 California Office of Environmental Health Hazard Assessment, "Health Effects of Diesel Exhaust."

29 Penning et al., "Environmental Health Research Recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations," Environmental Health Perspectives 122.14 (November 2009), 10.

Road dust

The construction and maintenance of oil and gas operations entails the transport of heavy equipment and truck traffic on local roads. New access roads may also be constructed to accommodate this traffic. The particulate matter ($PM_{2.5}$ and PM_{10}) generated can cause respiratory effects, particularly in vulnerable individuals. Dust can also worsen visibility conditions on roads, which can lead to traffic accidents.

Evaporation pits

Large surface pits that store produced water and other wastewater from the shale development process can be a source of emissions when VOCs and other hazardous air pollutants (HAPs) volatilize from the stored water. While the use of pits is declining as the industry transitions to the use of steel storage tanks for wastewater, pits remain the most common method for wastewater storage.[30] As a result, states have been increasing regulatory requirements for pits and standards for pit liners in particular.

Frac sand mining from the sky in Wisconsin. Oct 2013. Photo by Ted Auch. LightHawk provided aerial support: www.lighthawk.org.

Frac sand mining. Wisconsin 2013. Photo by Brook Lenker.

30 Ground Water Protection Council, “State Oil & Gas Regulations Designed to Protect Water Resources” (2014), 10, http://www.gwpc.org/sites/default/files/files/Oil%20and%20Gas%20Regulation%20Report%20Hyperlinked%20Version%20Final-rfs.pdf

BOX 6. FOCUS ON SILICA DUST AND SHALE DEVELOPMENT OPERATIONS

As silica sand is commonly used as a proppant during the hydraulic fracturing of shale deposits—requiring up to 10,000 tons of sand for the fracturing and re-fracturing of a single well[31] —the mining of silica sand for shale development operations has increased dramatically in recent years. Much of this silica is mined and processed in western Wisconsin, where the number of active silica sand facilities increased from 7 in 2010 to 85 in 2015.[32, 33] Illinois, Texas, and Minnesota also have significant silica sand facilities.[34] This boom in the production of silica sand has led to concerns about increased exposures for workers and residents near sand mining and shale development operations.

What are the health concerns with silica dust?

Silica dust, officially known as respirable crystalline silica, is composed of microscopic particles about 100 times smaller than ordinary beach or playground sand. It has long been known that silica dust creates health risks for employees working in certain industries, including during the mining of this naturally occurring mineral. Health risks from exposure include respiratory problems like bronchitis and asthma; chronic obstructive pulmonary disease (COPD); silicosis, which is a permanent scarring and chronic inflammation of lung tissue; lung cancer; and kidney disease. Exposure has also been associated with some autoimmune disorders like rheumatoid arthritis and lupus, as well as with heart disease.[35]

What is workers' exposure to silica?

In June 2012, the Occupational Safety and Health Administration (OSHA) disseminated a hazard alert for workers in the oil and gas industry, based on air samples taken at shale development sites.[36, 37] Many samples showed potential exposure levels above those considered safe, and some sites had levels ten times or more above the current permissible exposure limit (PEL). In September 2013, based on new research and analysis, the OSHA proposed more stringent standards for silica exposure.[38] If adopted, the new regulations would limit worker exposure to a PEL of 50 micrograms of respirable crystalline silica per cubic meter of air, averaged over an 8-hour workday. In addition, OSHA suggested provisions for measuring exposures and for reducing or mitigating risk. The National Industrial Sand Association (NISA), an industry group, has also developed a program for eliminating the adverse health effects of inhaled respirable silica through a program of careful monitoring and management of exposures.[39]

What is the community's exposure to silica?

The risks to communities in proximity to sand mining and shale development operations are currently not well understood. Community members near sand mining sites have voiced concerns about the local air quality and potential water contamination due to both the silica dust around the sites and the chemicals used in processing the sand. Silica dust could also affect residents living near rail lines transporting silica sand. In addition, some have pointed out that agricultural soils around mining sites may be compromised as the dust blows across farmland.[40]

To better understand the risks to communities near silica sand mines, in September 2013 the National Institutes of Health (NIH) approved a grant to the University of Iowa to study the impact of mines on respirable crystalline silica levels in nearby communities.[41] The researchers plan to take air samples from nearby homes, as well as to assess silica sand migration during rail transport.

What can be done to address health concerns?

Operators: The OSHA-NIOSH hazard alert and the NISA program contain the following recommendations that companies should undertake to protect workers:

- exploring the safety and effectiveness of alternative proppants
- monitoring the air at well pads for respirable silica using the new proposed standards
- controlling dust exposure through wetting down the sand and using air filters in both vehicles and buildings at the site
- providing respiratory protection, training, and hazard information to workers
- establishing medical monitoring of exposed workers[42]

Groups concerned about the effects on communities have also made suggestions for improving public safety, such as installing air monitors every 1,000 feet around the perimeter of sand mining facilities and using closed-car rail transport when possible.[43]

---

31 Zahra Hirji, "'Frac Sand' Mining Boom: Health Hazard Feared," ***Inside Climate News***, November 5, 2013, http://insideclimatenews.org/news/20131105/frac-sand-mining-boom-health-hazard-feared-lawmakers-aim-ease-regulation.

32 Zahra Hirji, "'Frac Sand' Mining Boom."

33 Wisconsin Department of Natural Resources, "Locations of Industrial Sand Mines and Processing Plants in Wisconsin," last revised September 8, 2015, http://dnr.wi.gov/topic/Mines/ISMMap.html.

34 Zahra Hirji, "'Frac Sand' Mining Boom."

35 Centers for Disease Control and Prevention, "Workplace Safety and Health Tips: Silica" (July 2013), http://www.cdc.gov/niosh/topics/silica.

36 Occupational Safety & Health Administration (OSHA), "OSHA-NIOSH Hazard Alert: Worker Exposure to Silica during Hydraulic Fracturing," accessed December 6, 2014, https://www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.html.

37 Eric Esswein, Max Kiefer, John Snawder, and Michael Breitenstein, "Worker Exposure to Crystalline Silica During Hydraulic Fracturing," ***NIOSH Science Blog*** (May 23, 2012), http://blogs.cdc.gov/niosh-science-blog/2012/05/23/silica-fracking.

38 OSHA, "OSHA's Proposed Crystalline Silica Rule: Overview" (September 2013), https://www.osha.gov/silica/factsheets/OSHA_FS-3683_Silica_Overview.html.

39 National Industrial Sand Association, "Occupational Health Program for Exposure to Crystalline Silica in the Industrial Sand Industry" (2011), http://sand.org/Silica/Occupational/Health/Program.

40 Wisconsin League of Conservation Voters, "Frac Sand Mining," accessed December 6, 2014, http://conservationvoters.org/issues/frac-sand-mining.

41 University of Iowa, Environmental Health Sciences Research Center, "Exposure Assessment and Outreach to Engage the Public on Health Issues from Frac Sand Mining," accessed December 6, 2014, http://cph.uiowa.edu/ehsrc/fracsand.html

42 OSHA, "OSHA-NIOSH Hazard Alert: Worker Exposure to Silica."

43 Wayne Feyereisn, "Potential-Public-Health-Risks-of-Silica-Sand-Mining-and-Processing," slide show, available as a PowerPoint presentation through ***The Sand Point Times***, accessed December 7, 2014, http://www.sandpointtimes.com.

TABLE 3. SELECT AIR CONTAMINANTS AND POTENTIAL HEALTH EFFECTS[44]

Note: It is important to take level of exposure into account when considering potential health effects of pollutants.

Pollutant	What is it?	Health Effect
Methane	A colorless, odorless, tasteless, and flammable gas that is the primary component of natural gas.	Toxicological data suggests that pure methane is nontoxic.[45] High concentrations can cause oxygen-deficient air spaces, fire hazards, or explosions.[46] Water contaminated with methane poses risk of explosion if ignited.[47]
Hydrogen Sulfide	Chemical air hazard produced during petroleum/natural gas drilling and refining.[48] It is a colorless, flammable, and extremely hazardous gas with a strong odor of rotten eggs at low concentrations. Regulations require onsite monitoring for hydrogen sulfide.	Lower levels and long-term exposure can cause eye irritation, headache, and fatigue.[49] Inhalation of very high concentrations can result in respiratory distress, respiratory arrest, or death.[50]
Benzene	A volatile organic compound (VOC) found in crude petroleum, natural gas, and diesel exhaust. May be released during well unloadings or other maintenance.[51] It is a colorless to light yellow liquid with an aromatic odor.	Low levels of exposure can result in irritation to skin, eyes, and respiratory systems, dizziness, tremors, and fatigue, among other symptoms; it has also been linked to reproductive effects.[52] Exposure to very high concentrations has been linked to leukemia and can result in death.[53]
Xylene	A VOC found in natural gas and hydrocarbons issuing from the well during the fracturing process. It is a colorless liquid with a sweet-smelling odor and is flammable.	Low levels of exposure are not associated with health risks.[54] However, short-term exposure at high levels can cause dizziness, confusion, irritation of skin, eyes, and throat, difficulty breathing, and possible changes in the liver or kidneys. Very high levels can result in unconsciousness or death.[55]
Toluene	A VOC found naturally in hydrocarbon deposits, and might be present in chemicals used during the drilling and fracking process.[56] It is a colorless liquid with distinct sweet odor.	Symptoms of low to moderate levels of toluene exposure include fatigue, confusion, memory loss, nausea, loss of appetite, and hearing and vision loss.[57, 58] Inhalation of high levels can cause light-headedness, dizziness, fatigue, unconsciousness, and death; it has also been linked to birth defects and kidney damage.[59]
Hexane	A VOC that is highly flammable; vapors can be explosive.[60] It is a colorless liquid with a gasoline-like odor.	Inhalation is most common route of exposure, but it can be found in contaminated private wells.[61] Inhalation of low levels is not associated with health effects.[62] High levels can result in nausea, eye and nose irritation, nerve damage, and paralysis.[63]

Pollutant	What is it?	Health Effect
Particulate matter ($PM_{2.5}$ and PM_{10})	$PM_{2.5}$ and PM_{10} are microscopic particles that can be found in diesel or smoke, near roads, or in dusty areas.	Due to their small size, these particles can be inhaled deeply into the lungs and some can enter the bloodstream, affecting the lungs and heart.[64] Individuals with heart or lung diseases, older adults, and children are particularly at risk. Short-term exposure can worsen existing lung or heart conditions.[65] Long-term exposure is linked to chronic bronchitis and premature death in some cases.[66]
Ground-level ozone (smog)	Under certain conditions, ozone can be formed when VOCs react with nitrogen oxide, which is found where combustion occurs, such as in diesel engines.	Short-term exposure can cause cough, reduced lung capacity, throat irritation, and other temporary respiratory effects.[67] Evidence about the effects of long-term exposure is inconclusive, although some studies link daily exposure to elevated levels of ozone with asthma, cardiovascular effects, increased hospital admissions, and increased daily mortality.[68] Children, older adults, and people with lung disease are at greatest risk.[69]

44 Modeled on Alliance of Nurses for Healthy Environments, "Facts on Fracking: What Healthcare Providers Need to Know," accessed November 21, 2014, http://concernedhealthny.org/wp-content/uploads/2013/10/ANHE-Fact-on-Fracking-Providers.pdf

45 Seth Shonkoff, Jake Hays, and Madelon L. Finkel, "Environmental Public Health Dimensions of Shale and Tight Gas Development" *Environmental Health Perspectives* 122, Issue 8 (August 2014), http://ehp.niehs.nih.gov/1307866.

46 Indiana Department of Natural Resources, Division of Oil and Gas, Division of Reclamation, and Indiana State Department of Health, "Methane Gas & Your Water Well: A Fact Sheet for Indiana Water Well Owners" (no date), http://www.in.gov/isdh/files/OGMethaneInWellWater_(2).pdf.

47 New York State Department of Health, "A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development" (December 2014), http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf.

48 Occupational Safety and Health Administration (OSHA), "OSHA Fact Sheet: Hydrogen Sulfide" (2005), https://www.osha.gov/OshDoc/data_Hurricane_Facts/hydrogen_sulfide_fact.pdf.

49 Agency for Toxic Substances and Disease Registry (ATSDR), Division of Toxicology and Human Health Sciences, "Hydrogen Sulfide-ToxFAQs" CAS # 7783-06-4 (October 2014), http://www.atsdr.cdc.gov/toxfaqs/tfacts114.pdf.

50 ATSDR, "Hydrogen Sulfide."

51 Centers for Disease Control and Prevention (CDC), "Facts about Benzene," (updated February 2013), http://www.bt.cdc.gov/agent/benzene/basics/facts.asp.

52 CDC, "NIOSH Pocket Guide to Chemical Hazards" (updated February 13, 2015), http://www.cdc.gov/niosh/npg/npgd0049.html.

53 CDC. "NIOSH Pocket Guide to Chemical Hazards."

54 ATSDR, "Xylene: Division of Toxicology and Environmental Medicine ToxFAQs" (August, 2007), http://www.atsdr.cdc.gov/toxfaqs/tfacts71.pdf.

55 ATSDR, "Xylene."

56 Valerie J. Brown, "Industry Issues: Putting Heat on Gas," National Center for Biotechnology Information (February 2007), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817691.

57 ATSDR, "Toluene: Division of Toxicology and Environmental Medicine ToxFAQs," CAS # 108-88-3 (February 2001), http://www.atsdr.cdc.gov/toxfaqs/tfacts56.pdf.

58 Valerie J. Brown, "Industry Issues."

59 ATSDR, "Toulene."

60 ATSDR, "n-Hexane," CAS ID # 110-54-3 (updated March 3, 2011), http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=68.

61 ATSDR, "Toxicological Profile for n-Hexane" (July 1999), http://www.atsdr.cdc.gov/toxprofiles/tp113.pdf.

62 ATSDR, "Toxicological Profile for n-Hexane."

63 ATSDR, "Toxicological Profile for n-Hexane."

64 U.S. EPA Office of Air and Radiation, "Particle Pollution and Your Health" (September 2003), http://epa.gov/pm/pdfs/pm-color.pdf.

65 U.S. EPA Office of Air and Radiation, "Particle Pollution and Your Health."

66 U.S. EPA Office of Air and Radiation, "Particle Pollution and Your Health."

67 U.S. EPA, "Health Effects of Ozone in the General Population" (updated January 30, 2015), http://www.epa.gov/apti/ozonehealth/population.html#effects.

68 U.S. EPA, "Health Effects of Ozone in the General Population."

69 U.S. EPA, "Ground-level Ozone: Health Effects" last updated October 1, 2015, http://www3.epa.gov/ozonepollution/health.html.

WATER QUALITY

What chemicals are used in the hydraulic fracturing process?

Hydraulic fracturing involves pumping *fracturing fluid* into oil and gas wells at high pressure in order to fracture underground rock formations and release the hydrocarbons within. Fracturing fluid contains a combination of chemicals to reduce friction, prevent the growth of microorganisms, and prevent corrosion and damage to the wellbore and pipes. According to an EPA analysis of operator disclosures to FracFocus, chemical additives generally make up less than 1% by mass of the fluid; approximately 88% by mass is water.[70] The remainder of the mixture (approximately 10% by mass) consists of a *proppant*—usually silica sand—which is added to the fluid to hold open the fractures created in the shale formation and allow the oil or gas to flow.

The chemical components of the fracturing fluid vary, depending on the company and the characteristics of the well site. (See Table 4 for a list of common components in fracturing fluid and their uses.) The EPA analysis found that a median of 14 additive ingredients were used in fracturing fluids, ranging from 4 to 28 ingredients (5th to 95th percentile), but there were only a few ingredients that appeared in more than half the disclosures.[71] Some of the potential fracturing fluid additives are known to be toxic to mammals and harmful to human health, even at very low doses.[72, 73] In order to determine risks to human health, potential exposures, and exposure pathways need to be taken into account. In light of the diversity of fracturing fluid composition, the EPA study noted the importance of considering specific company practices at the local level.[74]

The FracFocus website (www.fracfocus.org), a joint initiative of the Groundwater Protection Council and the Interstate Oil and Gas Compact Commission, encourages companies to disclose the chemicals used in fracturing fluid. Initially voluntary, by late 2013 companies in 14 states were required to report the chemicals used in their shale development operations on FracFocus.[75] Another 6 states imposed some level of disclosure requirements, and this area of legislation continues to evolve.

The EPA analysis notes that its assessment of FracFocus disclosures was limited in part by the designation of some of fracturing fluid ingredients as confidential business information (CBI). Over 70% of the disclosures reviewed in the study contained at least one ingredient designated as CBI.[76] The operator practice of claiming some fracturing fluids as confidential information has caused some stakeholders to assert the information on FracFocus is incomplete and/or unreliable.

Finally, some companies have developed "green" fracturing fluids that reduce the volume of water required and/or replace

70 U.S. Environmental Protection Agency (EPA) Office of Research and Development (ORD), "Analysis of Hydraulic Fracturing Fluid Data from the FracFocus Chemical Disclosure Registry 1.0" (Washington, DC: March 2015), 62, www.epa.gov/hfstudy.
71 U.S. EPA ORD, "Analysis of Hydraulic Fracturing Fluid Data," 63.
72 American Chemical Society, "A new look at what's in "fracking" fluids raises red flags" (August 13, 2014), http://www.acs.org/content/acs/en/pressroom/newsreleases/2014/august/a-new-look-at-whats-in-fracking-fluids-raises-red-flags.html.
73 U.S. House of Representatives, Committee on Energy and Commerce, Minority Staff, "Chemicals Used in Hydraulic Fracturing" (April 2011), 1–2.
74 U.S. EPA ORD, "Analysis of Hydraulic Fracturing Fluid Data," 65–66.
75 U.S. Department of Energy, "Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0" (Washington, DC: March 28, 2014), 9, http://energy.gov/sites/prod/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.
76 U.S. EPA ORD, "Analysis of Hydraulic Fracturing Fluid Data," 63–64.

some of the toxic chemicals with safer ones, including eco-friendly biocides.[77, 78, 79] These green alternatives may become more widely used as the technology improves and the price drops, particularly in areas where freshwater supplies are limited.[80]

What happens to the fracturing fluid after it is pumped into the well?

Once the fracturing fluid has been injected into the shale formation, some of it returns to the surface as *flowback*. The amount of flowback returning varies widely depending on the geologic characteristics of the formation, ranging from 30% to 70% of the original volume,[81] while the remaining portion of the injected fluid remains trapped in the shale. After it interacts with the existing water and minerals in the target formation and the wellbore, the composition of the injected fluid changes. When the flowback returns to the surface, it can contain total dissolved solids (TDS), heavy metals, volatile organic compounds (VOCs), and naturally occurring radioactive material (NORM) from the deep rock strata. Most of the flowback emerges in the first two weeks after hydraulic fracturing has taken place. After that, a small amount of fluid, referred to as *produced water*, continues to flow from the well along with the oil or gas during production. Produced water is the naturally occurring fluid present in the target formation (see Box 7). For the purposes of this guidebook, we will hereafter refer to both types of water flowing from the well as *produced water*.

BOX 7. COMPONENTS OF PRODUCED WATER

The water in the target geologic formation, which comes up to the surface as a component of hydraulic fracturing wastewater, can contain the following constituents:

- total dissolved solids (TDS), which are mostly salts
- heavy metals, such as lead, arsenic, and chromium, which are harmful to human health even at low concentrations and can bioaccumulate in food chains
- VOCs, including the BTEX chemicals
- NORM, which is present in small amounts in shale and other geological formations (see Box 8)

How is wastewater handled?

There are several options for the management and disposal of well site wastewater, which includes produced water. First, it is temporarily stored at the site, either in open pits (which may or may not have a protective liner) or tanks. The industry is increasingly moving toward the use of tanks because the risk of wastewater seeping into the groundwater is greater with open pits. Furthermore, open pits can overflow during periods of heavy rains, allowing the wastewater to enter surface waters; wastewater in the pits can also evaporate, introducing pollutants into the air. With tanks, it is easier to detect and plug any leaks. On the other hand, tanks are more likely to have catastrophic failures, leading to the release of all their contents. For this reason, tanks are often surrounded

77 Patrick J. Kiger, "Green Fracking? 5 Technologies for Cleaner Shale Energy," ***National Geographic Daily News***, March 19, 2014, http://news.nationalgeographic.com/news/energy/2014/03/140319-5-technologies-for-greener-fracking.

78 Apache Corporation, "Greener Chemicals," accessed October 3, 2015, http://www.apachecorp.com/Sustainability/Environment/Chemicals/Greener_chemicals/index.aspx.

79 Nathaniel Gronwold, "Entrepreneurs Turn to Bacteria to Fight Fracking Corrosion," (July 3, 2014), ***Energywire.***

80 Kiger, "Green Fracking?"

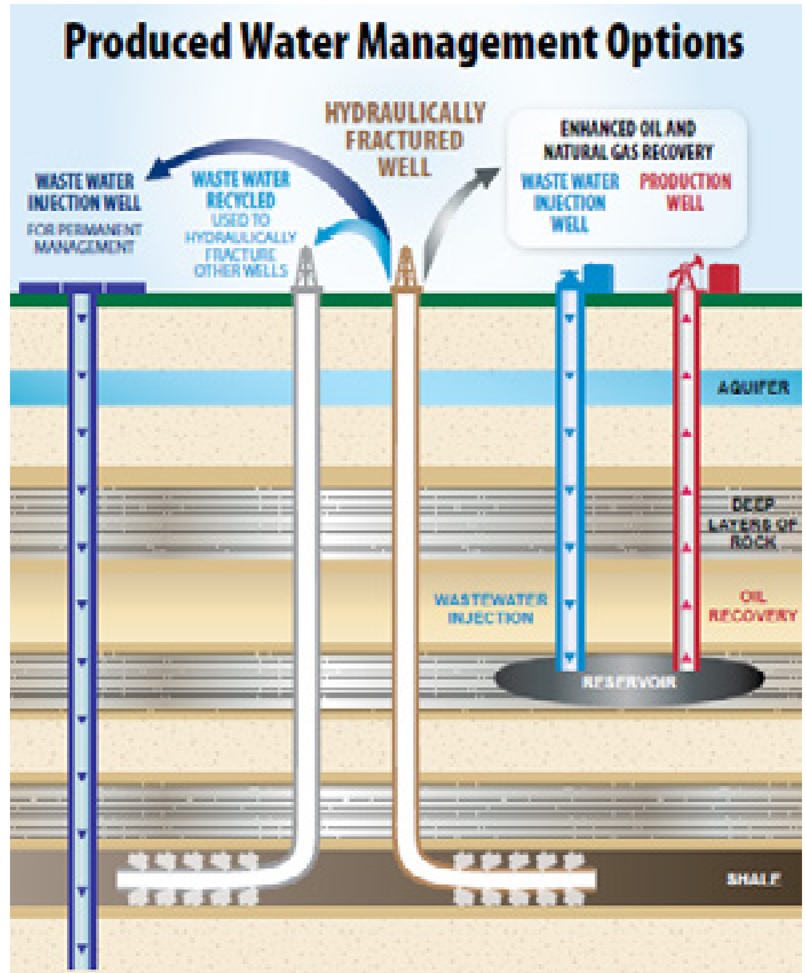
81 U.S. DOE, ***Modern Shale Gas, Development in the United States: A Primer (2***009), 66.

by a secondary containment.[82] Many states require secondary containments, but most have yet to set standards for tank materials, which can also be a concern.[83] For example, produced water may corrode uncoated steel over time.

Some companies recycle the wastewater for reuse in their fracturing operations and other uses. One method of disposal is to inject the wastewater in deep underground wells, which are isolated from water sources by thousands of feet of impermeable rock. These wells are permitted under the Underground Injection Control (UIC) program, which is regulated under the Safe Drinking Water Act (SDWA). There are six categories (or classes) of UIC injection wells; the oil and gas industry uses Class II injection wells to 1) permanently dispose of wastewater or 2) reinject it at the site of a production well in order to improve the recovery of the resource (see Figure 3). This method of disposal is more common in states where the underlying geology is favorable.

The wastewater could also be transported by truck or pipeline to a municipal treatment facility that is permitted to process industrial waste and drilling wastewater, either nearby or in another state. Questions have been raised, however, as to whether municipal treatment facilities have the capacity to handle the volume and type of wastewater generated by shale operations, and some facilities have refused to accept wastewater from shale operations.[84, 85] The wastewater could also be processed at a private industrial treatment facility that conforms to the same or similar regulatory requirements as the public treatment plants. Finally, depending on the treatment process, the wastewater can also be recycled for use in other industrial operations, as irrigation water, or even as drinking water.

FIGURE 3. PRODUCED WATER MANAGEMENT OPTIONS



Source: Independent Petroleum Association of America, "Induced Seismicity."

82 Ground Water Protection Council (GWPC), "State Oil & Gas Regulations Designed to Protect Water Resources" (2014), 11, http://www.gwpc.org/sites/default/files/Oil%20and%20Gas%20Regulation%20Report%20Hyperlinked%20Version%20Final-rfs.pdf.

83 GWPC, "State Oil and Gas Regulations," 11.

84 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards,"8313.

85 Geological Society of America, "Hydraulic Fracturing," 12.

TABLE 4. EXAMPLES OF FRACTURING FLUID ADDITIVES AND MAIN COMPOUNDS[86]

Additive Type	Main Compound(s)	Purpose
Acid	Hydrochloric or muriatic acid	Helps dissolve minerals and initiate cracks in the rock
Antibacterial agent	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive byproducts
Breaker	Ammonium persulfate	Allows a delayed breakdown of the fracturing gel
Clay stabilizer	Potassium chloride	Brine carrier fluid
Corrosion Inhibitor	N,n-dimethyl formamide	Prevents the corrosion of pipes
Crosslinker	Borate salts	Maintains fluid viscosity
Defoamer	Polyglycol	Lowers surface tension and allows gas to escape
Foamer	Acetic acid (with NH4 and NaNO2)	Reduces fluid volume and improves proppant carrying capacity
Friction Reducer	Petroleum distillate	Minimizes friction in pipes
Gel guar gum	Hyroxyethyl	Helps suspend the sand in water
Iron Control	Citric Acid	Prevents precipitation of metal oxides
Oxygen Scavenger	Ammonium bisulfate	Maintains integrity of steel casing of wellbore; protects pipes from corrosion by removing oxygen from fluid
pH Adjusting Agent	Sodium or potassium carbonate	Adjusts and controls pH of fluid
Proppant	Silica, sometimes ceramic particles	Holds open (props) fractures to allow fluids (oil and/or natural gas) to escape from shale
Scale Inhibitor	Ethylene glycol	Reduces scale deposits in pipe
Solvents	Stoddard solvent, various aromatic hydrocarbons	Improve fluid wettability or ability to maintain contact between the fluid and the pipes
Surfactant	Isopropanol	Increases the viscosity of the fracture fluids and prevents emulsions

86 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards," 8311.

How is wastewater containing NORM handled?

If the levels of NORM in the wastewater exceed standards set by state regulations or by OSHA for exposure risks, the operator is required to take it to a facility licensed to process such waste. Companies must comply with the Resource Conservation and Recovery Act (RCRA) standards for hazardous waste.[87] If the NORM levels are lower than those standards, then the wastewater can be disposed of using the methods described above for wastewater from oil and gas operations.

Could the water resources in my community be exposed to hazardous chemicals?

The principal pathway for the chemicals and other contaminants involved in shale development to enter local waterways is through improper management and disposal of wastewater or spills. Containment ponds, impoundments, and tanks can leak, allowing wastewater to enter surface and groundwater. Accidents involving the trucks transporting wastewater or other hazardous materials can result in spills, as can faulty equipment and human error. Additional water quality degradation may result from increased sedimentation caused by the construction of well pads and use of unpaved roads.

Determining the frequency of spills can be difficult because there is no national reporting system for oil and gas industry spills and other incidents, although state and federal regulations require reporting to states under certain circumstances. One EPA analysis of available data from 11 states from the period from 2006 to 2012 identified 457 spills at hydraulic fracturing well pad sites.[88] Low-volume spills (up to 1,000 gallons) were the most common, with relatively few high-volume spills (20,000 gallons or more). Produced water was the material most frequently spilled, usually due to human error. The incidents most often took place at storage units. The study found that the spilled material came into contact with the environment in over half the incidents, mostly with the soil, although in 33 cases the fluid reached surface or groundwater. Operators are required to have procedures and systems in place to properly manage any incidents or spills that might occur.

Some have expressed concern about another pathway for the chemicals involved in shale development to reach water resources—the possibility of fracturing fluid or other contaminants migrating into underground aquifers during the hydraulic fracturing process. The Geological Society of America notes that thus far there are possibly two such cases, and in one of them the fracturing operation was within 420 feet of the aquifer.[89] In general, fracturing activities are isolated from groundwater sources by thousands of feet of impermeable rock,[90] although wells must be drilled through usable groundwater in order to reach shale formations below. At groundwater depths, wellbores are encased in multiple thick layers of steel casing and concrete in order to prevent communication between

87 U.S. Environmental Protection Agency Office of Water, ***A Regulators' Guide to the Management of Radioactive Residuals from Drinking Water Treatment Technologies*** (Washington, DC: 2005), http://energy.wilkes.edu/PDFFiles/Library/EPA%20Guide%20to%20Treatment%20of%20Radionuclides%20in%20Wastewater%20Treatment.pdf.

88 The study authors note that this number is likely an under-estimate of total spills rated to shale development due to the difficulty of distinguishing them from other types of spills in the oil and gas sector and to incomplete data. The study also only took spills at well pad sites into account. U.S. Environmental Protection Agency Office of Research and Development, Review of State and Industry Spill Data: Characterization of Hydraulic Fracturing-Related Spills (Washington, DC: May 2015), 27, http://www2.epa.gov/sites/production/files/2015-05/documents/hf_spills_report_final_5-12-15_508_km_sb.pdf.

89 Geological Society of America, "Hydraulic Fracturing," 10.

90 An EPA analysis of disclosures to FracFocus found a median well depth of 8,100 feet, with a range of 2,900 to 13,000 feet (5th to 95th percentile).

the wellbore and water resources. Groundwater can become contaminated, however, if this protective casing and cement fails due to poor construction, and there have been instances of this occurring.[91] It is also possible that drilling the shallow section of a new well could allow for temporary communication between subsurface contaminants and groundwater resources before the well is cased.

It can be difficult to ascertain whether shale development operations have adversely affected local water supplies, largely because 1) baseline studies are not often performed and 2) many basins can naturally contain some of the hydrocarbons and metals accompanying shale development, such as methane. Nonetheless, the current scientific evidence indicates it is much more likely for leaks and spills to lead to surface water contamination than for the drilling and hydraulic fracturing of a well to cause groundwater contamination.[92]

The U.S. EPA has been studying the potential impact of shale development operations on drinking water resources, and released a draft assessment summarizing existing science and new EPA research in June 2015.[93] This external review draft concludes that although there are mechanisms through which shale development could impact drinking water resources, the study team did not find evidence of widespread, systemic impacts on U.S. drinking water supplies. It notes that the failure to detect such drinking water impacts could be due to 1) the absence of impacts on a nationwide scale or 2) insufficient and/or unavailable data.

Finally, emerging technologies might help to resolve some questions around water quality. There are efforts underway to develop tracers for fracturing fluids, which could help determine the fluid's fate in the environment.[94]

Stewart impoundment, PA. Photo by Bob Donnan, 2014

91 Paleontological Research Institution, "Water: Out of the Wells," *Marcellus Shale* 8 (November 2011), 10, http://www.museumoftheearth.org/files/marcellus/Marcellus_issue8.pdf

92 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards," 8312.

93 U.S. Environmental Protection Agency Office of Research and Development, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources: Executive Summary (External Review Draft) (Washington, DC: June 2015), ES-6, www.epa.gov/hfstudy. . At the time of release of this guidebook, the EPA's draft assessment is under review by the Science Advisory Board and is marked as not for citation. For this reason, other than mentioning the report's preliminary main conclusions, we are not drawing on any further details from this report in this version of the guidebook.

94 Dave Levitan, "Algae in Glass Cases Could Determine Fracking's Toll," *Scientific American* (March 6, 2014), http://www.scientificamerican.com/article/algae-in-glass-cases-could-determine-frackinge28099s-toll.

BOX 8. FOCUS ON NATURALLY OCCURRING RADIOACTIVE MATERIALS (NORM)

What is NORM?

Radiation is a particular kind of energy given off by unstable atoms. Our natural surroundings—including air, water, and mineral resources—contain various amounts of radioactive material. Since these radiation-emitting elements have always been a normal part of our environment, they are called ***naturally occurring radioactive material***, or NORM.

What is the impact of radiation on humans?

Human beings are exposed to radiation from several sources, including NORM, the sun's rays, and medical procedures. Low-level exposure is constant and can alter molecules in the human body, but the body generally protects itself from long-term damage with routine repair mechanisms. In contrast, higher levels of exposure can lead to permanent damage and can contribute to the development of cancer and other diseases.[95]

What are the recommended threshold levels for radiation exposure?

The EPA has determined that any exposure to radiation carries some risk, and, as exposure doubles, risk doubles. Routes of exposure include inhalation, ingestion, and direct (external) exposure.[96, 97] One threshold for exposure set by the EPA applies to community drinking water systems.[98, 99, 100] Household radon levels and management have also been addressed by the EPA.[101]

Why is it relevant to shale development?

Shale and soil particulates at the earth's surface contain some level of NORM, but generally not in damaging amounts. NORM can be higher, however, in buried shale deposits, especially in the Marcellus Shale of northeast Pennsylvania, with emissions of up to 20 times the amount of radioactivity found in normal background emissions at the earth's surface. Radioactive materials can also become unusually concentrated in fluids and solids from human activity such as road building, mining, and energy development, forming what is called ***technologically enhanced radioactive material*** (TENORM). The processes of drilling and hydraulic fracturing in underground shale basins can thus introduce TENORM into the liquid and solid wastes from the site. Additionally, in the presence of high salt content, radioactive materials can form solids, which accumulate on the inside of pipes and equipment, posing a particular risk for oil and gas workers.[102]

Does NORM from shale development pose a risk to nearby communities?

Several recent studies have looked into the question of how much radiation communities may be exposed to during shale exploration and development. A 2012 Wilkes University study of Pennsylvania's Marcellus Shale basin suggested that improper management of liquid and solid wastes from well sites

95 United States Environmental Protection Agency, "Radiation and Health," updated June 29, 2015, http://www.epa.gov/radiation/understand/health_effects.html.
96 U.S. Environmental Protection Agency, "Radiation and Radioactivity," last updated January 23, 2013, http://www.epa.gov/radiation/understand/radiation_radioactivity.html.
97 U.S. Environmental Protection Agency, "Radiation Doses in Perspective," last updated 9/24/2013, http://www.epa.gov/radiation/understand/perspective.html.
98 U.S. Environmental Protection Agency, "Radionuclides in Drinking Water," updated March 6, 2012, http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/index.cfm.
99 U.S. Environmental Protection Agency, *The Radionuclides Rule,* June 2001, http://www.epa.gov/ogwdw/radionuclides/pdfs/qrg_radionuclides.pdf.
100 U.S. Environmental Protection Agency, "A Regulator's Guide to the Management of Radioactive Residuals from Drinking Water Treatment Technologies," July 2005, http://www.epa.gov/rpdweb00/docs/tenorm/816-r-05-004.pdf.
101 U.S. Environmental Protection Agency, "A Citizen's Guide to Radon," updated August 4, 2015, http://www.epa.gov/radon/pubs/citguide.html.
102 Courtney Sperger, Kristin Cook, Kenneth Klemow, "Does Marcellus Shale Pose a Radioactivity Risk?" Institute for Energy and Environmental Research of Northeastern Pennsylvania Clearinghouse, August 1, 2012, http://energy.wilkes.edu/pages/184.asp.

could potentially compromise drinking water supplies, especially those downstream from water treatment plants that receive shale development wastewater. The researchers concluded that radiation risks from both liquid and solid wastes and from radon may vary by region—and even across drilling sites within a region.[103] Another report from the University of Maryland School of Public Health reached a similar conclusion— that more information is needed, not just about radiation levels in wastewater and solid waste from shale development sites, but also at water treatment plants and landfills that receive this waste. Ultimately, it is important to examine potentially impacted drinking water for radiation levels.[104]

In early 2015, the Pennsylvania Department of Environmental Protection (DEP) released a report that assessed potential worker and public radiation exposure from shale development in the state.[105] The report concluded that there is little potential risk of radiation exposure to workers and the public from the development and production of natural gas or from the disposal and treatment of wastes, provided that the fluids are not spilled. The report therefore recommended that the state should add radium to its spill protocols; it also noted that long-term disposal protocols for TENORM waste should be reviewed.

What can be done to address health concerns? What have others done?

Landowners: The EPA recommends that individuals with private water wells test annually for constituents of concern, in this case radionuclides and radon. If standards are exceeded, the agency suggests retesting immediately and contacting local health officials. Some local health departments may provide free water testing. The EPA also suggests being aware of nearby activities that could potentially compromise well water.[106] Some states recommend that all private wells and community drinking water supplies be tested within a five-mile radius of a well pad.[107] Routine indoor radon testing is also recommended by the EPA, and in fact is required by some states as part of real estate transactions.[108]

Local officials: One example of a community solution to protect against potentially radioactive solid waste has been to test dump trucks as they enter a landfill. Using an outdoor radiation monitor will detect any radioactivity that exceeds a set threshold above background levels.

State officials: In 2011, the Pennsylvania DEP set a statewide model for management of wastewater from shale development, requesting that operators not send this byproduct to water treatment facilities that discharge into waterways. As a result, almost 97% of wastewater from Pennsylvania energy operations is now recycled, injected into underground receiving wells, or treated at facilities that do not discharge into waterways.[109]

Operators: Both the Wilkes University and the University of Maryland studies recommend that energy development companies and municipal road maintenance crews refrain from applying wastewater fluids to roads as a de-icing and dust control technique until further investigation can determine the safety of this practice. While the Pennsylvania DEP study found little potential for exposure from wastewater-treated roads, it still recommended further study of the issue.

103 Sperger et al., "Does Marcellus Shale Pose a Radioactivity Risk?"

104 Maryland Institute for Applied Environmental Health (School of Public Health: University of Maryland), "Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland," July 2014, http://www.marcellushealth.org/uploads/2/4/0/8/24086586/final_report_08.15.2014.pdf

105 Perma-Fix Environmental Services, Inc.,"Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) Study Report," prepared for the Pennsylvania Department of Environmental Protection (January 2015), http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-105822/PA-DEP-TENORM-Study_Report_Rev._0_01-15-2015.pdf.

106 U.S. Environmental Protection Agency, "Water: Private Wells," updated March 6, 2012, http://water.epa.gov/drink/info/well/faq.cfm.

107 Pennsylvania State University Extension Agency, "Drinking Water," accessed November 21, 2014, http://extension.psu.edu/natural-resources/water/marcellus-shale/drinking-water.

108 U.S. EPA, "A Citizen's Guide to Radon," updated August 4, 2015, http://www.epa.gov/radon/pubs/citguide.html.

109 The Associated Press, "Marcellus Shale Gas Drillers Recycling More Waste," *The Times-Tribune* (Scranton, PA), February 17, 2012, http://thetimes-tribune.com/news/marcellus-shale-gas-drillers-recycling-more-waste-1.1273083.

SAFETY

Shale energy development, as an industrial operation, comes with safety risks for both workers and the local community. Occupational fatalities in the United States are high in the oil and gas industry, at seven times the rate for all U.S. industries.[110] Unlike conventional oil and gas, however, shale development often takes place in close proximity to residences, in both rural and more heavily populated areas, which can also increase the risks to the public. As previously mentioned, *The Wall Street Journal* reported in 2013 that approximately 15.3 million people in the United States live within one mile of a well drilled since 2000.[111]

The types of incidents that can threaten the safety of workers and community residents—causing injuries and even death—include vehicular accidents, spills of wastes and chemicals, ***blowouts*** (i.e., sudden, uncontrolled releases of gases or fluids), explosions, fires, and exposure to high levels of airborne chemicals.

Vehicular Accidents

The leading cause of worker fatalities in the oil and gas industry is traffic accidents, which pose risks to both workers and the community. Traffic accidents have been on the rise in areas where shale development is occurring, with North Dakota, Pennsylvania, and Texas reporting increased road incidents involving industry trucks.[112] For example, Bradford County, Pennsylvania witnessed a 40% increase in truck traffic over a five-year period, with a corresponding increase in accidents involving large trucks.[113] The high rate of traffic accidents for the industry is attributed in part to the condition of the trucks, but may also be due to the oil and gas industry's exemption from the highway safety regulations that limit the length of truck drivers' shifts.[114]

Uncontrolled Releases of Gas or Fluids at the Wellhead

Another safety issue occurs when gas or fluids are unintentionally released at the wellhead, causing a blowout. These rare instances can occur in both conventional oil and gas development and shale development when high pressure zones are encountered in the wellbore or there is a failure of the well casing and cement, valves, or other mechanical equipment. For this reason, blowout prevention devices are installed early in the process of drilling a well. A report from the Energy Institute at the University of Texas at Austin noted that data regarding blowout frequency are not available for onshore oil and gas wells, but offshore wells report 1 to 10 blowouts per 10,000 wells that have not yet had blowout preventers installed.[115]

For workers, this can create exposure risks, through inhalation

110 OSHA, "Oil and Gas Extraction: Safety and Health Topics," accessed December 1, 2014, https://www.osha.gov/SLTC/oilgaswelldrilling. The federal Occupational Safety and Health Administration (OSHA) is the regulatory agency for workforce safety. The OSHA website houses a tool for the oil and gas industry that details potential health and safety hazards by stage of production, along with preventative measures and solutions for each: https://www.osha.gov/SLTC/etools/oilandgas/index.html (accessed November 22, 2014).

111 Gold and McGinty, "Energy Boom."

112 Mike Lee, "In North Dakota's Oil Patch, Wrecks Increase as Trucks Push onto Farm Roads," ***E&E News***, April 11, 2014; Resources for the Future, "Shale Gas Development Linked to Traffic Accidents in Pennsylvania," March 2014, http://www.rff.org/RFF/Documents/RFF-Resources-185_Infographic.pdf; "In Texas, Traffic Deaths Climb amid Fracking Boom," National ***Public Radio***, October 2014, http://www.npr.org/2014/10/02/352980756/in-texas-traffic-deaths-climb-amid-fracking-boom.

113 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards," 8311.

114 Ian Urbina, "Deadliest Danger Isn't at the Rig but on the Road," The New York Times (May 14, 2012), http://www.nytimes.com/2012/05/15/us/for-oil-workers-deadliest-danger-is-driving.html?pagewanted=all&_r=2&

115 Charles G. Groat and Thomas W. Grimshaw, ***Fact-Based Regulation for Environmental Protection in Shale Gas Development***, Energy Institute (Austin: The University of Texas at Austin, February 2012), http://heartland.org/policy-documents/fact-based-regulation-environmental-protection-shale-gas-development.

of hydrocarbons and contact with chemicals. These unplanned releases can also on rare occasions lead to explosions and fires on the well pad, which endanger both workers and possibly nearby residents.

Blowouts may also occur on the subsurface, which is harder to track, and may affect aquifers or water wells in the area. The University of Texas report cited two examples from conventional oil and gas development in Louisiana and Ohio in which underground pressure changes during drilling caused water wells in the vicinity to bubble or spout water.[116]

Gas Migration into Residential Water Wells and Homes

Residents living in proximity to shale wells have also expressed concern about the possibility of toxic gases accumulating inside their water wells and homes, with inhalation risks and the potential for explosions. In most cases, such reported incidents have been attributed to naturally occurring methane migration that is unrelated to any shale energy development in the vicinity.[117] A few methane explosions in homes or well houses located near shale gas operations have been reported in Colorado, Pennsylvania, and Texas, with investigators concluding that gas may have migrated from hydraulically fractured wells nearby. In almost all such cases, gas migration occurred because well integrity was compromised due to faulty casings and/or inadequate cementing of the casings.[118]

Hydrogen Sulfide

When drilling for oil and gas, workers run the risk of encountering hydrogen sulfide (or *sour gas*), a flammable, highly toxic gas with the odor of rotten eggs, although the odor becomes unnoticeable after a period of exposure. Although not common at conventional and shale development sites, hydrogen sulfide is toxic even at low concentrations; workers therefore wear meters to monitor for its presence. Low-level chronic exposure to hydrogen sulfide may also cause cumulative health risks for workers, as well as for nearby residents who can live many years in proximity to oil and gas facilities.[119]

Causes

Most safety incidents are caused by the following:

- an influx of trucks on local roads and unsafe driving behaviors, sometimes on the part of local drivers; inadequate driver training; drug use and fatigue while driving; and poorly maintained trucks[120]
- improper construction of wells or wastewater impoundments
- faulty equipment, often due to inadequate maintenance
- inadequately trained well pad personnel
- failure to follow recommended practices to prevent blowouts and spills
- over-pressurized gas
- weather, particularly extreme weather events

For options for addressing these safety concerns, see the "What Can Be Done?" section below.

116 Groat and Grimshaw, ***Fact-Based Regulation,*** 23.
117 Groat and Grimshaw, ***Fact-Based Regulation,*** 23.
118 Groat and Grimshaw, ***Fact-Based Regulation,*** 23-24.
119 Earthworks Action, "Hydrogen Sulfide," http://www.earthworksaction.org/issues/detail/hydrogen_sulfide#.VZwpomAreFI.
120 Ian Urbina, "Deadliest Danger Isn't at the Rig but on the Road," The New York Times (May 14, 2012), http://www.nytimes.com/2012/05/15/us/for-oil-workers-deadliest-danger-is-driving.html?pagewanted=all&_r=2&

DISEASES

Mobile labor forces can contribute to disease transmission within a community, whether they consist of long-haul truckers, migrant farm workers, military personnel, or, in this case, industry workers assigned to shale development sites during the exploratory drilling and development phases.[121]

In North America, the main reported communicable disease risk for communities undergoing shale gas development[122] appears to be an increase in the incidence of sexually transmitted diseases—notably chlamydia, gonorrhea, and syphilis—introduced by project workers as they pursue sexual contacts with local partners (see the Social Impacts section). In Pennsylvania's Marcellus Shale, for example, one study found that the average increase in the occurrence of chlamydia and gonorrhea cases was 62% greater in counties experiencing shale development over those that were not.[123] In another example, syphilis rates began rising in Alberta, Canada along with tar sands development in the province.[124]

There is some debate about whether adverse impacts such as an increase in the disease burden or increased crime levels are proportionate to the increase in population or are due to the particular characteristics of the temporary workforce. It is nonetheless evident that such increases, whether absolute or proportionate, can place a health burden on local health care infrastructure and resources, particularly in smaller communities.[125]

QUALITY OF LIFE—ECONOMIC IMPACTS

Many communities have the opportunity to benefit from natural resource development in their area. Shale energy development offers the prospect of jobs to local economies; lease payments and royalties for property owners; and increased tax revenues, royalties, and lease payments for state and local governments. Local workers employed on shale gas projects can enhance their skills and increase their earnings potential. Projects can also stimulate demand for local businesses, including the construction, retail, and services industries. The presence of the oil and gas industry can also contribute to or attract investments in regional infrastructure, which benefit other area businesses. Such benefits can improve the economic outlook for the community and its residents, contributing to an enhanced quality of life.

Whether a community will benefit in the long term depends on several factors, principally on its size, the diversity of its economy, and the state of its economy when development begins. Smaller, rural communities with little economic diversity and a high rate of energy development activities are at greater risk of succumbing to a boom/bust cycle.[126] Larger communities can often better absorb some of the adverse effects of development.

121 Yorghos Apostolopoulos and Sevil Sonmez (eds.), ***Population Mobility and Infectious Disease*** (New York: 2007), http://www.springer.com/public+health/book/978-0-387-47667-4.

122 In other parts of the world, shale gas development may pose more of a disease risk for industry workers, where the rate of endemic disease is high, both vector-borne and through person-to-person transmission—e.g., illnesses like HIV/AIDS, tuberculosis, malaria, and cholera. Food and drinking water contamination may also pose risks for itinerant workers in some regions. In North America, particularly in the northeast, there can be exposure to Lyme disease through tick bites, and the industry should caution workers to wear protective clothing in certain areas.

123 Food and Water Watch, "The Social Costs of Fracking: A Pennsylvania Case Study" (September 24, 2013), http://www.foodandwaterwatch.org/reports/the-social-costs-of-fracking.

124 Josh Wingrove, "Alberta's Rate of Syphilis Infection Still Rising," ***The Globe and Mail,*** last modified August 23, 2012, http://www.theglobeandmail.com/life/health-and-fitness/health/conditions/albertas-rate-of-syphilis-infection-still-rising/article572646.

125 Ron Dutton and George Blankenship, "Socioeconomic Effects of Natural Gas Development" (Denver, Colorado: August 2010), paper prepared to support NTC Consultants under contract with the New York State Energy Research and Development Authority, 23.

126 David Kay, "The Economic Impact of Marcellus Shale Gas Drilling: What Have We Learned? What Are the Limitations?" Working Paper Series: A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale (Cornell University: April 2011), http://www.greenchoices.cornell.edu/downloads/development/shale/Economic_Impact.pdf

The rate of development also matters, with a slower pace allowing the community to adapt to changes, as does the extent to which benefits are accrued and spent locally.[127]

One important factor in a community's long-term economic success is whether its economy becomes dependent upon the oil and gas industry. A study of the costs and benefits of fossil fuel extraction in the western United States showed that the counties that were more dependent on extractive industries (*energy focusing*) did not fare as well economically in the long term as their counterparts focused on other industries.[128]

A 2014 Duke University report reviewed the fiscal impacts of shale development on local governments in the top producing counties in eight states between 2007 and 2012.[129] It found that county and municipal governments have generally received net financial benefits from shale development in the recent boom, although there has been some regional variation. Notably, costs have thus far outweighed benefits for many local governments in rural areas where large-scale development has occurred rapidly (i.e., in the Bakken Shale region of North Dakota and Montana).

Employment

The oil and gas industry can generate three types of employment—*direct employment* in the activities of well construction, drilling, development, and production or related industry services; *indirect employment* with suppliers or service industries stimulated by industry demand; or *induced employment*, in jobs created by oil and gas employees spending their income on goods and services.[130] In the oil and gas industry, many of the jobs generated are initial construction jobs, with fewer long-term jobs available in the production phase. It is these long-term positions, however, which are considered more important to the area's long-term economic development.[131]

In the exploratory drilling phase, many of the jobs do not require specialized skills (e.g., construction, truck driving) and the operator may hire locally for such positions. Given that the initial activity is limited to one or a few wells, the impact on the local economy is relatively modest at this stage. Work on the drilling rigs does require specialized skills and the operator tends to bring in outside workers to fill these positions. Locals may be hired into retail and service industries that are responding to the increased demand from the industry and new workers.

Housing

A limited number of outside transient workers are moving to the area at this stage, and they tend to seek temporary housing in the community or in other towns within commuting distance. If there is a housing shortage in the area, companies sometimes build temporary housing for their crews on the pad site or in another location. Often referred to as *man camps*, these temporary housing facilities can be the locus of some social problems (see the Quality of Life—Social Impacts section).

127 Susan Christopherson and Ned Rightor, "How Should We Think About the Economic Consequences of Shale Gas Drilling?" Working Paper Series: A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale (Cornell University: May 2011), http://www.greenchoices.cornell.edu/downloads/development/shale/Thinking_about_Economic_Consequences.pdf

128 Headwaters Economics, "Fossil Fuel Extraction as a County Economic Development Strategy: Are Energy-focusing Counties Benefiting?" (September 2008), http://headwaterseconomics.org/pubs/energy/HeadwatersEconomics_EnergyFocusing.pdf.

129 Daniel Raimi and Richard G. Newell, "Shale Public Finance: Local Government Revenues and Costs Associated with Oil and Gas Development," Duke University Energy Initiative Report (Durham, NC: May 2014), http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/9216/Shale%20Public%20Finance%20Local%20Revenues%20and%20Costs.pdf?sequence=1.

130 Dutton and Blankenship, "Socioeconomic Effects," 11.

131 Amanda L. Weinstein and Mark D. Partridge, ***The Economic Value of Shale Natural Gas in Ohio*** (The Ohio State University Department of Agricultural, Environmental and Development Economics, December 2011), 2, http://aede.osu.edu/sites/aede/files/publication_files/Economic%20Value%20of%20Shale%20FINAL%20Dec%202011.pdf

Local Infrastructure and Services

Given that outside project workers are not too numerous at this point, they usually have a limited impact on local services, principally affecting law enforcement, emergency response, and road maintenance services.[132] The transport of equipment, supplies, water, and wastes to and from the drilling site can impact the quality of roads, bridges, and the local transportation network. Road maintenance and repair is the leading cost for most county governments in areas of oil and gas development.[133] To handle oversight, permitting, and code enforcement for the new facilities and infrastructure installed for the project, local governments might need additional resources and staffing. State and local governments can collect revenues from shale development from a variety of sources, including property taxes, lease and royalty payments on publicly owned land, and fees for services. Some states impose ***severance taxes***[134] on operators to offset costs, and some local governments institute fees in order to fund infrastructure maintenance. Additional sales taxes can be a main source of revenue for municipal governments as the population increases with development. Local governments might also receive in-kind donations from operators who help to maintain and repair local roads, perhaps by establishing road use agreements with them.

As mentioned above, the Duke University report observed that these revenues have tended to keep pace with or exceed costs associated with shale development for most local governments. In some areas, however, additional revenues might not be commensurate with the increased demand for services. Governments also might receive these revenues later than community needs accumulate, however, leading to a funding gap.[135] This gap might begin to materialize in the exploration phase, but could become more pronounced in the development phase when there can be heavy demands on local infrastructure and services.

QUALITY OF LIFE—SOCIAL IMPACTS

Depending on the size and existing character of the host community, an influx of temporary workers can bring increased social problems. These workers are often male and generally live in cluster housing, geographically separated from family members. They have disposable income and leisure time with which to seek entertainment or distractions. These circumstances may contribute not only to substance misuse, but also to other problems like traffic accidents, disorderly conduct, violent behavior, unwanted pregnancies, domestic violence, child abuse, and sexually transmitted diseases. Furthermore, there is evidence that illegal drug and gun trafficking, gambling, and prostitution can increase in the surrounding area.[136]

As mentioned in the diseases section, it is unclear whether the increase in such social problems is proportionate to the population increase or is linked to the specific profile of the transient workers in the oil and gas industry. In any case, depending on the size and resources of the community involved, some communities can find their law enforcement, health care,

132 Dutton and Blankenship, "Socioeconomic Effects," 41–43.
133 Daniel Raimi and Richard G. Newell, "Shale Public Finance," 2.
134 Taxes levied on the extraction of natural resources from the earth.
135 Headwaters Economics, "Oil and Natural Gas Fiscal Best Practices: Lessons for State and Local Governments" (November 2012), 1-3, http://headwaterseconomics.org/wphw/wp-content/uploads/Energy_Fiscal_Best_Practices.pdf.
136 National Public Radio, "The Great Plains Oil Rush" (2014), radio broadcast, http://www.npr.org/series/268211390/the-great-plains-oil-rush.

and emergency response systems overwhelmed by this spike in demand.[137]

Such issues may begin to emerge during the exploration phase and significantly increase during the development phase. Over time, however, as the industry matures to the production phase, the number of transient workers declines and more permanent workers fill the long-term development and production positions.

QUALITY OF LIFE—NOISE IMPACTS

Overview of the Effects of Noise

Excessive noise is not merely an annoyance, but also a health concern. Elevated noise levels can affect both hearing and speech comprehension, and can impact other physical and mental functions. The U.S. Environmental Protection Agency (EPA) has recommended outdoor limits for noise at 55 ***A-weighted decibels (***dB [A]), and indoor limits at 45 dB (A). The agency has also noted that a 24-hour exposure above 70 dB (A) may lead to permanent hearing impairment.[138]

Prolonged exposure to elevated noise levels is associated with a range of health problems. It can activate the sympathetic and endocrine systems and contribute to cardiovascular disease, prenatal complications, and immunosuppression, as well as increased incidence of diabetes, mental disorders like anxiety, and general physical and mental fatigue. These health issues can occur even when people have become habituated to the noise and claim to no longer be disturbed by it.[139]

One significant impact of noise is sleep disturbance. Uninterrupted sleep is a prerequisite for physical and mental health and well-being. For a good night's sleep, sound levels should not exceed 30 dB (A), which corresponds with average nighttime noise levels of 25 to 30 dB (A) in quiet rural and suburban areas.[140, 141] Maintaining a quiet ambiance is important because even when individuals are not awakened by it, noise can cause detectable changes in heart and brain activity, as well as in next-day stress levels.[142]

Smaller increases in the normal ambient sound levels can also be a stressor. Increases of only 6 dB (A) above ambient levels can be detected by the average person.[143, 144] Exposure to this level of noise can lead to complaints of annoyance, headache, and mental and physical fatigue. The effects can vary greatly, however, depending on individual sensitivities and circumstances. With prolonged irritating noise, people may experience feelings of aggression and declines in cognition and performance.[145]

Noise and Shale Development Operations

With shale development operations often taking place around-the-clock—often in otherwise quiet rural areas, where

137 Food and Water Watch, "The Social Costs."

138 U.S. Environmental Protection Agency, "EPA Identifies Noise Levels Affecting Health and Welfare," updated May 20, 2015, http://www2.epa.gov/aboutepa/epa-identifies-noise-levels-affecting-health-and-welfare.

139 Monica S. Hammer, Tracy K. Swinburn, and Richard L. Neitzel, "Environmental Noise Pollution in the United States: Developing an Effective Public Health Response," Environmental Health Perspectives 122: 115–119.

140 World Health Organization Europe, "Night Noise Guidelines for Europe," (Copenhagen, Denmark: WHO Regional Office for Europe, 2009), 108, http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf.

141 Earthworks. Oil and Gas at Your Door? I-45.

142 Monica S. Hammer, Tracy K. Swinburn, and Richard L. Neitzel, "Environmental Noise Pollution."

143 New York State Department of Environmental Conservation Study (April 2015), http://www.dec.ny.gov/energy/75370.html.

144 For a useful illustration of noise pollution from oil and gas development, a Colorado study recorded the average decibel levels of typical noises emanating from well pads (see chart Earthworks, ***Oil and Gas at Your Door?***, pp. I-45, http://www.earthworksaction.org/files/publications/LOguide2005book.pdf)

145 Hammer et al., "Environmental Noise Pollution."

nighttime sounds can be as low as 25 to 30 dB (A)—communities are frequently concerned about the noise from these operations. According to a study of a shale development site in West Virginia, noise from diesel-powered equipment and machinery such as drills, pumps, and compressors averaged 70 dB (A) at the periphery of the site. Noises above 55 dB (A)—the level at which sound begins to become a nuisance, according to WHO[146]—occurred frequently, with occasional there were short bursts of noise above 85 dB (A).[147]

Once drilling and hydraulic fracturing begin, the level of ambient noise can increase by 37 to 42 dB (A).[148] Well pad sites are noisiest during the phases of road and pad construction; drilling and hydraulic fracturing; and well completion. This entire process can extend intermittently over several weeks to months for the first well. When water for hydraulic fracturing is not piped to the site or recycled, large numbers of truck trips are required—up to 1,148 one-way heavy truck trips and 831 one-way light truck trips in the early phase of well development, according to one estimate.[149] A study in Colorado found that water haulage trucks emit 88 dB (A) at 50 feet and 68 dB (A) at 500 feet.[150, 151]

Activities that can generate noise during the exploratory drilling phase and beyond include:

- the construction of access roads and well pads, requiring earth-moving equipment and gravel deliveries
- multiple truck trips to and from the site[152]
- the drilling and hydraulic fracturing of each well, which often proceed 24 hours a day[153]
- venting or flaring during well completion, both of which can occur around the clock for several days[154]

There are a number of measures that can be taken to reduce or avoid the impacts of noise from shale development projects. These are described in the "What Can Be Done?" section below.

QUALITY OF LIFE—VISUAL IMPACTS

Much shale development takes place in rural areas, with their mix of natural landscape, forests, agricultural vistas, and small communities. For communities reliant on sectors such as agriculture, tourism, and recreation, the installation of industrial infrastructure can negatively impact natural and visual resources. Surveys indicate that residents and visitors

146 Earthworks, "Oil and Gas at Your Door?" I-45.

147 See Michael McCawley, ***Air, Noise, and Light Monitoring Results for Assessing Environmental Impacts of Horizontal Gas Well Drilling Operations,*** study for the West Virginia Department of Environmental Protection (May 3, 2013), http://wvwri.org/wp-content/uploads/2013/10/A-N-L-Final-Report-FOR-WEB.pdf

148 New York State Department of Environmental Conservation, ***High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement (SGEIS) Documents (***April 2015), 6-301, http://www.dec.ny.gov/energy/75370.html.

149 New York State Department of Environmental Conservation, ***High-Volume Hydraulic Fracturing in NYS***, 6-305, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch6b.pdf.

150 Earthworks, ***Oil and Gas at Your Door?*** http://www.earthworksaction.org/files/publications/LOguide2005book.pdf

151 For a chart of truck noise as a function of truck size and speed, see New York State Department of Environmental Conservation Study (April 2015), 6-299, http://www.dec.ny.gov/energy/75370.html.

152 Composite noise levels for these activities can be found in New York State Department of Environmental Conservation (April 2015), 6-292–6-293, http://www.dec.ny.gov/energy/75370.html.

153 For composite noise levels for drilling and hydraulic fracturing, see New York State Department of Environmental Conservation Study (April 2015): pp. 6-295–6-297, http://www.dec.ny.gov/energy/75370.html.

154 New EPA regulations, effective January 2015, ban venting and significantly restrict flaring.

in these regions are concerned about the potential for development to diminish aesthetics, property values, tourism, and public enjoyment.[155] From a health perspective, whether in a rural or another setting, residents can experience distress as changes to their environment materialize, contributing to anxiety, depression, or anger.[156]

With shale development, multiple wells are often located on a single pad; according to industry estimates, for instance, over 90% of shale gas wells in the Marcellus Shale region will be located on multi-well pads.[157] This impacts a larger area per site compared to single-well pads, although fewer well pads overall are distributed throughout an area and require fewer access roads. Infrastructure that could have visual impacts includes the well pad site itself, fluid retention basins, access roads, and utility corridors (electric service, water pipelines, and gas-gathering pipelines). Off-site storage facilities and centralized water impoundments (often covering up to 5 acres), as well as increased population density and accompanying traffic can also cause changes to the viewshed. In addition, compressor stations, which remain in place throughout the productive life of the wells, are generally installed every 50 to 100 miles.[158, 159]

As with noise, the greatest visual impacts occur during the exploratory drilling and development phases, due to the disruption of the landscape and installation of the well pad and its associated infrastructure. Although estimates vary, overall site disturbance during this phase averages 7.4 acres for a multi-well pad, and 4.8 acres for a single well pad (both estimates include portions of access roads and utility corridors).[160] The well pad alone averages 3.5 acres of disturbed land during the drilling and fracturing phase for a multi-well pad, although this can vary significantly. For example, in the Fayetteville Shale region, multi-well pad disturbance ranges from 1.7 acres to 5.7 acres.[161]

Access roads add to site disturbance and may also have the requisite utility corridors running alongside. The roads are often 20 to 40 feet wide and average 400 feet in length (again, there is variation—they have been permitted for up to 3,000 feet in the Marcellus shale region[162]). The installation of roads and utility corridors generally creates a linear visual disturbance in the landscape and may cause the fragmentation of wildlife habitat.

In addition to the infrastructure, numerous tanks, trucks, diesel-powered equipment, personnel sheds, and rigs for

155 Tompkins County Council of Governments, "Community Impact Assessment: High-Volume Hydraulic Fracturing" (December 2011) 62-63, http://www.tompkinscountyny.gov/files/tccog/Gas_Drilling/TCCoG_Community_Impact_Assessment_12-15-11%20Final.pdf.

156 S. L. Perry, "Using Ethnography to Monitor the Community Health Implications of Onshore Unconventional Oil and Gas Developments: Examples from Pennsylvania's Marcellus Shale," New Solutions 23 (2013), http://www.ncbi.nlm.nih.gov/pubmed/23552647.

157 New York Department of Environmental Conservation, Final SGEIS (2015), 5-2, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch5a.pdf.

158 Energy Information Administration, Office of Oil and Gas, "Natural Gas Compressor Stations on the Interstate Pipeline" (November 2007), http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngcompressor/ngcompressor.pdf.

159 For photographs depicting visual impacts of shale gas development at various stages and from varying distances, see Upadhyay, "Visual Impacts of Natural Gas Drilling in the Marcellus Shale Region," Cornell University Study (2010), http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Visual%20Impact_Final%20Report.pdf. For charts summarizing "Generic Visual Impacts Resulting from Horizontal Drilling and Hydraulic Fracturing in the Marcellus and Utica Shale Area of New York," see New York State Department of Environmental Conservation Study (April 2015), 6-285–6-288, http://www.dec.ny.gov/energy/75370.html.

160 New York Department of Environmental Conservation, Final SGEIS (2015), 5-2, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch5a.pdf.

161 New York Department of Environmental Conservation, Final SGEIS (2015), 5-7, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch5a.pdf.

162 New York Department of Environmental Conservation, Final SGEIS (2015), 5-3, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch5a.pdf.

drilling (up to 100 or more feet high) and fracturing (up to 150 feet high) can contribute to the visual footprint of the site.[163] Depending on topography and any screening methods employed, daytime visual impacts are greatest up to a half mile away. Furthermore, work can take place around the clock during active well development. The lights used at night for safety purposes can disturb residents close to the site and generate an ambient sky glow. If flaring is conducted, the open flame can also be seen at a distance.[164]

QUALITY OF LIFE—PSYCHOLOGICAL IMPACTS

In addition to these physical changes in a community after shale energy development begins, shifts in quality-of-life perceptions can also occur, depending on the character of the community. In smaller communities with a strong sense of community character, residents may describe no longer having a sense of peace, psychological refuge, or a rural quality of life.[165] These feelings do not necessarily correlate with actual damage or direct health impacts, but can nonetheless create stress that sometimes leads to physical illness.[166] Such feelings can become much more acute with the accelerated and cumulative changes in the development phase. Reactions to the changes brought by development can vary, however. In economically depressed areas, some residents may welcome newcomers and a sense of revitalization that development brings to their area.[167]

Drilling truck convoy. Courtesy of WV Host Farms Program (http://www.wvhostfarms.org).

PA Gas Well. By Sara Gillooly, Tyler Rubright, Samantha Malone.

163 New York Department of Environmental Conservation, Final SGEIS (2015), 6-273, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch6a.pdf.
164 As noted above, however, EPA regulations effective January 2015 restrict this practice.
165 S. L. Perry, "Using Ethnography to Monitor the Community Health Implications of Onshore Unconventional Oil and Gas Developments: Examples from Pennsylvania's Marcellus Shale," *New Solutions* 23 (2013), 40, http://www.ncbi.nlm.nih.gov/pubmed/23552647.
166 S. L. Perry, "Using Ethnography."
167 Dutton and Blankenship, "Socioeconomic Effects," 42.

What can be done to address health concerns? What have others done?

It is important for local governments, industry representatives, and other local stakeholders to begin sharing information and opening a dialogue early in the development process. As discussed above, the long-term health of the community and its environment can be linked to the presence of industry. To ensure that the community benefits in the long term, it is important for local officials to carefully manage the short-term benefits to offset costs and prepare for the long term.

COLLABORATIVE ACTIVITIES

In the exploratory drilling phase, it is still uncertain whether or not the project will proceed to development and production. Factors that enter into a company's decision to develop the resources in the area include: the size and viability of the resource; the political and regulatory environment; the availability of local infrastructure, gathering systems, and pipelines; proximity to market; the feasibility of constructing well pads and infrastructure on the available land; presence of other operators; and oil and gas prices, which can be volatile.[168]

While conversations will necessarily be iterative as circumstances change and new information emerges, it can be useful for local officials and industry representatives to hold initial discussions on the following topics:

- information-sharing on the company's activities and plans, to the extent possible
- regional infrastructure development, transportation planning, traffic management, and road safety
- approaches for meeting housing needs and maintaining the availability of affordable housing
- educational and job-skills training programs with community leaders and local educational institutions
- ideas for potential investment strategies to maximize project benefits and diversify and stabilize the local economy if the site moves to the development phase (recognizing that this may not occur)

Safety

When a company begins exploration activities in the area, it could engage with local officials on the capacity of the local health care system and its emergency response services. Given that the operator relies on these services for the care of its personnel, it would be valuable for local health officials, company representatives, health care providers, and emergency responders to jointly identify needs. If the local health care system lacks the necessary capacity to respond to shale development-related incidents, companies could support local efforts to expand services, upgrade equipment, or provide training.[169]

168 API "Community Engagement Guidelines," 3.
169 Daniel Raimi and Richard G. Newell, "Shale Public Finance," 4.

BOX 9. CASE STUDY: DRIVER SAFETY—PERU LIQUEFIED NATURAL GAS PIPELINE[170]

Peru, home to extremely challenging terrain for drivers, has the third-highest traffic mortality rate in the world (21.5 casualties per 1,000 inhabitants).[171] During the installation of a 408-kilometer liquefied natural gas pipeline, the company Peru Liquefied Natural Gas (PLNG) instituted a program to achieve driver safety.

Over the course of the project, a variety of stakeholders, including PLNG, government officials, drivers, and community members all contributed to the effort—with monthly assessment meetings, ongoing driver safety programs, community road safety workshops, reporting of concerns by both drivers and the community, and a driver incentive program that rewarded incident-free on-time delivery.

Drivers delivering pipes and equipment to the project traveled approximately 69 million kilometers during the two-year installation (2008–2010)—often navigating unpaved roads affected by heavy rains, snow, and freezing temperatures—from sea level to altitudes as high as 4,900 meters. Despite these challenges, with very careful attention to vehicular safety, incidents during the entire installation averaged 2.82 per 1,000,000 kilometers driven, exceeding the program's target of 7.53; and, in 2012, there were no road accidents related to the pipeline work at all.

Much of the project's success was due to ongoing evaluation and adaptation, as each incident was studied and underlying causes determined. Other elements contributing to the success of the program included:

- Instituting a company safety accountability framework to support the safety program.
- Implementing a system of management controls, including:
  - Road risk maps highlighting potential hazards such as heavy pedestrian traffic, winding roads, and open trenches were developed and updated regularly. Drivers were instructed on how to use these, and electronic versions were synced with the vehicle's GPS.
  - Speed controls were initiated, such as posted signage, vehicular GPS recording, and use of real-time speed radar guns by road supervisors.
  - Drivers were regularly monitored for blood alcohol levels (with a zero tolerance standard) and for signs of altitude impairment. Some of the monitoring for speed and driver condition took place at five strategically located checkpoints along the route. Vehicles and loads were also inspected, and driver services were provided.
- Working with the community to raise awareness of safe driving practices.
- Focusing on improving the health and safety of drivers. For example, drivers were educated on appropriate nutrition and water intake for high-altitude driving.
- Holding third-party contractors to the same standards, with this requirement included in the procurement bidding process.
- Providing incentives for deliveries without incident.

Diseases

Given that the increased occurrence of sexually transmitted diseases is common in communities with a mobile workforce, local health officials and companies could work together on informing workers, industry subcontractors, and community members about the risks and methods of prevention. It is critical for companies to provide preventative guidance and set standards for both their workers and subcontractors.[172]

Sexually transmitted diseases are best prevented with the use of condoms, which should be made readily available to workers at their places of residence and in public locations like pharmacies, bars, and convenience stores. Health officials and companies could also collaborate to ensure that workers and residents have access to clinics for testing and treatment.

---

170 Summary of International Finance Corporation (IFC), "Lessons of Experience: Peru LNG: A Focus on Continuous Improvement" (No. 3, March 2013).

171 IFC, p. 4.

172 Shira M Goldenberg, Jean A Shoveller, Aleck C Ostry, Mieke Koehoorn, "Sexually Transmitted Infection (STI) Testing among Young Oil and Gas Workers: The Need for Innovative Place-based Approaches to STI Control," *Canadian Journal of Public Health* 99, no. 4 (July/August 2008), http://journal.cpha.ca/index.php/cjph/article/viewFile/1666/1850.

Quality of Life—Economic Impacts

In some areas, local governments, educational institutions, and companies have collaborated on designing and delivering educational and job skills training programs to equip local residents with the knowledge and skills needed to work in the oil and gas industry (see Box 10 for examples).

Local Infrastructure & Services: To maintain local roads and infrastructure, companies and local governments can develop road use agreements that set forth parameters for the industry such as hours of usage, route selection, and upgrades. Given that much of the truck traffic to a shale development site is for the transport of water and other liquids (over 90%, according to one study[173]), exploring alternatives to trucking, such as pipelines and onsite waste treatment and disposal, could be worth considering. For an overview of the issues related to pipelines, see Appendix E.

LOCAL OFFICIALS AND COMMUNITY LEADERS

Water Quality

Given that many of the potential contaminants associated with shale development, such as methane, are naturally occurring, it can be difficult to substantiate the source of any groundwater contamination. It is therefore important to establish a baseline for water quality prior to development and create an ongoing water monitoring program. Community members could have a role in assisting with water monitoring efforts. For examples of community involvement in water monitoring, see the Good Neighbor Agreement case study (Box 4) and the report from the International Council on Mining and Metals, "Water Management in Mining," listed in the resources section below.

173 New York State Department of Environmental Conservation, Final SGEIS (April 2015), 7-134, http://www.dec.ny.gov/docs/materials_minerals_pdf/fsgeis2015ch7.pdf.

BOX 10. EXAMPLES OF EDUCATION AND TRAINING PROGRAMS

San Antonio, TX (Eagle Ford Shale)—Educators in San Antonio, Texas are collaborating with energy firms to create a program that would give middle school and high school age students the opportunity to build a skillset that would prepare them for working in the oil and gas industry. By creating educational programs in communities affected by the increased presence of oil and gas development, the residents of those areas are given an opportunity of having a leg up in that job market. Local hiring would reduce the number of transient workers that would have to be hired from out of town. It will be an optional field of study meant to spark students' interest in work in the energy field or college courses in related fields. As of April 2014, this project was in the planning stages, with the goal of having information about the project disseminated throughout the school system in the following months.

ShaleNet: Pennsylvania, Ohio, West Virginia (Marcellus and Utica Shales)—The ShaleNet program (http://www.shalenet.org) was developed in 2010 by members of Westmoreland County Community College in Youngwood, Pennsylvania with the goal of meeting specific demands of the oil and gas job market. The program received funding through a grant from the U.S. Department of Labor Employment and Training Administration. With that financial support, the college developed a job training program to prepare a new corps of workers for high-demand jobs in the oil and gas industry. The program offers a range of credentials, including training courses that are several weeks long, one- or two-year degree certificates, associates degrees, and a bachelor's degree in Technology Management. The program partners with educational institutions to provide the training and education programs and works with industry partners to connect learners to upstream, midstream, and downstream careers in the oil and gas industry. It serves as a way for people with an interest in working in the oil and gas industry to obtain the required knowledge and skillsets for the job they want. By June 2013, the program had 20 training providers across 4 states, and had trained 5,000 people, connecting 3,400 of them with jobs. For more information on the program, contact a career counselor at http://www.shalenet.org/contact.

Shale Education and Training Center (ShaleTEC): Pennsylvania (Marcellus and Utica Shales)—A collaboration of the Pennsylvania College of Technology and Penn State Extension, the Shale Training and Education Center (http://www.shaletec.org) offers courses in applied technology, such as heavy equipment operation and civil engineering, as well as community-focused topics such as land and leasing; environment and water quality; and first responder training. The Pennsylvania College of Technology is the lead implementing partner in the ShaleNet program. The ShaleTEC program was created with the goal of building an "educational pipeline" of skilled technicians that would feed into the energy industry. Since the program's creation in 2008, over 8,500 people have participated in its oil and gas-related courses.[174]

174 ShaleTec Reflects Growing Opportunities," *PCT Today*, last updated October 4, 2012, http://pctoday.pct.edu/renamed-shaletec-reflects-growing-opportunities.

INDUSTRY REPRESENTATIVES

The activities described below can be undertaken by operators to address some of the air quality, water quality, safety, and quality of life concerns that are associated with exploratory drilling and subsequent phases. Some operators may already be implementing some of these options.

Air Quality

There are a range of measures that can be taken to reduce air pollution from shale development. The EPA's Natural Gas STAR program, a voluntary program that partners with industry, offers an extensive list of recommended technologies and practices for reducing methane and VOC emissions.

Options for reducing air emissions include:

- transitioning from diesel-powered equipment to natural gas- or solar-powered or reduced-emission engines and motors (some companies are using gas produced at the site to fuel equipment engines, thus reducing the use of diesel fuel)
- constructing pads and roads of gravel, or applying water or other dust suppressants to them
- instituting carpooling and busing programs to transport workers, thereby reducing the number of vehicles accessing the site
- establishing driver training and incentive programs to ensure local speed limits are obeyed (also relevant to safety)
- establishing a community-based participatory monitoring program, in which trained and experienced volunteers conduct air sampling in the surrounding area to monitor for chemical constituents that could pose a health risk

In order to ascertain the amount of air emissions that might be coming from the site, it is important to conduct monitoring activities before, during, and after drilling takes place.

Gustavo Aguirre Jr. with air monitor in Arvin, CA. Photo Credit: Sarah Craig/Faces of Fracking.

Water Quality

Approaches the operator may undertake to address water quality concerns include:

- using tanks to store wastewater instead of open pits, following best practices for their design, construction, and operation to prevent leaks and spills[175]
- following best practices for well-casing construction, following best practices and industry guidelines[176]

175 GWPC, "State Oil and Gas Regulations," 11.

176 API, "Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines," API Guidance Document HF1, First Edition (October 2009), http://www.api.org/~/media/Files/Policy/Exploration/API_HF1.pdf.

- adopting the use of green fracturing fluids (strategies include drawing on the chemicals listed in EPA's Design for the Environment program and establishing a staff position responsible for reducing the volume and toxicity of chemicals used)
- implementing storm water plans to control runoff and flooding
- publicly disclosing the contents of hydraulic fracturing fluids, possibly using a "systems approach" to reporting that separates trade names from chemical ingredients and concentrations, allowing operators to preserve confidential information while sharing the chemicals used[177]
- as mentioned in the safety section, providing driver training programs and establishing safety controls such as speed monitors and road risk maps to avoid accidents and spills
- establishing a community-based participatory monitoring program, in which trained and experienced volunteers conduct water sampling in the surrounding area to monitor for chemical constituents that could pose a health risk

Safety

Activities that can serve to protect the safety of project workers and the community include:

- siting well pads as far away from residences and water wells as possible
- pressure testing of blowout prevention equipment prior to production
- following best practices and industry guidance for well construction and maintenance, particularly for well casing
- providing safety training for workers on proper equipment maintenance and practices to prevent blowouts and spills
- engaging in emergency planning in which operators meet with emergency room staff and local first responders to review emergency response plans and provide the information on the chemicals used at the project site
- conducting joint trainings and drills for hazardous materials (hazmat) incidents with operators, emergency room departments, fire departments, and other first responders
- assessing local health care and emergency response capacity and helping to improve capacity where needed
- providing driver training programs, along with safety controls such as speed monitors, road risk maps, driver drug testing, stringent rules regarding shift lengths and proper rest, and routine vehicle maintenance and inspection[178]

Quality of Life—Noise

The impact of noise on nearby residents can be reduced in several ways—by increasing the distance between the source of the sound and person hearing it (*the receptor*); by directing the

177 U.S. Department of Energy, "Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0" (Washington, DC: March 28, 2014), 2, http://energy.gov/sites/prod/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

178 Ian Urbina, "Deadliest Danger Isn't at the Rig but on the Road," The New York Times (May 14, 2012), http://www.nytimes.com/2012/05/15/us/for-oil-workers-deadliest-danger-is-driving.html?pagewanted=all&_r=2&

noise away from the receptor; and by altering the time of day that the sound is produced.[179] It is important for the operator to be aware of the noise levels generated in order to help take appropriate corrective actions when needed; installing sound meters on the well pad to monitor sound levels 24 hours a day can therefore be useful. Residents can also monitor sound levels in their homes.

When considering how to best mitigate noise impacts, it is important to take into account:

- the combined effects of various sources of noise
- the time of day when people are exposed
- vulnerable groups, including people with medical problems or disabilities such as blindness or hearing impairment; those managing complex cognitive tasks; those in learning environments; fetuses; children, particularly during the stage of language acquisition; and the elderly
- low frequency sounds, which are often experienced as vibrations or pressure sensitivity, and are extremely bothersome to certain individuals[180]
- distinctive sounds or those generated by an impact, particularly when they are intermittent or unpredictable
- effects of noise on wildlife and livestock, which can also affect livelihoods

Measures that operators can undertake to reduce noise impacts in the exploratory drilling and development phases include:

- erecting sound barriers like those used on highways around the site, or arranging infrastructure like storage tanks and other onsite materials (trucks, hay bales, topsoil) to serve as sound barriers
- using rubber hammer covers
- installing high-grade noise reduction baffles on equipment and air-relief lines

Quality of Life—Visual Impacts

During the construction of well pad facilities, following some basic principles may help to reduce the potential visual impacts of the site:

- reducing the height of facilities and equipment when possible
- placing equipment so that it is screened from view by topographical features or vegetation
- painting equipment to blend with the surroundings
- avoiding the use of reflective surfaces
- ensuring the site is clean and well-kept

With regard to the potential disturbance caused by night-time work, lighting should be used for safety purposes only and turned off when not in use. Operators can also use energy-efficient lighting and shielded light fixtures, as well as angle light paths downward rather than horizontally. Nearby residents may need to use window coverings at night so that the light from the well pad does not disturb sleep or affect melatonin production and circadian rhythms.[181]

179 See New York State Department of Environmental Conservation Study (April 2015), http://www.dec.ny.gov/energy/75370.html
180 Earthworks. *Oil and Gas at Your Door?*
181 McCawley, *Air Noise and Light Monitoring.*

BOX 11. CASE STUDY: WEST TEXAS DARK SKY RESERVE

When the Permian Basin in West Texas experienced a fivefold increase in number of oil rigs, Bill Wren at the University of Texas McDonald Observatory began to educate both private companies and the public on the adverse effects too much light can have on a community. Lights that stay on 24 hours a day can be detrimental to organizations such as the McDonald Observatory that depend on a dark sky at night. Additionally, in places known for their beautiful night skies, too much light can mean the loss of a viewshed of great value to the community. Concerned about this potential loss, Wren has given several presentations and demonstrations to educate people about ways to enhance the efficiency of light fixtures while protecting the sky from the light pollution.

Rather than demand that companies turn off the bright lights, Wren and the McDonald Observatory have shown businesses that installing dark sky-friendly fixtures can improve light efficiency and save them money.[182] Both visibility and security are improved when measures are taken to prevent light pollution. Overall, it is estimated that $1.74 billion is wasted in the United States every year on energy for light shining directly upward.[183] By switching to shielded light fixtures for street lighting, the Canadian city of Calgary saved an estimated $1.7 million per year on energy costs.

In an effort to help restore dark skies in West Texas, Wren reached out to Stacy Locke, the CEO of Pioneer Energy Services in San Antonio, and together they implemented a trial of new fixtures. Although Locke and Pioneer were initially unaware of the issue, once approached, they were open to implementing the changes.[184] Wren suggested that Pioneer direct their lights downward rather than horizontally, which reduces the amount of light lost into the sky.[185] Aiming the lights in this way creates a more efficient light and saves the company money due to decreased energy costs. This change has also provided companies with a safer working environment because the downward-pointing light does not cause glare like horizontally aimed lights do. Workers are better able to see instrument controls, which creates a safer and more efficient workplace.[186]

Wren's work has now expanded beyond Texas, and he has collaborated with the National Park Service to develop these light-managing techniques in Utah.[187] According to Wren, it is critical to educate people about the problems associated with too much light in order to implement needed changes.

Wren has also been at the forefront of the movement to create legislation to reduce lights that are adversely affecting the night sky. As a result, a light ordinance was implemented in the seven counties surrounding the Permian Basin in 2011. Each county is responsible for writing and implementing its own ordinance to reduce light pollution in that area. This legislation will prevent more light pollution linked to an increasing population as oil and gas development in West Texas continues to grow.[188]

For more information, contact Bill Wren, McDonald Observatory, University of Texas at Austin at wren@nexus.as.utexas.edu or (432) 426-3621.

182 Rachel Gleason, "Astronomers Look to Protect Earth's Dark Skies," last modified May 8, 2014, http://www.mrt.com/top_stories/article_5f897a0e-d71d-11e3-ad5b-0019bb2963f4.html.
183 International Dark-Sky Association, "IDA Energy Brochure" (2008), http://www.darksky.org/assets/documents/ida_energy_brochure.pdf
184 Laura Petersen, "Public Lands: Drilling Boom Brings 'Light Pollution' to Southwest's Pristine Night Skies," *E & E News*, March 12, 2014, http://www.eenews.net/stories/1059996009.
185 Petersen, "Public Lands."
186 Gleason, "Earth's Dark Skies."
187 Petersen, "Public Lands."
188 "Talk At Ten Interview: Bill Wren," by Rachel Osier Lindley, Marfa Public Radio, May 24, 2012, http://marfapublicradio.org/blog/talk-at-ten/bill-wren

What resources can provide further information?

EXPLORATORY DRILLING STAGE

- American Petroleum Institute (API), "Hydraulic Fracturing Operations—Well Construction and Integrity Guidelines," API Guidance Document HF1, First Edition (October 2009), http://www.api.org/~/media/Files/Policy/Exploration/API_HF1.pdf. API, an industry association, has produced industry guidance documents and recommended practices on shale development operations. This documents pertains to well construction, while two sets of recommended practices released in August and October 2015 address well integrity and environmental considerations: "Hydraulic Fracturing – Well Integrity and Fracture Containment" (ANSI/API Recommended Practice 100-1) and "Managing Environmental Aspects Associated with Exploration and Production Operations Including Hydraulic Fracturing" (ANSI/API Recommended Practice 100-2). These newly released documents are available for free public viewing (or for sale to download) on the API website: http://publications.api.org. To access, register, select "Browse read-only documents now," then select "Exploration and Production," and scroll to recommended practices 100-1 and 100-2.
- Explore Shale, a project of Penn State Public Broadcasting funded by the Colcom Foundation, is a public media project dedicated to informing the public about hydraulic fracturing in the Marcellus Shale. The interactive media web page can be used to explore the drilling and development of the Marcellus Shale: http://exploreshale.org.
- The FracTracker Alliance (http://www.fractracker.org/about-us) provides maps for oil and gas sites in over 30 states. The information provided includes drilled wells, violations, proximity to populations, sand mining operations, and more.
- Grand Valley Citizens' Alliance, The Rifle, Silt, New Castle Community Development Plan: A Collaborative Planning Document between the RSNC Defined Area Residents, Antero Resources Corp. and Galaxy Energy (January 1, 2006), http://www.oilandgasbmps.org/docs/CO68-RSNCCommunityDevelopmentPlan.pdf. This community development plan, developed in collaboration between the community and the industry, is a non-legally binding framework for the development of energy resources in Garfield County, Colorado. It contains ten guidelines for development, including ideas for addressing financial and infrastructure impacts to the community. It also includes provisions for community participation in the plan implementation and for community education on natural gas development operations. The agreement was challenged in 2009 when one of the companies planned to undertake more intensive development than had been agreed upon, but in the end the original planning document was upheld; see a case study of the plan at http://www.oilandgasbmps.org/resources/casestudies/RSNC-CDP.php.
- The Intermountain Oil and Gas BMP Project, a project of the University of Colorado Law School, houses a database of best management practices, policies, and laws relating to oil and gas development: http://www.oilandgasbmps.org/index.php. The database is searchable by keyword and other fields and contains best management practices on air quality, community, human health and safety, noise, visual aesthetics, water quality, and water quantity, among other issues.
- Richard Liroff, Danielle Fugere, Lucia von Reusner, and Steven Heim, "2014 Disclosing the Facts: Transparency and Risk in Hydraulic

Fracturing," http://disclosingthefacts.org. This project of a coalition of investment advisory firms and advocacy organizations (As You Sow, Boston Common Asset Management, LLC, Green Century Capital Management, Inc. and the Investor Environmental Health Network) tracks the self-reported best practices of companies engaged in hydraulic fracturing operations in terms of environmental and community impacts. It assesses companies on their practices and disclosures in five areas: 1) toxic chemicals; 2) water and waste management; 3) air emissions; 4) community impacts; and 5) management accountability. The 2014 report is the third in a series of annual reports ranking company performance. It also highlights examples of innovative best practices.

- Rational Middle Energy Series, ***Realities of Drilling: Extended and Recut*** (Updated 2014), video (14:02), http://rationalmiddle.com/movie/realities-of-drilling-extended-and-recut. This video episode gives an overview of the process of drilling and hydraulically fracturing a shale well, as well as the risks involved and potential mitigation strategies.

AIR QUALITY

- The Center for Dirt & Gravel Road Studies is a non-profit organization that operates under the Larson Transportation Institute at Penn State University. The organization has several research, education, and outreach programs related to environmentally sensitive maintenance of unpaved roads and trails. Their mission is to create more environmentally friendly maintenance techniques and implement them in Pennsylvania. Their website, http://www.dirtandgravel.psu.edu, provides:
  - One-day oil and gas road maintenance training: http://www.dirtandgravel.psu.edu/center/marcellus/one-day-oil-and-gas-road-maintenance-training
  - A presentation on dirt and gravel road maintenance and shale gas development: http://www.dirtandgravel.psu.edu/center-info/marcellus-gas-and-road-impacts
- Department of Health and Human Services, CDC, NIOSH, and IMA-NA, "Dust Control Handbook for Industrial Minerals Mining and Processing"(January 2012), http://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2012-112.pdf. This handbook was produced for industrial minerals producers to provide guidance on use of state-of-the-art dust control techniques for all stages of mineral processing, in effort to eliminate or reduce hazardous dust exposures and create safer, healthier conditions for mine workers.
- National Industrial Sand Association (NISA), "Occupational Health Program for Exposure to Crystalline Silica in the Industrial Sand Industry" (2011), http://sand.org/Silica/Occupational/Health/Program. NISA offers guidelines for industry to monitor and manage workers' exposure to silica dust, which can occur during sand mining operations, during transport, and at the well pad.
- Southwest Pennsylvania Environmental Health Project (SWPA-EHP), "Air," http://www.environmentalhealthproject.org/health/air. SWPA-EHP, a nonprofit environmental health organization that provides assistance to local residents concerned about the health impacts of shale gas development, offers information and resources to residents for home air monitoring.
- U.S. EPA, "Natural Gas STAR Program," last updated October 23, 2014, http://www.epa.gov/gasstar. The Natural Gas STAR Program is a voluntary program for oil and gas companies that aims to help companies employ new techniques to increase efficiency and reduce emissions. Through the Natural Gas STAR program, industry participants share information on

cost-effective emission reduction technologies and practices. For recommendations, see http://www.epa.gov/gasstar/tools/recommended.html, last updated May 30, 2014.

WATER QUALITY

- Agency for Toxic Substances and Disease Registry, "Toxic Substances Portal," last updated July 23, 2014, http://www.atsdr.cdc.gov/toxfaqs/index.asp#M. This agency housed with the Centers for Disease Control and Prevention has a set of fact sheets on hazardous chemicals containing information on their health effects, exposure pathways, government recommendations, and ways to reduce risks.
- Alliance of Nurses for Healthy Environments, "Assessment Tools & More," http://envirn.org/pg/pages/view/79769/assessment-tools-amp-more. The Alliance of Nurses for Healthy Environments (ANHE) is an international network of nurses that deals with environmental health issues through education, research, advocacy, and practice. The ANHE website contains assessment tools for healthcare practitioners in areas experiencing shale development.
- The FracFocus website (www.fracfocus.org) is a repository where operators can voluntarily disclose the chemicals used in hydraulic fracturing operations. It is searchable by well site.
- International Council on Mining & Metals, "Water Management in Mining: A Selection of Case Studies" (May 2012), http://www.icmm.com/document/3660. This selection of case studies gives some examples from the mining sector of strategies to reduce water use and protect water quality in collaboration with stakeholders.
- Matthew McFeeley, "State Hydraulic Fracturing Disclosure Rules and Enforcement: A Comparison" *(*Natural Resources Defense Council, July 2012), http://www.nrdc.org/energy/files/Fracking-Disclosure-IB.pdf*.* This report discusses the importance of disclosure of the chemicals used in the shale development process to allow for water quality testing prior to exploration, and summarizes regulations by state.
- Southwest Pennsylvania Environmental Health Project (SWPA-EHP), "Water," http://www.environmentalhealthproject.org/health/water. SWPA-EHP, a nonprofit environmental health organization that provides assistance to local residents concerned about the health impacts of shale gas development, offers guidance and resources on home water testing.
- Susquehanna River Basin Commission, "Overview of Remote Water Quality Monitoring Network," last updated June 2014, http://mdw.srbc.net/remotewaterquality*.* The Susquehanna River Basin Commission created the Remote Water Quality Monitoring Network to collect and analyze water quality data from the Susquehanna River. The data is used to monitor the effects of drilling operations in the area on the health of the river.
- Town of Palisade and City of Grand Junction, Colorado et al., Watershed Plan for the Town of Palisade and the City of Grand Junction, Colorado (August 2007), http://www.oilandgasbmps.org/resources/casestudies/palisade.php. This collaboratively developed watershed plan between community, government, and company stakeholders offers a framework for identifying and addressing risks, conducting third-party water monitoring, and implementing best management practices with regard to energy development in the watershed.

- U.S. Environmental Protection Agency Office of Research and Development, "Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources" External Review Draft (Washington, DC: June 2015). This draft assessment provides a review and synthesis of available information concerning the potential impacts of hydraulic fracturing for oil and gas on drinking water resources in the United States. http://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=244651. At the time of the release of this guidebook, the draft assessment is under review by the EPA's Science Advisory Board.

SAFETY

- National Institute for Occupational Safety and Health (NIOSH), "NIOSH Pocket Guide to Chemical Hazards," last updated August 5, 2013, http://www.cdc.gov/niosh/npg/default.html. The pocket guide contains general industrial hygiene information on chemicals for workers and occupational health professionals. It is available for download and free copies can be ordered from the website.
- Occupational Safety and Health Administration (OSHA), "Oil and Gas Extraction," https://www.osha.gov/SLTC/oilgaswelldrilling/standards.html. This website has health and safety standards pertaining to the oil and gas industry. There is also a tool that details potential health and safety hazards by stage of production, along with preventative measures and solutions for each: https://www.osha.gov/SLTC/etools/oilandgas/index.html.

QUALITY OF LIFE—ECONOMIC IMPACTS

- Headwaters Economics, "Oil and Natural Gas Fiscal Best Practices: Lessons for State and Local Governments" (November 2012), http://headwaterseconomics.org/wphw/wp-content/uploads/Energy_Fiscal_Best_Practices.pdf. This brief explains the four main fiscal challenges related to oil and natural gas development for local communities—revenue amount, timing, distribution, and volatility—and offers 12 recommendations for state and local governments to address them.
- International Finance Corporation, "Projects and People: A Handbook for Addressing Project-Induced In-Migration," http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/learning+and+adapting/knowledge+products/publications/publications_handbook_inmigration__wci__1319576839994. The International Finance Corporation (IFC) is a member of the World Bank Group. Their mission is to end extreme poverty by 2030 and boost prosperity in every developing country. This handbook offers guidance to extractive sector industries on addressing project-related in-migration in an international context. It offers the business case for addressing in-migration, gives an overview of the phenomenon and its effects, and provides management approaches and tools.
- Pennsylvania State University Center for Dirt and Gravel Road Maintenance, "Sample Road Use Maintenance Agreement," http://www.dirtandgravel.psu.edu/sites/default/files/Center/Marcellus/Sample_RUMA.pdf. A sample road use agreement as a starting point for communities wishing to develop their own agreement with a gas operator.

QUALITY OF LIFE—NOISE IMPACTS

- Earthworks, "Oil and Gas at Your Door? A Landowner's Guide to Oil and Gas Development" (Durango, Colorado: Oil and Gas Accountability Project, 2005) http://www.earthworksaction.org/library/detail/oil_and_gas_at_your_door_2005_edition#.UxjPSj9dWSo. The effects of noise are covered on pp. I-45–I-49. For a useful illustration of noise impacts from oil and gas development, a Colorado study recorded the average decibel levels of typical noises emanating from well pads; see chart, p. I-45.
- New York State Department of Environmental Conservation, "High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement Documents" (Albany, New York: April 2015), http://www.dec.ny.gov/energy/75370.html. New York's Final SGEIS covers a wide variety of potential issues resulting from shale gas development. For composite noise levels for drilling and hydraulic fracturing, see pp. 6-295 to 6-297. For composite noise levels of other well pad activities, see pp. 6-292 and 6-293. For a chart of truck noise as a function of truck size and speed, see p. 6-299.
- The Noise Pollution Clearing House (http://www.nonoise.org/index.htm) is a national non-profit organization with extensive noise-related resources. Its mission is to raise awareness about noise pollution, strengthen laws, and assist activists in order to "create more civil cities and more natural and rural wilderness areas by reducing noise pollution at the source." To aid in their efforts, they maintain a database for noise regulations and ordinances in cities, counties, and towns within the United States: http://www.nonoise.org/lawlib/cities/cities.htm.
- The Southwest Pennsylvania Environmental Health Project, a nonprofit environmental health organization that provides assistance to local residents concerned about the health impacts of shale gas development, has guidance for monitoring noise levels in homes using smartphone apps: http://www.environmentalhealthproject.org/health/noise-light.

QUALITY OF LIFE—VISUAL IMPACTS

- National Park Service, "Making a Difference," last updated April 23, 2012, http://www.nature.nps.gov/night/difference.cfm. This website has information and guidance on reducing light pollution.
- New York State Department of Environmental Conservation, "High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement Documents" (Albany, New York: April, 2015), http://www.dec.ny.gov/energy/75370.html. New York's Final SGEIS covers a wide variety of potential issues resulting from shale gas development. For charts summarizing "Generic Visual Impacts Resulting from Horizontal Drilling and Hydraulic Fracturing in the Marcellus and Utica Shale Area of New York," see pp. 6-285 to 6-288.
- Sarita Rose Uphadyay and Min Bu, "Visual Impacts of Natural Gas Drilling in the Marcellus Shale Region" (Cornell University: Fall 2010), http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Visual%20Impact_Final%20Repo]rt.pdf. This study contains photographs depicting visual impacts of shale gas development at various stages and from varying distances.

STAGE 4
DEVELOPMENT & PRODUCTION

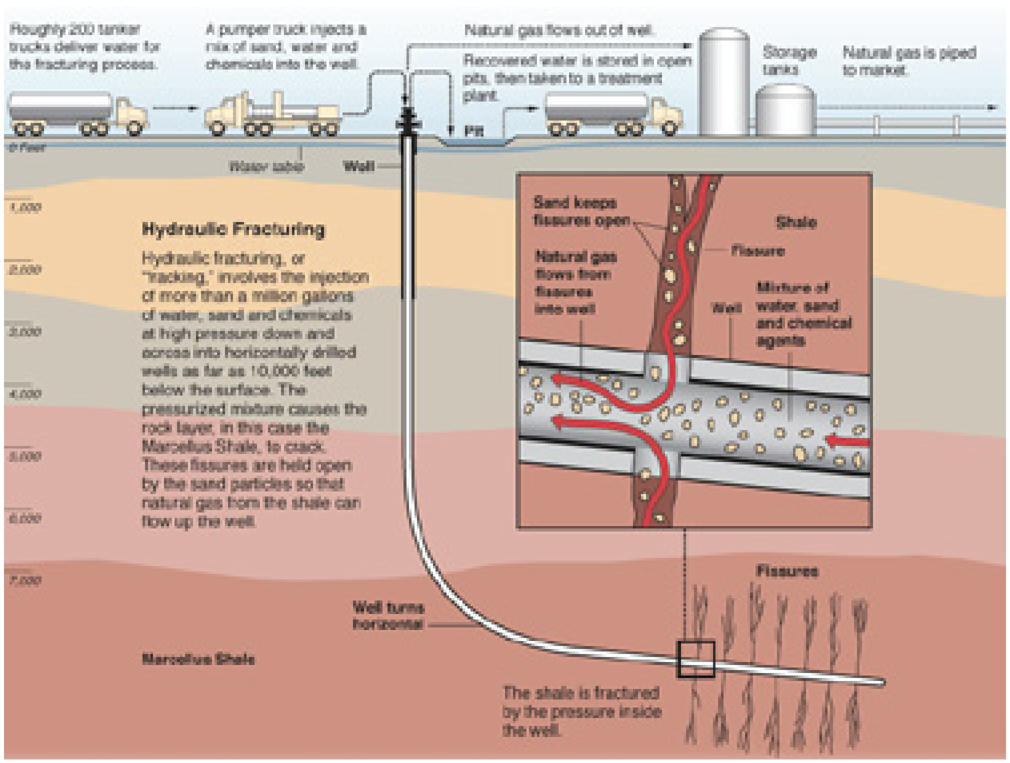
HEALTH ISSUES IN THIS SECTION

What is the company doing at this stage?

DEVELOPMENT

Once the company makes the decision to move ahead with development in a particular area, it may proceed with development drilling at several different locations throughout the project area. When it returns to an exploration site, the operator often begins drilling multiple wells, also known as *infilling*. Activities at such a site, which may have been dormant for a while, ramp up during this intense phase of construction, site development, and drilling. The site operates 24 hours a day, 7 days a week. The workforce also grows to its largest size with staff engaged in site operations, transportation of materials and equipment, and support activities. As certain jobs require specialized skills and training, many of the workers may be brought in from outside the local area.

Figure 4. An example illustration of the development and production process in the Marcellus Shale region



Source: Al Granberg, ProPublica, http://www.propublica.org/special/hydraulic-fracturing-national

The construction and well development activities described in the exploratory drilling phase intensify as multiple wells are built on the pad. The company installs equipment for processing the oil or natural gas produced at the site. Additional infrastructure may also be built, including ***flowlines*** that carry gas, oil, and other fluids at or near the wellhead, ***gathering lines*** that transport the oil or gas to a central collection point, and ***transmission pipelines*** that take the product to market. New processing facilities and compressor stations may also be needed in the area. (See Appendix E for additional information about pipelines.)

When a site moves to development and into production, the company has been present in the community for months, possibly years, and has likely developed relationships with local stakeholders. Now that the company is committed to development in the area, it will need to maintain a productive engagement with the community over the life of the project.

PRODUCTION

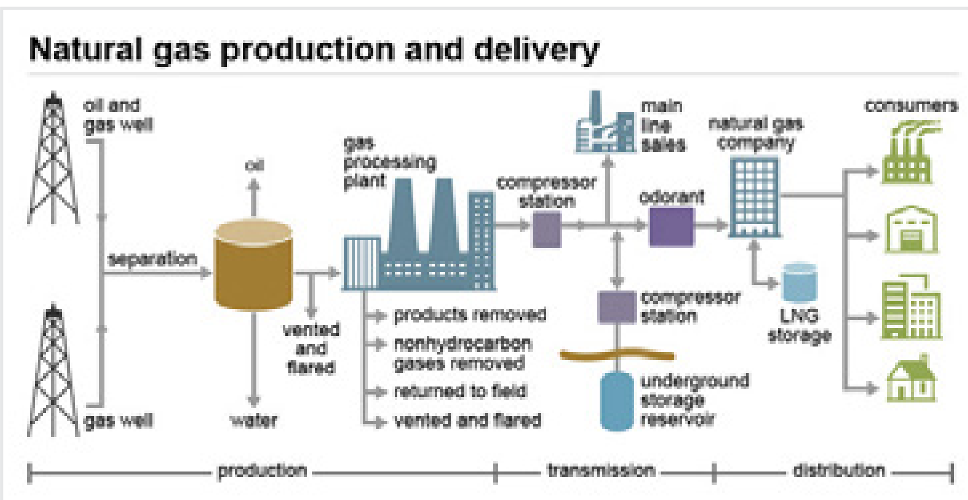
After the wells are completed through hydraulic fracturing, the operator removes the rig and installs a ***wellhead***, also referred to as a "Christmas tree" due to the many valves sprouting from it. The valves control pressure in the well and permit the flow of oil or gas to the flowlines. The remaining infrastructure on the pad is required for gas storage, produced water storage or treatment, and pipeline infrastructure (see Figure 4).

In the natural gas industry, the phases of development and production are not distinct, with production beginning soon after the wells are completed and connected to the gathering systems. This often occurs while the site is still in development.[1] After the gas emerges from the well, it may first be sent to a processing station to remove impurities. Then gathering lines convey the natural gas to a compressor station that pressurizes the gas for longer-distance transport. From there, the product is piped to export terminals or to end users like residences and businesses (see Figure 5).

In the case of oil production, the product is transported through flowlines to a local gathering station. It is then sent to a refinery to be processed; finally, it is transported either to market or to export facilities.

Once the well pad has turned over to the production phase, work activity slows principally to monitoring the site. The operator reduces its workforce to fewer, longer-term staff. Over the lifetime of the well—which could be 10–50 years—periodic activities may take place to re-stimulate production and perform maintenance. When the production of oil or gas begins to decline, the operator may seek to enhance production by re-fracturing the well, depending on the geology of the source rock at the site. Specialized teams of workers may periodically visit the site to conduct re-fracturing, perform routine maintenance on aging equipment, or perform ***workovers***, a more extensive overhaul of the equipment. Therefore, while there is a decline in activity in the post-development phase of production, work at the site continues intermittently for many years.

Figure 5. An illustration of the production, transmission, and distribution of natural gas



Source: U.S. Energy Information Administration, "Natural Gas Explained: Delivery and Storage of Natural Gas," http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_delivery.

Photo provided by Shell Oil Company.

1 Dutton and Blankenship, "Socioeconomic Effects," 7-8.

What might my community experience?

With the operator's decision to develop in your area, the uncertainty surrounding the project has been resolved. While the company might have previously been hesitant to invest in the local community, it might feel more comfortable in making longer-term commitments. The challenge for the community and local planners will be to take advantage of any economic benefits to invest in building a diverse local economy and focus on long-term needs.

The population growth that begins in the exploration phase typically expands as the site is developed and then drops again when the temporary workforce departs. The community will likely experience the most significant health impacts at this stage as development activities peak; these impacts tend to taper off and change in nature as the site moves into the post-development phase of production.

What health considerations are there?

All of the potential health considerations discussed in the exploratory drilling phase—**air quality, water quality, disease burden, safety, and** health-related quality of life (including changes to the local economy, society, noise level, viewshed, and psychology of the community)—continue to be relevant in Stage 4, with many of them intensifying during development when multiple wells are constructed and the temporary workforce swells to its largest size.

As the wells begin producing oil or gas for market, new activities that could have health impacts may emerge, such as the use of compressor stations for the transport of gas. Although large quantities of water are used to hydraulically fracture the wells in the exploration phase, water usage is more likely to cause concern in this phase when multiple wells are drilled, fractured, and later re-stimulated.

AIR QUALITY

In addition to the air quality impacts discussed in Stage 3, new activities and infrastructure come online in the production phase that may contribute to air emissions. In the production stage for oil operations, the associated natural gas that emerges from the well is separated from the crude oil. While saleable gas is sometimes captured and transported to market, it is often flared or vented due to the lack of natural gas pipelines in the area. As discussed in Stage 3, however, new EPA regulations effective in 2015 and 2016 will significantly limit both practices.

In natural gas operations, the produced gas generally undergoes processing to remove water and other constituents to meet sales quality requirements prior to transport. The dehydration units that remove water from the gas can also release VOCs and other hazardous air pollutants (HAPs) into the air. If the gas contains sulfur, it goes through a *sweetening* process to remove it. Once extracted, the sulfur may be flared, incinerated, or possibly captured for market.

After the gas has been conditioned, it is piped to compressor stations where it is pressurized for transport over longer distances. If the compressor engines are diesel-powered, they can emit nitrogen oxides, carbon monoxides, and VOCs.

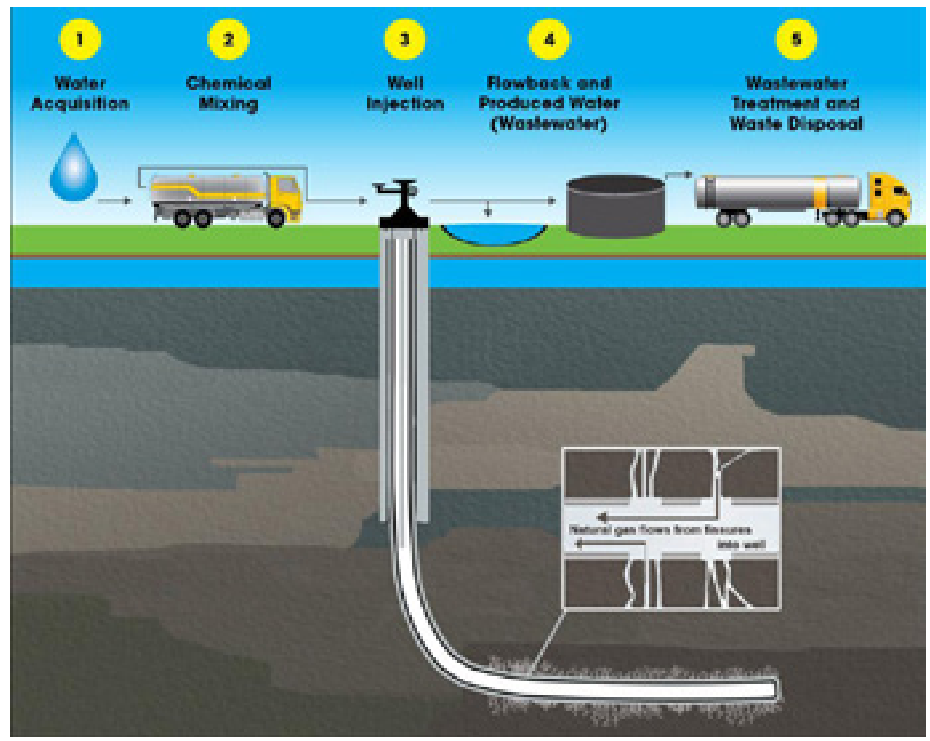
There are also fugitive emissions of methane from pipelines and other equipment, as well as releases from the pneumatic instruments controlling the operation of valves. Researchers have identified these pneumatic devices, which release gas as part of their regular operation, as a major source of methane emissions from natural gas infrastructure.[2] These sources too will be affected by the EPA's proposed regulations under the Clean Air Act, which require operators to locate and plug leaks from equipment and infrastructure, including pneumatic pumps, pneumatic controllers, and compressor stations.[3] The agency anticipates the rule will be final in 2016.

WATER QUANTITY

Shale development using hydraulic fracturing involves pumping a mixture of sand, water, and chemicals into deep rock formations at high pressure in order to release natural gas or oil. A single well may use 3–6 million gallons of water, although usage can vary widely depending on the well and the specific shale formation.[4] The majority of the water usage takes place in the development and production stages of the project, when drilling and hydraulic fracturing require fluids for cooling, lubricating, maintaining pressure in the well, and fracturing the shale.

Three Brothers Compressor Station, PA. By Bob Donnan, 2014

Figure 6. The Hydraulic Fracturing Water Cycle



Source: U.S. EPA, "The Hydraulic Fracturing Water Cycle," http://www2.epa.gov/hfstudy/hydraulic-fracturing-water-cycle#1.

2 David T. Allen, Adam P. Pacsi, David W. Sullivan, Daniel Zavala-Araiza, Matthew Harrison, Kindal Keen, Matthew P. Fraser, A. Daniel Hill, Robert F. Sawyer, and John H. Seinfeld, "Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers" Environmental Science and Technology 49 (2015), 633-4, http://pubs.acs.org/doi/pdf/10.1021/es5040156.

3 U.S. EPA, "Proposed Climate, Air Quality and Permitting Rules for the Oil and Natural Gas Industry: Fact Sheet," 1.

4 U.S. Government Accountability Office, "Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks" (September 2012), http://www.gao.gov/assets/650/647791.pdf.

BOX 12. FOCUS ON U.S. WATER LAW AND REGULATION

There are several different water law regimes in the U.S. The two dominant regimes are the ***riparian doctrine***, applied in most Eastern states (with some permutations on the West coast), and the ***prior appropriation doctrine***, which applies in most states west of the 100th meridian. Under the riparian doctrine, landowners along waterways have "riparian rights" to the natural quantity and quality of flow in the waterway, except as diminished by the "reasonable use" of the water by other riparian landowners. Under riparian doctrine, the right to use the water may be obtained by purchasing land along the waterway.

Under the prior appropriation doctrine, water is allocated in specific amounts for "beneficial use." Each water right has a priority date that determines its place in the hierarchy of withdrawals, and it maintains the same date even if it is sold to another user. Older water rights have priority over more recently created ones—"first in time, first in right"—and are therefore more valuable. In times of water shortage, holders of "younger" water rights are required to stop withdrawing water from the waterway to ensure that senior rights holders can withdraw the full amount they were allocated. Under prior appropriation, rights to specific amounts of water may be bought and sold by users without the requirement of riparian land ownership. Prior appropriation rights are generally considered stronger property rights than rights established under the riparian doctrine, and have been subjected to buying and selling in a marketplace. In some states, therefore, holders of water rights may benefit from shale development by selling a portion of their right to an operator.

Water rights are also governed by the ***federal reserved right doctrine***, under which American Indian tribes retain rights to water even if those rights were not specifically allocated to them in treaties with the U.S. government; ***reclamation law***, which is a specialized area of federal contract law for federal reclamation projects such as California's Central Valley Project; and ***federal regulatory water rights***, which are regulatory constraints (such as Endangered Species Act requirements) that often trump other water laws.

Water used in these operations can be sourced from surface waters such as rivers, lakes and streams, from municipal water supplies, or from underground aquifers. Overuse of an area's groundwater can cause land subsidence, a reduction in surface waters, and, due to the interconnected nature of the water cycle, long-term unsustainability of water supplies. In an effort to reduce their use of fresh water supplies, operators also draw on municipal wastewater, recycled water, or brackish water.[5]

In the United States, the states are primarily responsible for the regulation and permitting of withdrawals from surface and groundwater. According to a study of 31 states by Resources for the Future, most states require permits for water withdrawals, although some only require them for withdrawals above a certain threshold.[6] Others require disclosure of withdrawals, with the exception of Kentucky, which exempts the oil and gas industry from water allocation regulations. Pennsylvania and West Virginia require companies to submit a water management plan that includes an impact analysis of the planned withdrawals.[7]

Although the water needed for drilling the wells and fracturing operations may represent a fraction of the overall water resources available, the timing of withdrawals over the short time period that operations occur—as well as cumulative withdrawals for multiple sites—can bring the industry into competition with other local uses, including municipal, agricultural, and recreational. Due to the location of the oil and gas reserves,

5 Water whose salt content falls between that of fresh and seawater.
6 Richardson, Nathan, Madeline Gottlieb, Alan Krupnick, and Hannah Wiseman, ***The State of State Shale Gas Regulation,*** Resources for the Future (June 2013), http://www.rff.org/rff/documents/RFF-Rpt-StateofStateRegs_Report.pdf.
7 Nathan Richardson et al., ***The State of State Shale Gas Regulation***, 40–41.

shale energy operations are often concentrated in small communities with limited resources to handle any stress on their water supplies. If the area is experiencing drought, which is the case for over half the areas of shale development in North America, withdrawals can exacerbate stressed conditions.[8]

After hydraulic fracturing has taken place, a portion of the injected water—ranging from 30% to 70% of the original[9]—returns to the surface, while the remaining portion is trapped in the shale formation. This produced water often contains naturally occurring chemicals such as salts, heavy metals, and naturally occurring radioactive materials (NORM) from the rock formation. (For information on water quality issues, see Stage 3.)

There are several methods for managing well site wastewater. It can be processed on the well pad site or transported to a waste treatment facility. If the water is treated to remove pollutants, it can ultimately be returned to surface waters, where it re-enters the water cycle. Some companies recycle the wastewater, treating it and mixing it with fresh water before reusing it in their operations or providing it for other industrial or agricultural uses. Wastewater can also be injected into underground disposal wells, where it is stored between layers of impermeable rock thousands of feet from usable groundwater resources. From a water availability perspective, disposing of the water in this manner effectively removes it from the global water cycle.

In June 2015, the EPA published a draft report on the potential impact of hydraulic fracturing on drinking water resources. The final report will include the effects of each stage of hydraulic fracturing on the quantity and quality of drinking water.[10] The cycles under consideration in this report include water acquisition, chemical mixing, well injection, produced water, and wastewater treatment and waste disposal.

SAFETY

Incidents involving production infrastructure and facilities

The production of shale oil and gas involves other infrastructure in addition to that found at the well site, such as pipelines (see Appendix E), processing plants, and compressor stations. Some communities have been concerned that methane leaks, releases of other airborne toxins, fires, and explosions could occur at these facilities, many of which are situated close to large population areas. In 2013, for example, dramatic floods affected oil and gas infrastructure in Colorado, releasing oil and produced water into the environment. Post-flooding monitoring concluded, however, that the volume of floodwater diluted the releases to the point that they were unlikely to pose a public health concern.[11]

Can shale development operations cause earthquakes?

As discussed above, shale development operations require the disposal of a large quantity of wastewater, which is often injected into underground wells (or injection wells). Although

---

8 Monika Freyman, ***Hydraulic Fracturing & Water Stress: Water Demand by the Numbers*** (Ceres, February 2014), http://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers/view, 6.

9 Ground Water Protection Council and ALL Consulting, "Modern Shale Gas in the United States: A Primer," Prepared for U.S. Department of Energy Office of Fossil Energy and the National Energy Technology Laboratory, April 2009, 66. http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf.

10 Given that the draft report is currently under review by the EPA's Science Advisory Board and is marked as not for citation, we have refrained from citing the study's preliminary conclusions on water quantity in this version of the guidebook.

11 Adgate, Goldstein, and McKenzie, "Potential Public Health Hazards," 8310.

it has long been known that certain human activities—such as underground injection, oil and gas extraction, mining, and geothermal projects—can lead to ***induced seismicity***,[12] the magnitude of these earthquakes was thought to be too minor to pose a risk to people or property.

Since 2009, however, the number of earthquakes has spiked in the central and eastern regions of the United States at the same time that wastewater disposal from shale development has significantly increased.[13] This increase in seismic activity was remarkable, given that areas such as central and northern Oklahoma are accustomed to very few felt earthquakes. While the majority of these tremors are too minor to cause any damage, several 2011–2012 quakes in Colorado, Oklahoma, Texas and Arkansas had magnitudes of over 5.0, resulting in some injuries and damage.[14]

According to recent studies by independent scientists and the U.S. Geological Survey (USGS), the underground injection of high volumes of produced water is associated with the increase in earthquakes in the central and eastern United States.[15, 16, 17] It should be noted, however, that there are over 150,000 approved injection wells in the United States, used for various purposes, most of which have no measurable seismic activity associated with them. Approximately 40,000 of these disposal wells are for oil and gas operations.[18] It thus appears that only a very few wastewater disposal wells used by the oil and gas industry could potentially cause earthquakes large enough to be felt on the surface.[19] The challenge is therefore identifying which injection wells, at which locations, have the potential to trigger seismicity.

A 2015 USGS and University of Colorado analysis of the relationship between wastewater injection and induced seismicity concluded that the injection rate is strongly correlated with the incidence of earthquakes. Wells injecting more than 300,000 barrels a month are much more likely to be associated with a seismic event than wells injecting at a lower rate.[20] The researchers indicated that managing the injection rate could therefore be a promising approach to reducing the likelihood of induced earthquakes.

Although there have been concerns that the process of hydraulic fracturing could trigger earthquakes, the vast majority of these tremors have been linked to wastewater injection rather than to hydraulic fracturing.[21] In its investigation of a

12 Ground Water Protection Council and Interstate Oil and Gas Compact Commission, Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation (2015), 1, http://www.gwpc.org/sites/default/files/finalprimerweb.pdf.

13 There was an annual average of 21 earthquakes of magnitude 3 or larger (M3+) in central and eastern parts of the United States between 1973 and 2008; from 2009 through 2013, the annual rate averaged 99 M3+ earthquakes in these areas; and in 2014 alone, there were 659 M3+ earthquakes in the central and eastern states (U.S. Geological Survey, "Induced Earthquakes," last modified September 20, 2015, http://earthquake.usgs.gov/research/induced).

14 M. Weingarten, S. Ge, J.W. Godt, B.A. Bekins, J.L. Rubinstein, "High-Rate Injection Is Associated with the Increase in U.S. Mid-Continent Seismicity, Science 348, no. 6241 (June 19, 2015), 1336, https://profile.usgs.gov/myscience/upload_folder/ci2015Jun1814143055600Weingarten_etal.pdf.

15 M. Weingarten et al., "High-Rate Injection," 1336.

16 F. Rall Walsh III and Mark D. Zoback, "Oklahoma's recent earthquakes and saltwater disposal," *Science Advances* 1, no. 5 (June 18, 2015), http://advances.sciencemag.org/content/1/5/e1500195.

17 Ground Water Research and Education Foundation (GWREF), "White Paper II Summarizing a Special Session on Induced Seismicity: Assessing and Managing Risk of Induced Seismicity by Injection" (November 2013), 19, http://www.gwpc.org/sites/default/files/files/White%20Paper%20II%20Summarizing%20a%20Special%20Session%20on%20Induced%20Seismicity-%20November,%202013%20(GWPC).pdf.

18 USGS, "USGS FAQs," last modified August 19, 2015, http://www.usgs.gov/faq/categories/9833/3424.

19 USGS, "Induced Earthquakes."

20 M. Weingarten et al., "High-Rate Injection," 1336.

21 USGS, "How is hydraulic fracturing related to earthquakes and tremors?" USGS FAQs, last modified August 19, 2015, http://www.usgs.gov/faq/categories/10132/3830.

magnitude 3.0 quake that occurred in March 2014, however, the Ohio Department of Natural Resources concluded that the incident may be due to hydraulic fracturing activity itself, and not to wastewater disposal.[22]

The USGS continues to conduct research into induced seismicity with a set of studies designed to monitor and evaluate seismic events; better understand and predict the linkages between injection and earthquakes; and estimate earthquake hazards.[23] The Oklahoma Geological Survey is also conducting a study of quakes related to hydraulic fracturing activity.[24] While researchers work to shed more light on the connections between seismicity and industrial activity, a work group composed of state oil and gas regulatory agencies and geological surveys has produced a guidance document for regulators on evaluating and managing the risks of induced seismicity and developing response strategies.[25] Depending on the circumstances, the mitigation options described include increasing seismic monitoring in at-risk areas, altering injection rates or pressures, introducing permit modifications, and halting injection activities.

States are addressing these induced seismicity concerns in various ways. In 2013, for example, Oklahoma put in place an evolving "traffic light" system for regulating disposal injection wells that involves a seismicity review of proposed wells, along with monitoring and increased testing of wells in areas of possible seismic activity.[26] Directives issued by the Oklahoma Corporation Commission have resulted in reductions in well depth and the volume of injections at certain wells, and have required some wells to cease injections.[27] Ohio has issued new permitting requirements for injection wells and now requires additional seismic monitoring at both injection well and shale development sites.[28, 29] Texas, on the other hand, has been more cautious about taking regulatory action, opting to wait for the results of further research on the connection between injection wells and seismicity.[30] The Texas Railroad Commission has, however, required additional testing from certain wells where links to induced seismicity have been suspected.[31]

HEALTH-RELATED QUALITY OF LIFE

With regard to socioeconomic impacts, the phases of development and post-development production can have very different effects on the community's health and quality of life. As mentioned above, the influx of outside workers in the development phase often leads to a number of boomtown effects that can put stress on the community's infrastructure, housing, services, community character, and the psychology of its residents. The extent to which these pressures negatively affect the community depends upon its size, the magnitude and pace of development,

22 Edward McAllister, "Ohio Links Fracking to Earth Quakes, Announces Tougher Rules," ***Reuters*** (April 11, 2014), http://www.reuters.com/article/2014/04/11/us-ohio-fracking-earthquakes-idUSBREA3A1J620140411.
23 For more information, see the United States Geological Survey, "Induced Earthquakes," last modified September 11, 2014, http://earthquake.usgs.gov/research/induced.
24 Mike Soraghan, "Oklahoma Agency Gets $1.8M to Study Seismic Links to Drilling," E&E News, July 16, 2014.
25 Ground Water Protection Council and Interstate Oil and Gas Compact Commission, Potential Injection-Induced Seismicity Associated with Oil & Gas Development, 4.
26 Oklahoma Corporation Commission, "OCC Announces Next Step in Continuing Response to Earthquake Concerns" (July 17, 2015), http://www.occeweb.com/News/DIRECTIVE-2.pdf.
27 Oklahoma Corporation Commission, "OCC Announces Next Step."
28 GWREF, "White Paper II," 27.
29 Edward McAllister, "Ohio Links Fracking to Earthquakes."
30 GWREF, "White Paper II," 26–27.
31 Barclay R. Nicholson and Emery G. Richards, "Induced Seismicity Legal Issues Break New Ground," ***Law360***, (May 15, 2015) http://www.law360.com/articles/654837/induced-seismicity-legal-issues-break-new-ground.

the area's capacity to absorb a population increase (e.g., nearby towns with available worker housing), and the predisposition of residents to development.

QUALITY OF LIFE—ECONOMIC IMPACTS

Development

During exploration and the early phase of development, many of the jobs require specialized skills, prompting companies to bring in temporary outside workers to fill those positions. As development expands in the area, more direct and indirect opportunities for local employment may become available, particularly in businesses involved in trucking and construction. Such an increase in development can lead to a rise in incomes and increased economic activity in the area.

In addition to stimulating some businesses, the oil and gas industry can come into competition with other local businesses and local government for workers, which can put upward pressure on wages. If the local labor supply is limited, the industry may draw increasing numbers of outside workers to the area. This population influx can increase local demand for food, fuel, and housing, which drives up prices. For some local businesses—often those already on the margin—rising costs for items such as wages, fuel, and transport could cause them to fail, decreasing the economic diversity of the community (a phenomenon known as *crowding out*).

Depending on the size of the community and its proximity to other towns with available housing, the arrival of project workers can put a strain on the community's housing supply. Housing shortages can be acute in small communities without existing construction capacity. Oil and gas workers can often afford to pay higher rental prices than other workers, thereby reducing the availability of affordable housing. This can result in the displacement of some long-term residents, particularly renters and the elderly, who are forced to leave the area to seek lower-cost housing elsewhere.

As mentioned in Stage 3, if there is a gap between additional local government revenues (from taxes, leases, and royalty payments) and the demands on community services and infrastructure, it may be particularly pronounced at this stage of heavy development. A rapid influx of project workers and their families can put a strain on local infrastructure and services. Affected services can include the following:

- Transportation infrastructure
- Water
- Sanitation
- Waste management
- Power generation
- Emergency response system
- Police
- Traffic control
- Schools
- Communications networks
- Recreational facilities
- Health care system

A 2014 Duke University report found that the highest costs to county governments due to shale development have been road maintenance and repair, followed by increased staffing costs needed to respond to growing service demands (such as law enforcement and emergency services).[32] For municipal governments, the highest costs have tended to be upgrading

32 Daniel Raimi and Richard G. Newell, "Shale Public Finance: Local Government Revenues and Costs Associated with Oil and Gas Development," Duke University Energy Initiative report (Durham, NC: May 2014), 2.

sewer and water infrastructure, followed by greater staffing costs.[33] As noted in Stage 3, the study found that while local governments have financially benefitted from the advent of shale development overall, in certain regions (the Bakken Shale in particular) where large-scale development has occurred at a rapid pace, governments have struggled or failed to keep pace with increased costs.

Production

Over time, as the industry matures to the post-development production phase, the number of transient workers declines and workers that are more permanent fill the long-term development and production positions. These permanent employees are either transplants who choose to relocate with their families or locals who have acquired the skills and training needed to compete for jobs. As community residents, they spend a significant part of their income locally, contributing to the area's long-term economic activity. Companies also continue to buy some goods and services locally, generating indirect and induced employment opportunities and further contributing to economic growth.

Some communities in the western United States, which have long been host to oil and gas development, have seen the benefits of oil and gas development begin to materialize as development enters the production phase. At this point, revenues tend to exceed the costs of natural resource development from a fiscal standpoint. These revenues can be used to fund improvements in community services and infrastructure or to provide tax relief to communities.[34] At the same time, it is important for governments to be wary of becoming too dependent on these revenues, as they typically decline with the end of production and may fluctuate with oil and gas prices.[35]

QUALITY OF LIFE—SOCIAL IMPACTS

The size and character of the community, as well as the views of its residents on shale development, can play significant roles in how a community experiences the changes accompanying development. In economically depressed areas, many residents may welcome the economic activity and opportunities brought by shale development. In rural communities that are focused on agriculture or tourism, however, industrial development can be seen as a threat to livelihoods and community character.

In many towns experiencing an economic boom, the benefits and costs of development are not distributed equally among residents, which can lead to social friction. While some residents may receive royalties from leasing land to developers, their neighbors may not enjoy these rewards. Some may feel they are experiencing the negative impacts of rapid industrialization and population growth (e.g., strained municipal services, widespread construction, and unfamiliar social issues) but are not receiving any benefits. In a recent survey of residents from areas experiencing shale development, those not holding leases or receiving gas royalties describe the area as "worse" or "much worse" as a result of energy development, while those with income from wells describe their area as "much better."[36] As mentioned in the economic impacts section above, some local businesses may thrive but others may suffer, particularly

32 Daniel Raimi and Richard G. Newell, "Shale Public Finance," 3.
34 Dutton and Blankenship, "Socioeconomic Effects," 20.
35 Dutton and Blankenship, "Socioeconomic Effects," 21.
36 Jeffrey B Jacquet, "Review of Risks to Communities from Shale Gas Development," ***Environmental Science and Technology***, published electronically (March 13, 2014), PubMed Central, http://www.ncbi.nlm.nih.gov/pubmed/24624971.

agricultural, recreational, and tourism-based enterprises. Housing prices may increase, creating higher income for property owners and capital gains for those selling real estate; yet low-income individuals may no longer be able to afford to live within the community. These economic divisions may result in increased tensions; mistrust; overt conflict and even litigation; and generally diminished cohesiveness in the social fabric.

As development moves into the production phase, many communities eventually adapt to the changes, especially if new local jobs are created, the economy expands, and the number of transient workers decreases.[37]

QUALITY OF LIFE—PSYCHOLOGICAL IMPACTS

As noted in the social impacts section above, several factors can play into whether community residents feel positively or negatively about the changes in their communities. Certainly, people may welcome some changes while feeling concerned about others. When the arrival of shale development brings significant change, in particular to a small community or one that is unfamiliar with industrial development, the scale and pace of changes in the development phase can be overwhelming to some residents. Community members may find it difficult to manage the cumulative impacts of population influx and industrial development, which can potentially include increases in traffic, a rise in crime, overcrowded schools, and stressed local infrastructure and services.

The psychosocial stress on some individuals as they experience the cumulative impact of the many changes in their communities may contribute to physical illness,[38] addiction, and mental illness.[39] The increased occurrence of other physical symptoms should be considered in the context of possible air and water quality impacts (see the air quality and water quality sections in Stage 3).

QUALITY OF LIFE—NOISE IMPACTS

In the development phase, the operator often installs multiple wells per pad, prolonging the period when the project is generating noise (see Stage 3 for an overview of the effects of noise). During the longer production phase, the operator may occasionally re-stimulate or perform workovers on the well, which entails noise at the site and additional truck traffic transporting materials to and from the site. Workovers are, however, infrequent throughout the life of a producing well.

QUALITY OF LIFE—VISUAL IMPACTS

The effects on the local viewshed are the most dramatic in the development phase as multiple wells are constructed on the pad. Once the operator has completed drilling and hydraulic fracturing and the site moves into post-development production, however, the company can undertake interim reclamation of the site.[40] In this period, the footprint of staging and storage facilities, water impoundments, and truck traffic should all diminish.

37 Roxana Witter, Lisa McKenzie, Meredith Towle, Kaylan Stinson, Kenneth Scott, Lee Newman, and John Adgate, ***Health Impact Assessment for Battlement Mesa, Garfield County, Colorado***, University of Colorado School of Public Health (Denver, Colorado: September 2010), http://www.garfield-county.com/public-health/documents/1%20%20%20Complete%20HIA%20without%20Appendix%20D.pdf.

38 Jeffrey B Jacquet, "Review of Risks."

39 S. L. Perry, "Using Ethnography to Monitor the Community Health Implications of Onshore Unconventional Oil and Gas Developments: Examples from Pennsylvania's Marcellus Shale," ***New Solutions*** 23, no. 1 (2013), 33–53, http://www.ncbi.nlm.nih.gov/pubmed/23552647.

40 While often mandated by state regulations, interim reclamation is not always enforced.

What can be done to address health concerns? What have others done?

COLLABORATIVE ACTIVITIES

Now that the company is investing in your area, it is an opportune time for local officials, operators, and other local stakeholders to begin collaborative planning efforts and/or begin implementing plans that were previously developed. There are numerous challenges that companies and communities could work together to address; for example, API's Community Engagement Guidelines suggest that operators engage local stakeholders in dialogue around mitigating or eliminating potential negative economic impacts and maximizing economic benefits to the community.[41] Another suggestion is to plan for sustainable solutions to temporary housing challenges.[42] Examples of initiatives on both of these topics are described in Boxes 13 and 16.

BOX 13. CASE STUDY: ECONOMIC PLANNING

Communities in the Eagle Ford Shale region know from experience that an influx of oil and gas development can mean infrastructure updates, inflated housing prices, and an increase in traffic, among other impacts. In an effort to prevent the typical boom-bust cycle that occurs in many communities experiencing natural resource development, Shell Oil Company and the University of Texas—San Antonio (UTSA) have collaborated to develop community-based solutions in the region. With the goal of helping communities make the most of their existing resources, the UTSA launched a capacity-building training series.[43] The program aims to help communities plan for typical boomtown effects in a way that considers the long-term benefits to the community as a whole. For some of these communities, long-term planning to maximize the benefits of development has meant building strong collaborative relationships with their neighboring towns.

Shell has also funded a workshop series that focuses on how to build successful local businesses. The purpose is to develop realistic, achievable community vision plans with an emphasis on proactivity and preparing communities for the implementation of municipal improvement projects. For example, La Vernia, Texas has developed a unified plan for how to invest increased sales tax revenue.[44] Their overall goal is to invest in projects that will benefit the broader community and the town's cultural environment. With this in mind, the city will be investing in downtown public spaces, not only to encourage business growth in the downtown area, but also to provide features that residents will enjoy. Local business owners plan to participate in this effort by using income from increased revenue to make updates and diversify their services. The city is also emphasizing strategic planning for long-term job creation.

While the training sessions are intended to help communities plan for their future, the program itself is temporary. It is designed to be adaptable, placing the importance of the desired outcomes in the hands of the community that will be affected. For the Eagle Ford Shale program, change is already afoot, due to Shell's recent divestment of its acreage in the region. The effort is instead moving to the Permian Basin in West Texas, where development is booming.

For more information: Small business development centers and/or community colleges can often help with similar planning efforts. For more information on the UTSA/Shell project, please contact RESOLVE at communityhealthguide@resolv.org.

41 API, "Community Engagement Guidelines," 7.
42 API, "Community Engagement Guidelines," 11.
43 Pamela King, "Industry Initiative Helps Communities Embrace Boom-Time Opportunities," *E&E News*, May 21, 2014, http://www.eenews.net/energywire/stories/1059999908.
44 Pamela King, "Texas Towns Consider Deep Makeovers to Prepare for Inevitable Oil Field Bust," *E&E News*, May 20, 2014, http://www.eenews.net/stories/1059999739.

INDUSTRY REPRESENTATIVES

Air Quality & Safety

In 2011, the Shale Gas Roundtable, a multi-stakeholder group of leaders in Pennsylvania, convened to consider ways to promote effective and responsible oil and gas development in the state. One of the roundtable's recommendations is to consider building pipelines to transport water to and from the well site (see Box 14 for a case study example).[45] It is also important to consider, however, the issues raised by pipeline construction (for more on pipelines, see Appendix E). Furthermore, operators could work with other companies in the region, as well as state and local authorities, to identify locations for centralized processing facilities and infrastructure that would optimize transport routes while reducing surface disturbance and traffic.[46]

Water Quantity

Engaging in consultations with local stakeholders, proactively developing water management plans, and coordinating with other operators in the region to develop shared, centralized infrastructure can help a company to sustainably manage its consumption of water resources. In addition, the company may seek to engage its employees in water conservation efforts and encourage sustainable practices on the part of its suppliers and contractors.

To reduce fresh water withdrawals, the operator can treat and reuse wastewater on site for use in its hydraulic fracturing operations or for other industrial or agricultural uses

BOX 14. CASE STUDY: A SOLUTION IN WATER SOURCING

At its sites in the Fayetteville Shale play in Arkansas, Chesapeake Energy had been purchasing most of its water for drilling and hydraulic fracturing from private sources and trucking it to the well pads. While this process was working for the company, the truck traffic was causing damage to local roads. In 2008, therefore, Chesapeake decided to look into new water supply sources. The company found that by creating what is essentially a holding lake for the overflow from the Little Red River, it could cut down on some of its trucking needs.

Under the system the company developed, water is pumped from the river to the holding lake and transferred into a gravity-fed pipeline that traverses over 40,000 feet, with fourteen hydrants positioned at crossroads where the water can be pumped into trucks. The piping system reduces the air quality impacts and safety concerns of trucking, and serves a dual purpose as a source of water for local fire departments. The project was approved to extract a limit of 1,550 acre-feet of water annually.[47]

Although water is only diverted from the river during periods of high flow, as mandated by the Arkansas Natural Resources Commission (ANRC), there were local concerns about how this project would affect the Little Red River's ecosystem. The river is home to a trout population prized by anglers, so Chesapeake turned to the local chapter of Trout Unlimited for input on the project.

As a result of this collaborative effort, various methods were identified to protect the wildlife in the river—for example, the intake pipe is oriented to face upstream and is covered with a metal mesh to prevent harm to the fish.[48] The company has also instituted monitoring of water quality and both game and nongame fish species in the reach of river surrounding the intake. Working with the community, Chesapeake was able to identify and implement measures to protect the river's wildlife and its recreational and scenic values to the community.

---

45 University of Pittsburgh Institute of Politics, "Shale Gas Roundtable: Deliberations, Findings, and Recommendations" (August 2013): 10.

46 University of Pittsburgh, 12.

47 National Energy Technology Laboratory, "Modern Shale Gas Development in the United States: A Primer," prepared for U.S. Department of Energy, Office of Fossil Energy, April 2009, 65, http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf.

48 Chesapeake Energy, "A River Runs Through It: Environmentally Sensitive Operations in the Natural State," Spring 2008, 2, http://www.chk.com/media/publications/theplay/pages/spring2008.aspx.

(if the treated water meets the user's chemical criteria and the operator obtains the necessary permits). Some companies are achieving nearly 100% recycling of their produced water, which reduces their freshwater consumption by 10 to 30 percent.[49] Companies could also seek to replace the use of fresh water in their operations with municipal wastewater or brackish water.

Other activities that can serve to reduce impacts on local water supplies include:

- minimizing the subsurface injection of produced water to prevent its removal from the water cycle
- considering the practice of groundwater banking, in which an entity stores water in a groundwater basin for the purpose of future withdrawal
- timing surface water withdrawals to avoid coinciding with periods of low flow or of heavy usage (see Box 14 for a case study example)

Quality of Life

There are numerous ways to ease the transition within a community experiencing rapid shale gas development. For example, communities could create a task force to identify and anticipate social issues, tap into regional resources for information on how to respond to changes, and maintain ongoing engagement with industry representatives. Part of the task force's role could be to anticipate the recreational needs of temporary workers and facilitate their participation in community activities and programs.

Beginning in the development phase, API's Community Engagement Guidelines suggest that operators support local activities and nonprofit organizations seeking to address local challenges. The guidelines emphasize the importance of working with local officials and other stakeholders, being responsive to community concerns, and maintaining and continuously improving high industry standards for road and traffic safety, among other considerations.

Furthermore, employee assistance personnel and project managers can be engaged in discussions of how to address substance misuse, given that it is not only a medical and public health problem, but also an issue of workplace safety.[50] In one example, when methamphetamine addiction emerged as a serious health problem in Gillette, Wyoming, Marathon Oil Company undertook an educational awareness campaign to combat the problem (see Box 15).

Quality of Life—Noise Impacts

In addition to the management options described in Stage 3, here are some additional measures to help reduce noise during the phases of development and production:

- erecting sound barriers around engines and/or adding mufflers to them
- enclosing compressors and other noisy equipment in sound-proofed buildings, particularly when in proximity to residences, schools, or places of assembly
- to the extent possible, monitoring the site remotely during the production phase to reduce traffic to the site

49 Freyman, "Hydraulic Fracturing & Water Stress," 39.
50 International Association of Oil and Gas Producers, ***Substance Misuse: A Guide for Managers and Supervisors in the Oil and Gas Industry*** (2010), http://www.ogp.org.uk/pubs/445.pdf.

BOX 15. CASE STUDY: METH EDUCATION PROGRAM

In October 2006, Marathon Oil Company launched an educational awareness program intended to address the methamphetamines (meth) crisis taking place in Wyoming. Although the problem was not unique to Wyoming, Governor Freudenthal had expressed concern, citing it as one of the top social issues in the state.[51] With its long history in Wyoming, Marathon had not only witnessed the issue first hand, but was also in a unique position to do something about it. The company had found that the high incidence of meth use had become a concern for hiring and maintaining contractors for all operators in the area. In some locations, the issue had even begun to affect the company's operations because its contractors were experiencing failed pre-employment drug testing, an increase in absenteeism, and shortages in the local workforce, leading to project delays. Marathon was also hearing that families, especially those with teenagers, were concerned about moving into the area for oil and gas industry jobs.

In response, Marathon designed an educational awareness program intended to start a discussion among its employees about the dangers of meth. After a weeklong presentation series attended by nearly 350 Marathon employees and contractors, the feedback was overwhelmingly positive. Many employees commented that their families, friends, and neighbors needed to see it as well in order to initiate an open community dialogue about the issue.

Amy Mifflin was manager of Marathon's corporate social responsibility program when she took on the question of whether to bring the awareness program to the larger community. She was initially met with in-house skepticism about taking on an issue as significant as meth addiction that was seemingly unrelated to oil and gas development. After discussing the project internally to define its parameters, the company agreed on the value of an awareness-raising campaign that would serve as a resource to employees, their families, and potential employees, as well as build a strong relationship with the local community.

The first community workshop included a presentation by health, environment, and safety expert Eddie Hill about the dangers of meth; information from the local sheriff's office and the mayor; and testimonies from people who had been directly affected by meth. According to Mifflin, the success of the initial workshops and subsequent presentations in other communities transformed many company skeptics into champions. For a relatively small investment, the program helped strengthen community relationships and build a positive reputation for the company.

Brett Martin, a certified addictions practitioner, participated in the outreach and education campaign when it came to his hometown of Cody. He gave a presentation at the Marathon project's events in Cody and on the nearby Wind River Reservation. In his role as an addictions counselor, he often speaks to audiences about his own struggle with meth addiction and his pathway to recovery. Due to Marathon's reputation and standing in the area, he observed that the company was able to reach a larger and more diverse audience than the local health department could. Hundreds of people attended the presentation, including those in key leadership roles, such as city councilors, commissioners, and local mayors. The presentation was well received in the community and people even brought their families to see it—which, Martin said, indicated that the Marathon project was able to transcend the usual stigma. "It helped to show that we can talk about this and it doesn't have to be about shame," he said. "Marathon found a way to allow people to talk about it, to say 'we're all in this together.'"

Marathon's meth education and awareness campaign ran from 2006–2009, reaching an estimated 75,000 people in 11 states. It was delivered free of charge at high schools and town community centers. There were workshops with state health departments and non-governmental organizations (NGOs). The company also filmed the presentation, producing a video for each community and distributing it free of charge. By the time the campaign was winding down, Mifflin was receiving requests from other oil and gas companies that wanted to do similar projects in communities where they were operating.

Asked about advice she might offer to others confronting similar challenges, Mifflin encouraged companies to engage in conversations with communities, even difficult ones. "It starts to alleviate tension with private sector industries, such as oil and gas," she said, "and people begin to see you as an advocate for collaboration and actively engaged in solving the problem."

For companies considering undertaking a similar outreach project, Martin suggests finding ways to support continued conversations in affected communities. For example, the company could offer regular meeting space and resources for developing outreach materials to those who are inspired by the project and want to keep the conversation going.

For more information, contact Amy Mifflin at amy@global-collaborations.com. For short video clip with an overview of the program, see https://www.youtube.com/watch?v=nlmP2vhKn-Q (accessed November 30, 2014).

51 Amy Mifflin (Global Collaborations, Inc.), interview by Erica Bucki and Dana Goodson, June 2014.

Quality of Life—Visual Impacts

During interim reclamation, much of the infrastructure and equipment used during development can be removed. The wellhead will be visible above ground; small brine storage tanks (often painted green to blend with the surroundings) and a metering system remain at the site. The size of the pad and surrounding land disturbance can be reduced by replanting much of the site with appropriate vegetation. There is also the option of adding a landscaped earth berm to enhance visual screening. Access roads can be shrunk to 10 to 20 feet wide and revegetated. On average, a multi-well pad can be reduced to 5.5 acres, and a single-well pad to 4.5 acres, with even smaller footprints possible.[52]

A partially reclaimed single-well site in Chemung County, New York. The footprint of the drill site was 3.2 acres, reduced to a fenced area of 0.45 acres. Photo credits: Henkel, 2002 and 2009. Used with permission. Source: NY Draft SGEIS 2011, p. 6-336.

LOCAL OFFICIALS

Quality of Life—Economic Impacts

If your community is experiencing housing shortages brought about by project-related population influx, one option is to consider reaching out to the operators to identify mutually beneficial solutions (see Box 16 for a case study example). Other potential options for maintaining an adequate supply of affordable housing in the context of shale development were offered in a 2011 study by the Institute for Public Policy and Economic Development at Wilkes University.[53] According to

52 The New York Department of Environmental Conservation Study suggested average production-phase pads of .5 to 1 acre in size.
53 Institute for Public Policy & Economic Development, "Impact on Housing in Appalachian Pennsylvania as a Result of Marcelllus Shale" (Wilkes Barre, PA: November 2011).

the institute, local officials could work with local, state, and regional stakeholders from the public, private, and nonprofit sectors, to consider establishing or promoting:

- **rental ordinances** requiring rental registrations and rent stabilization programs.
- **land banking**, or a public- or privately-funded effort to purchase foreclosed, run down, or abandoned properties; rehabilitate; and resell them. This effort would ideally take place across several counties and would aim to maintain property values and a supply of affordable housing, among other goals.
- **housing trust funds** to provide financial assistance to low-income homebuyers or renters.
- **community development corporations**, or nonprofit organizations that pool funding from multiple public and private donor sources and apply it to local housing problems. Strategies can include purchasing, developing, and renovating residential and commercial properties as affordable housing units and/or offering loan assistance to low-income families.
- **zoning codes** that encourage affordable housing development (e.g., mixed use development/redevelopment/infill, high-density development, and inclusionary zoning).

BOX 16. CASE STUDY: EMPLOYEE HOUSING[54]

When Shell Oil Company arrived in the small town of Harper, Kansas in 2011 to begin shale oil exploration, the company found limited housing options available for its employees. In fact, the town of about 1,500 struggled to provide adequate housing for some of its own citizens, especially seniors. The housing shortage meant that pressure for available housing could drive up rents, with low-income locals losing out to the higher-paid oil field workers.

Some local business owners then approached the company with a proposal—to build housing for Shell employees that would then revert to community use when the employees departed. Shell agreed to support this innovative solution. After carefully vetting several proposals, the sponsors selected builders for two projects who had long-standing community roots and a good sense of the needs of the local citizenry.

The first project involved new construction, initially of 15 one-bedroom units, to be expanded to 32 units after Shell left town. The company agreed to pay for five of the units in exchange for their use as employee flex housing for up to one year. Shell then provided support for the construction of several more bedroom units and common areas. The builder expanded on this initial footprint with two-bedroom apartments to complete the project.

For the second project, the builder renovated the upper stories of a local bank. Six additional employee apartments were created in this space, with laundry facilities and Wi-Fi making them desirable accommodations. To support administration and planning for Shell personnel, the company decided to add a boardroom to this facility.

As discussed in the section above, housing temporary workers, especially in rural areas, can be challenging. This collaboration between Shell and community entrepreneurs resulted in a plan that avoided both shortsighted overbuilding and the displacement of low-income residents. Shell stayed in Harper for approximately 18 months, with comfortable accommodations for its workers, and the town received much-needed housing for its senior citizens and other temporary residents.

For more information on this housing case study, contact RESOLVE at communityhealthguide@resolv.org.

54 Interview by Kathleen Arcuri of Shell staff, June 2014.

What resources can provide further information?

WATER QUANTITY

- Juliet Christian-Smith, "Improving Water Management through Groundwater Banking: Kern County and Rosedale-Rio Bravo Water Storage District" (The Pacific Institute, 2013), http://resources.pacinst.org/wp-content/uploads/sites/21/2013/02/groundwater_banking3.pdf. A case study of water banking programs in Kern County in California's Central Valley. The Pacific Institute, a California-based organization dedicated to reaching environmental solutions through interdisciplinary research, funded this study.
- Monica Freyman, "Hydraulic Fracturing & Water Stress: Water Demand by the Numbers" (Ceres, February 2014), http://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers/view. Ceres is a nonprofit organization whose mission is to mobilize business and investor leadership on climate change and sustainability issues. This paper analyzes water demand in shale development operations in North America, focusing on eight regions of intense development and water use. It offers recommendations to investors, lenders, and companies for mitigating their exposure to water sourcing risks.
- International Council on Mining & Metals, "Water Management in Mining: A Selection of Case Studies" (May 2012), http://www.icmm.com/document/3660. This selection of case studies gives some examples from the mining sector of strategies to reduce water use and protect water quality in collaboration with stakeholders.

SAFETY

- Ground Water Protection Council (GWPC) and Interstate Oil and Gas Compact Commission (IOGCC), "Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation" (2015), http://www.gwpc.org/sites/default/files/finalprimerweb.pdf. TThis primer was developed by a StatesFirst (an initiative of the GWPC and the IOGCC) work group composed of state oil and gas regulatory agencies and geological surveys. It gives an overview of induced seismicity and how it is assessed and offers for regulators on evaluating and managing the risks of induced seismicity, as well as on developing response strategies.
- U.S. Geological Survey (USGS), "Induced Earthquakes," last modified, June 23, 2015, http://earthquake.usgs.gov/research/induced. The website has information on induced seismicity and preliminary findings from USGS research on the issue.

A centralized production facility (CPF). Photo provided by Shell Oil Company.

QUALITY OF LIFE—ECONOMIC IMPACTS

- NeighborWorks America, a nonprofit organization providing support to community development corporations nationwide, has information and resources on community development and expanding affordable housing opportunities on its website: http://nw.org/network/index.asp.

QUALITY OF LIFE—SOCIAL IMPACTS

- International Association of Oil and Gas Producers (OGP) and International Petroleum Industry Environmental Conservation Association (IPIECA), "Substance Misuse: A Guide for Managers and Supervisors in the Oil and Gas Industry," OGP Report No. 445 (London, UK: 2010), http://www.ogp.org.uk/pubs/445.pdf. Produced by IPIECA, the global oil and gas industry association for environmental and social issues, and OGP, this guide for managers in the oil and gas industry focuses on substance misuse prevention techniques applicable to the workplace.

A pumper jack. Photo provided by Shell Oil Company.

STAGE 5
PROJECT CLOSURE & LAND RESTORATION

HEALTH ISSUES IN THIS SECTION

Bureau of Land Management, "Visual Resource Management: Final Reclamation, Part 5" (May 2006)

What is the company doing at this stage?

A well can be hydraulically fractured multiple times to re-stimulate the flow of oil or gas. Once the operator determines the well to be past production or unsuccessful, it is shut down. The state regulates the well abandonment process, often mandating the materials used to plug the well and their placement. Depending on the state, the regulatory agency might also send staff to witness the plugging of the well. In addition to proper well abandonment at the end of the production phase, ongoing inspection and maintenance is required.

Plugging the well involves permanently sealing it with cement and other materials to prevent fluid migration to aquifers, surface water, and surface soils.[1] To maintain integrity, multiple plugs are placed in the wellbore, along with fluids at specific pressures in certain well depths. The operator conducts tests to ensure stability. The steel casing of the wellbore is cut off below the surface and capped with a steel plate. The company removes any remaining equipment from the site, reducing the footprint down to the wellhead. The company then usually works with the surface owner—and is often required to by state law—to restore the land, soil and vegetation as specified in the surface use agreement (or according to regulatory requirements on state and federal lands). According to the API Community Engagement Guidelines, "Communities can expect the land to be reclaimed or restored as close as possible to its original or current surrounding state."[2] The operator may also install a marker on the site that indicates the well location, well number, and operator to facilitate site identification in the future.[3]

In some cases, if the company has other nearby wells still in production, the well might be converted to an injection well that can accept produced water from other sites. These wells are reclassified as Underground Injection Control (UIC) Class II injection wells. Established by the Safe Drinking Water Act (SDWA) in 1974 and regulated by the U.S. Environmental Protection Agency, the UIC program sets forth requirements for different types of injection wells in order to ensure the protection of underground sources of drinking water (USDWs). Class II wells accept liquid wastes from the oil and gas industry (for more information on the UIC program, see Appendix C).

What might my community experience?

With the closure of the project site and departure of the temporary workforce, the community might undergo an economic bust as described in Stage 3. For this reason, it is important to plan for project closure from the outset and to use revenues from the project to strengthen local infrastructure, build community services, and diversify the local economy. Community representatives should also bear in mind the potential long-term impacts of activities associated with the project (for an example, see Box 16: Case Study: Employee Housing).

1 American Petroleum Institute (API), "Environmental Protection for Onshore Oil and Gas Production Operations and Leases," API Recommended Practice 51R, First Edition (July 2009), 17, http://www.api.org/~/media/Files/Policy/Exploration/API_RP_51R.pdf.
2 API, "Community Engagement Guidelines," 9.
3 API, "Environmental Protection for Onshore Oil and Gas Production Operations and Leases," 19.

What health considerations are there?

AIR & WATER QUALITY AND SAFETY

If wells are not properly sealed when they are abandoned, they can pose a safety risk to residents and livestock, as well as air and water quality risks, given that contaminants could be released into the air or migrate to ground and surface waters. When this has been suspected of occurring, it has been linked to old, historically abandoned sites (*orphaned wells*). A 2013 study conducted in New York found that three-fourths of the abandoned oil and gas wells had never been plugged.[4] The National Petroleum Council also acknowledged the problem nationwide in a 2011 working paper.[5] Furthermore, a 2014 study of 19 abandoned wells in Pennsylvania—some dating back to the 19th century—found that not only were most of them unplugged, but both plugged and unplugged wells were leaking methane. Extrapolating the amount released from the wells under study, the researchers estimated that such abandoned wells could be responsible for 4%–7% of the state's methane emissions in 2010.[6]

The Interstate Oil and Gas Compact Commission (IOGCC), in collaboration with the U.S. Department of Energy, has been studying the problem of orphaned wells and making recommendations to the states, which are ultimately responsible for locating and plugging the wells. As of 2007, the states had identified about 60,000 such wells, with potentially 90,000 more yet to be located.[7] The IOGCC concluded that while the states have improved their response to the problem, funding remains an issue.[8] The IOGCC therefore recommended that wells presenting the greatest safety risks be prioritized and urged states and industry to collaborate in finding creative solutions.[9]

QUALITY OF LIFE—ECONOMIC IMPACTS

As mentioned above, the local economy can undergo a contraction after the project closes; economic opportunities accompanying the project dwindle, and project workers and employees in associated industries leave the area. The community can suffer a corresponding loss of revenue for infrastructure and critical services, such as public health departments and policing.

QUALITY OF LIFE—NOISE IMPACTS

In the decommissioning phase, there can be temporary noise impacts from construction and earth-moving equipment and some truck traffic as the operator removes all equipment, grades the site, spreads topsoil, and restores vegetation in the area.

4 R. E. Bishop, "Historical Analysis of Oil and Gas Well Plugging in New York: Is the Regulatory System Working?" *New Solutions 23,* no. 1 (2013), 113- 114, http://www.ncbi.nlm.nih.gov/pubmed/23552650.

5 National Petroleum Council, *Plugging and Abandoning Oil and Gas Wells* (2011), http://www.npc.org/Prudent_Development-Topic_Papers/2-25_Well_Plugging_and_Abandonment_Paper.pdf.

6 Mary Kang, Cynthia M. Kanno, Matthew C. Reid, Xin Zhang, Denise L. Mauzerall, Michael A. Celia, Yuheng Chen, and Tullis C. Onstott, "Direct Measurements of Methane Emissions from Abandoned Oil and Gas Wells in Pennsylvania," Proceedings of the National Academy of Sciences 111, no. 51 (December 23, 2014), 18173-18174, http://www.pnas.org/content/111/51/18173.full.pdf.

7 Interstate Oil and Gas Compact Commission (IOGCC), *Protecting Our Country's Resources: The States' Case* (2007), 3, http://iogcc.myshopify.com/products/protecting-our-countrys-resources-the-states-case-orphaned-well-plugging-initiative-2008

8 IOGCC, *Protecting Our Country's Resources, 16-17*.

9 IOGCC, *Protecting Our Country's Resources, 17*.

QUALITY OF LIFE—VISUAL IMPACTS

As described above, in many cases the land can be restored to the condition specified in surface use agreements or in accordance with state and/or regulatory requirements. In some areas of the country, however, significant deforestation can persist for many years after decommissioning. For example, in Pennsylvania, 64% of projected well locations are on forested lands; as a result, 34,000 to 82,000 acres of forest may be cleared by 2030.[10]

What can be done to address health concerns? What have others done?

COLLABORATIVE ACTIVITIES

From the beginning of the development process, it is important that local officials, company representatives, and other local stakeholders plan for project closure in order to minimize the impacts of the company's withdrawal and counteract a potential bust. Such planning could focus on building long-term community assets, establishing "rainy day" funds, diversifying the local economy, and avoiding unsustainable investments in infrastructure that would require ongoing revenue to maintain. Finally, holding community meetings focused on the decommissioning phase can help to clarify the company's activities and timeline and identify any issues or concerns.

INDUSTRY REPRESENTATIVES

In addition to making an effort to restore the land as close as possible to its original state per the API guidelines, the company can maintain a dialogue with local officials and community members to get their input during the decommissioning process. It can anticipate safety and environmental risks that could arise from the site and strive to reduce or eliminate those risks. The API guidelines recommend adopting a "consistent and forward-looking focus on safety and the environment."[11]

STATE OFFICIALS

State officials have a role in ensuring that wells are properly plugged and abandoned. At this stage, any surface use agreements that were signed prior to site development can help to guide the site restoration.

LANDOWNERS

Property owners can work with the operator to make sure that the site is properly restored to the specifications in the surface use agreement.

10 New York Department of Environmental Conservation Study (April 2015), http://www.dec.ny.gov/energy/75370.html.
11 API, "Community Engagement Guidelines," 9.

What resources can provide further information?

PROJECT CLOSURE & LAND RESTORATION

- American Petroleum Institute (API), "Environmental Protection for Onshore Oil and Gas Production Operations and Leases," API Recommended Practice 51R, First Edition (July 2009), http://www.api.org/~/media/Files/Policy/Exploration/API_RP_51R.pdf. API, an industry association, developed this guidance for environmental considerations in onshore oil and gas production operations, including design, production, abandonment, and restoration procedures. API also released two sets of recommended practices in August and October 2015 specific to hydraulic fracturing: "Hydraulic Fracturing—Well Integrity and Fracture Containment" (ANSI/API Recommended Practice 100-1) and "Managing Environmental Aspects Associated with Exploration and Production Operations Including Hydraulic Fracturing" (ANSI/API Recommended Practice 100-2). These newly released documents are available for free public viewing (or for sale to download) on the API website: http://publications.api.org. To access, register, select "Browse read-only documents now," then select "Exploration and Production," and scroll to recommended practices 100-1 and 100-2.
- Bureau of Land Management, "Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development, 4th ed., U.S. Department of the Interior (2007)," http://www.blm.gov/wo/st/en/prog/energy/oil_and_gas/best_management_practices/gold_book.html. A guide for operators and landowners on environmentally responsible oil and gas operations on federal lands and privately owned land where the minerals are federally owned (*split estate*).
- Intermountain Oil and Gas BMP Project, "Reclamation Resources Guide for Oil and Gas Development," accessed October 28, 2015, http://www.oilandgasbmps.org/resources/reclamation.php. This website maintained by the University of Colorado Law School has a resources page devoted to oil and gas reclamation. It includes a description of the reclamation process and a set of resources on revegetation, soil restoration, and reserve pit reclamation. It also links to federal and state restoration regulations and guidelines.
- International Council on Mining and Metals, "Planning for Integrated Mine Closure: Toolkit" (London, UK: 2008), http://www.icmm.com/document/310. This toolkit offers tools and guidance for planning for project closure in collaboration with communities from the initial stages of a project. It was developed for the mining industry, but the tools are useful guides and could be adapted to the oil and gas sector.

Seedlings photo © Derek Bridges CC BY 2.0
https://www.flickr.com/photos/derek_b/3123029944

GLOSSARY OF TERMS

A

abandoned well A well no longer in use.

access roads Roads that allow for traffic to move to and from the well pad.

allostatic load The "wear and tear" on the body due to exposure to repeated or chronic stress.

aquifer A permeable rock layer through which water flows.

B

blowout A sudden, uncontrolled release of gases or fluids.

boom-and-bust cycle A sharp increase in a community's economic growth due to an economic stimulus, such as natural resource development, accompanied by a significant, temporary population influx, followed by a sharp economic decline when the project closes and the population falls.

boomtown A community that undergoes the boom-and-bust cycle.

brackish water Water whose salt content falls between that of fresh and salt water.

C

casing Steel and cement lining the wellbore, intended to seal off the well from the surrounding rock.

CO The chemical formula for carbon monoxide, a colorless, odorless gas that forms from the partial oxidation of carbon-containing compounds. It is toxic to humans at concentrations above approximately 35 parts per million and plays a role in the formation of ground-level ozone.

compressors Machines that pressurize gas and vapor to create a pressure gradient and force natural gas to move in a desired direction through pipelines.

containment pond A pond used for the disposal or treatment of wastewater.

crowding out A phenomenon that occurs when increasing economic activity and population influx lead to higher local prices, causing some local businesses on the margin to fail and decreasing the economic diversity in a community.

D

decibels (dB) A measurement of sound. Db(A), or decibels adjusted for human hearing frequencies, is a standard measurement of environmental noise.

deforestation The process of cutting down trees to clear land in a forested area.

distribution lines *(also: mains)* A type of natural gas pipelines that carry gas under reduced pressure from large high-pressure transmission lines to low-pressure customer service lines.

downstream In oil and gas development, refers to the stages associated with the processing, transmission, and distribution of oil and gas (as opposed to *upstream*, which refers to exploration and production).

drill cuttings Rock fragments generated by the drill bit.

drilling fluid *(also: drilling mud)* Fluids used to lubricate and maintain pressure in the well during drilling.

drilling unit An area designated by the state that can contain an oil or gas well. The allotted acreage can vary widely by state.

E

easement Financial compensation to a private property owner for the use of their land for public purposes, such as the passage of an interstate natural gas transmission line.

eminent domain A legal process by which a state, municipality, private person, or corporation can acquire rights to private property for public use. Allowed under the Fifth Amendment of the Constitution of the United States and referenced in most state constitutions, eminent domain is specifically granted for interstate natural gas transmission pipelines under the 1938 Natural Gas Act.

erosion The process of water removing particles of soil and rock as it flows from high to low ground and depositing it elsewhere.

evaporation pits or ponds Surface areas of standing wastewater. Water, along with some chemicals contained in the wastewater, is allowed to evaporate into the air, leaving behind a concentrated solution of chemicals for disposal.

exploratory well A well drilled to determine the potential productivity of the oil or gas resources at a site.

exposure pathway The course a contaminant takes from its source to the person(s) contacted.

exposure route Means of entry of a contaminant into the body (e.g., eating, drinking, inhaling).

F

federal regulatory water rights Regulatory constraints (such as Endangered Species Act requirements) that often trump other water laws.

federal reserved right doctrine The doctrine stipulating that American Indian tribes retain rights to water, even if those rights were not specifically allocated to them in treaties with the U.S. government.

fissures Small cracks in a rock formation.

flaring The process of burning off excess natural gas.

flowback fluid The fluid that initially returns to the surface after being injected in the shale formation to fracture the rock; it contains both the original fracturing fluid and some constituents from the formation, which can include salts, heavy metals, volatile organic compounds, and naturally occurring radioactive materials (NORM). (See also *produced water*.)

flowlines A network of low-pressure pipes that connect oil or gas wells to a gathering station.

forced pooling The state's ability to incorporate adjacent plots of land into a drilling unit.

formation water Naturally occurring water found in geological formations below the surface of the earth.

fugitive emissions Gases that unintentionally leak out of oil and gas equipment and infrastructure.

G

gathering lines A type of pipeline that transports the oil or gas to a central collection point.

geophysical prospecting Quantitative testing to determine the character of the underlying rock formations.

green completion A process that separates commercially useful hydrocarbons from the flowback water issuing from the well during the well completion stage; it captures many of the volatile organic compounds emitted during this stage.

green fracturing fluids Fluids that differ from traditional fracturing solutions by removing some of the more harmful chemicals and reducing the solution volume.

H

health-related quality of life (HRQOL) A person's or group's perception of physical and mental health over time.

hydraulic fracturing The process of injecting a formulation typically composed of water, sand, and chemicals into a geologic formation at high pressure to fracture the formation and extract trapped hydrocarbons (i.e., oil and gas).

I

impoundment A body of water that is completely enclosed.

induced seismicity Earthquakes triggered by human activity.

infilling The process of drilling multiple wells at an extraction site that a company determined to be worth investment and development.

in-migration A significant population movement into a particular geographic area, often drawn by real or perceived economic opportunities.

L

landmen Representatives of an oil company or independent speculators who negotiate oil and gas leases.

lease (oil and gas) A legal agreement between a mineral owner and another party that grants the exclusive rights to drill or produce oil or gas in an area of land defined by the lease.

local gathering station A facility at a junction point that connects gathering lines from the wells in a specific area, collecting oil or gas into a central location.

M

methane The main component of natural gas with the chemical formula CH_4, methane is a flammable gas that can act as a greenhouse gas.

mineral owner The owner of a property's subsurface minerals; the mineral owner is not necessarily the same as the owner of the surface land above the minerals.

N

NO_x Refers to the mono-nitrogen oxides: nitric oxide (NO) and nitrogen dioxide (NO_2), which form when nitrogen and oxygen in the air react during combustion. In the presence of sunlight, NO_x can interact with volatile organic compounds to produce ground-level ozone.

O

open pit Usually designed to hold wastewater, any uncovered containment hole in the ground.

operator A person or company that operates an oil or gas well and oversees the well site at every stage.

orphaned well Old, historically abandoned wells that have often not been properly decommissioned and plugged.

P

particulate matter (PM) A complex mixture of fine airborne particles and liquid droplets. Depending on their size (the U.S. EPA is concerned with those 10 micrometers in diameter or smaller), they can cause serious health effects if inhaled.

plat A map drawn to scale that shows the division of land. Such maps become legally valid when approved by a local government authority.

plugged well A well that the operator determines is past production and is therefore shut down and permanently sealed.

preemption A legal doctrine stipulating that state authority overrides local laws that conflict with state laws in the same field.

primacy Authority granted to a state to enforce federal agency regulations within the state's territory.

prior appropriation doctrine The water law regime that predominates in the western United States, under which water is allocated in specific amounts for "beneficial use." Each water right has a priority date that determines its place in the hierarchy of withdrawals, and it maintains the same date even if it is sold to another user.

processing plant Site where crude gas or oil is transported to be converted into a refined, workable form. It can be located on or off the well site.

produced water Water that emerges from the well along with the oil or gas after the initial *flowback fluid* (the two can also be referred to collectively as *produced water*). It is mostly composed of water from the target formation (see also: *formation water*), which can contain salts, heavy metals, volatile organic compounds, and naturally occurring radioactive materials.

proppant Sand grains or similar materials added to fracturing fluids and used to hold fissures open and allow oil or gas to flow out of the rock formation.

R

receptor The person hearing noise generated by a particular source.

reclamation law Specialized area of federal contract law for federal reclamation projects, such as California's Central Valley Project.

re-stimulation Hydraulically fracturing a previously fractured well to release more gas or oil.

riparian doctrine The water law regime that predominates in the eastern United States, under which landowners along waterways have rights to the natural quantity and quality of flow in the waterway, except as diminished by the "reasonable use" of the water by other riparian landowners.

royalty An interest in gas and oil production. The royalty owner receives a percentage of the production from the lease area.

S

sedimentation Particles suspended in fluid flow, which can be a source of pollution of waterways.

seismic survey Monitored seismic test waves that reveal underground rock formations.

setback Where applicable, the required distance that a development operation must legally maintain from residences or other sensitive areas.

severance taxes Taxes levied on the extraction of natural resources from the earth.

shale development The process of seeking and extracting oil and/or natural gas reserves from shale deposits using a combination of horizontal drilling and high-volume hydraulic fracturing techniques to reach and break open previously inaccessible "tight" geologic formations like shale deposits, allowing the trapped resources to flow into the well and up to the surface for capture.

shale formation *(also: shale rock)* Fine-grained sedimentary rock formations of mostly compacted clay and mud.

shale play An area where shale formations potentially containing natural gas and oil are present.

shot holes Small diameter holes drilled during seismic surveying for the purpose of detonating explosives underground and generating sound waves in order to develop a subsurface map.

siting The process of choosing the appropriate place to locate a drilling operation.

SO_2 The chemical formula for sulfur dioxide, a toxic air pollutant and highly reactive gas largely emanating from fossil fuel combustion at industrial sites.

sour gas Gas containing significant amounts of hydrogen sulfide (H_2S), a highly toxic gas with an odor of rotten eggs.

split estate A property whose subsurface minerals do not belong to the surface owner, but have been previously separated, sold, or allotted to another owner.

staking (a well site) Mapping out the area where the company intends to locate a well pad and marking it with stakes. States sometimes require operators to do this in order to obtain a drilling permit.

stressor Any physical, chemical, or biological entity that can induce an adverse response in humans, plants, animals, or entire ecosystems.

sweetening The process of removing sulfur from the natural gas produced from a well.

T

thumper truck Used in seismic exploration, a truck carrying a heavy weight that is dropped on hard surfaces to generate a seismic pulse.

total dissolved solids (TDS) Dissolved organic and inorganic substances contained in a liquid; salts are a key component. TDS levels are used as an indication of water quality.

transmission lines A type of pipeline that carries natural gas over long distances, transporting processed gas to and from storage facilities and compressor stations and to distribution lines.

V

venting The process of releasing excess gas into the atmosphere.

viewshed The landscape or scenery visible to the eye from a fixed vantage point.

W

wastewater Water that has previously been used in the hydraulic fracturing process, including *produced water*, and contains fracturing-related compounds.

well pad The central site containing one or multiple oil or gas wells and associated equipment and infrastructure.

well spacing The permissible proximity of wells within one geological formation, as determined by the state.

wellbore A bore or hole in the earth created by the drill bit.

wellhead *(also known as a "Christmas tree")* A set of pressure gauges and control valves that control the flow of gas or oil and maintain set conditions at the surface of the well.

workover An extensive overhaul of the equipment on the well pad during the production phase.

APPENDIX A: BIBLIOGRAPHY BY SOURCE TYPE

The resources in this bibliography are organized by the following source types:

- Academic Institutions
- Books
- Consultants and Independent Practitioners
- Government Entities
- Industry
- Intergovernmental Bodies and International Institutions
- Journal Articles
- News Media
- Nongovernmental Organizations and Public Health Associations
- Policy and Research Institutions

Academic Institutions

Christopherson, Susan, and Ned Rightor. “How Should We Think About the Economic Consequences of Shale Gas Drilling?” Working Paper Series: A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale. Cornell University: May 2011. http://www.greenchoices.cornell.edu/downloads/development/shale/Thinking_about_Economic_Consequences.pdf.

Cornell University Cooperative Extension. “Gas Exploration and Leasing on Private Land: Tips and Guidance for New York Landowners.” Updated July 2008. http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/Gas%20Leasing%20on%20Private%20Land%20Tips.pdf.

Cornell University Cooperative Extension. “Things to Consider When You Consider Leasing.” 2014. http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Pages/Landowners.aspx.

Explore Shale. Produced by Penn State Public Broadcasting. Accessed October 8, 2015. http://exploreshale.org.

FrackMap. Harvard University. Accessed October 15, 2015. http://worldmap.harvard.edu/maps/FrackMap.

Groat, Charles G. and Thomas W. Grimshaw. “Fact-Based Regulation for Environmental Protection in Shale Gas Development.” Energy Institute, The University of Texas at Austin: February 2012. http://heartland.org/policy-documents/fact-based-regulation-environmental-protection-shale-gas-development.

Intermountain Oil and Gas BMP Project. “Best Management Practices.” University of Colorado Law School. Accessed October 15, 2015. http://www.oilandgasbmps.org/index.php.

Intermountain Oil and Gas BMP Project. “Hydraulic Fracturing.” University of Colorado Law School. Accessed October 15, 2015. http://www.oilandgasbmps.org/resources/fracing.php.

Intermountain Oil and Gas BMP Project. “Law Atlas: Oil and Gas—Water Quality,Water Quantity, and Air Quality.” University of Colorado Law School. Accessed October 15, 2015. http://www.lawatlas.org/oilandgas.

Intermountain Oil and Gas BMP Project. “LawAtlas: Water Quality—Permitting, Design, and Construction Map.” University of Colorado Law School. Updated April 30, 2014. http://www.lawatlas.org/query?dataset=water-quality-permitting-design-construction.

Intermountain Oil and Gas BMP Project. “Law and Policy.” University of Colorado Law School. Accessed October 15, 2015. http://www.oilandgasbmps.org/laws.

Kay, David. “The Economic Impact of Marcellus Shale Gas Drilling: What Have We Learned? What Are the Limitations?” Working Paper Series: A Comprehensive Economic Impact Analysis of Natural Gas Extraction in the Marcellus Shale. Cornell University: April 2011. http://www.greenchoices.cornell.edu/downloads/development/shale/Economic_Impact.pdf.

Maryland Institute for Applied Environmental Health. “Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland.” University of Maryland School of Public Health: July 2014. http://www.marcellushealth.org/uploads/2/4/0/8/24086586/final_report_08.15.2014.pdf.

Pennsylvania College of Technology. “ShaleTEC: Shale Training and Education Center.” Accessed November 23, 2014. http://www.shaletec.org.

Pennsylvania State University Center for Dirt and Gravel Road Studies. “Better Roads, Cleaner Streams.” Accessed October 15, 2015. http://www.dirtandgravel.psu.edu.

Pennsylvania State University Center for Dirt and Gravel Road Studies. “Sample Road Use Maintenance Agreement.” Accessed November 23, 2014. http://www.dirtandgravel.psu.edu/sites/default/files/Center/Marcellus/Sample_RUMA.pdf.

Pennsylvania State University Extension Agency. “Drinking Water.” Accessed November 21, 2014. http://extension.psu.edu/natural-resources/water/marcellus-shale/drinking-water.

Pennsylvania State University Extension Agency. “Negotiating Pipeline Rights-of-Way in Pennsylvania.” Accessed October 15, 2015.. http://extension.psu.edu/natural-resources/natural-gas/publications/negotiating-pipeline-rights-of-way-in-pennsylvania.

Raimi, Daniel and Richard G. Newell. “Shale Public Finance: Local Government Revenues and Costs Associated with Oil and Gas Development.” Duke University Energy Initiative Report. Durham, NC: May 2014. http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/9216/Shale%20Public%20Finance%20Local%20Revenues%20and%20Costs.pdf?sequence=1.

ShaleNet. Accessed October 5, 2015. http://www.shalenet.org.

University of Iowa, Environmental Health Sciences Research Center. “Exposure Assessment and Outreach to Engage the Public on Health Issues from Frac Sand Mining.” Accessed October 15, 2015. http://cph.uiowa.edu/ehsrc/fracsand.html.

University of Pittsburgh Institute of Politics. “Shale Gas Roundtable: Deliberations, Findings, and Recommendations.” August 2013. http://iop.pitt.edu/shalegas/PDF/90696%20SHALE%20GAS%20FULL%20REPORT-final.pdf.

Upadhyay, Sarita Rose, and Min Bu. “Visual Impacts of Natural Gas Drilling in the Marcellus Shale Region.” Cornell University: Fall 2010. http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/City%20and%20Regional%20Planning%20Student%20Papers/CRP5072_Visual%20Impact_Final%20Report.pdf.

Weinstein, Amanda L. and Mark D. Partridge. "The Economic Value of Shale Natural Gas in Ohio." The Ohio State University Department of Agricultural, Environmental and Development Economics: December 2011. http://aede.osu.edu/sites/aede/files/publication_files/Economic%20Value%20of%20Shale%20FINAL%20Dec%202011.pdf.

Witter, Roxanna, Lisa McKenzie, Meredith Towle, Kaylan Stinson, Kenneth Scott, Lee Newman, and John Adgate. "Health Impact Assessment for Battlement Mesa, Garfield County, Colorado." Colorado School of Public Health: September 2010. http://www.garfield-county.com/public-health/documents/1%20%20%20Complete%20HIA%20without%20Appendix%20D.pdf.

Books

Apostolopoulos, Yorghos and Sevil Sonmez, eds. ***Population Mobility and Infectious Disease.*** New York: Springer, 2007. http://www.springer.com/public+health/book/978-0-387-47667-4.

Getches, David H. ***Water Law In a Nut Shell (***4th ed). St. Paul: Thompson/Reuters, 2009.

National Research Council. ***Environmental Epidemiology, Volume 2: Use of the Gray Literature and Other Data in Environmental Epidemiology***. Washington, DC: The National Academies Press, 1997. http://www.nap.edu/catalog/5804/environmental-epidemiology-volume-2-use-of-the-gray-literature-and.

National Research Council. ***Improving Health in the United States: The Role of Health Impact Assessment.*** Washington, DC: National Academies Press, 2011. http://www.nap.edu/catalog/13229/improving-health-in-the-united-states-the-role-of-health.

Consultants and Independent Practitioners

Barron, Tania, Marla Orenstein, and Ame-Lia Tamburrini. "Health Effects Assessment Tool (HEAT): Innovative Guide for HIA in Resource Development Projects." Habitat Health Impact Consulting & Environmental Resources Management. January 2010. http://www.erm.com/en/Analysis-and-Insight/publications/archived-publications-2009---2010/health-effects-assessment-tool-heat-an-innovative-guide-for-hia-in-resource-development-projects.

Dutton, Ron and George Blankenship. "Socioeconomic Effects of Natural Gas Development." Paper prepared to support NTC Consultants under contract with the New York State Energy Research and Development Authority. Denver, Colorado: August 2010.

Law Offices of Carolyn Elefant. "Knowing and Protecting Your Rights When an Interstate Gas Pipeline Comes to Your Community." May 17, 2010. http://lawofficesofcarolynelefant.com/wp-content/uploads/2010/06/FINALTAGguide.pdf.

Mifflin, Amy. Global Collaborations, Inc. Interview by Erica Bucki and Dana Goodson. June 2014.

Rational Middle Energy Series. ***Realities of Drilling: Extended and Recut.*** Updated 2014. Video (14:02). http://rationalmiddle.com/movie/realities-of-drilling-extended-and-recut.

Government Entities

Agency for Toxic Substances and Disease Registry. "Hydrogen Sulfide-ToxFAQs." CAS # 7783-06-4. October 2014. http://www.atsdr.cdc.gov/toxfaqs/tfacts114.pdf.

Agency for Toxic Substances and Disease Registry. "n-Hexane." CAS ID # 110-54-3. Updated March 3, 2011. http://www.atsdr.cdc.gov/substances/toxsubstance.asp?toxid=68.

Agency for Toxic Substances and Disease Registry. "Toxic Substances Portal." Updated May 23, 2014. http://www.atsdr.cdc.gov/substances/index.asp.

Agency for Toxic Substances and Disease Registry. "Toxicological Profile for n-Hexane." July 1999. http://www.atsdr.cdc.gov/toxprofiles/tp113.pdf.

Agency for Toxic Substances and Disease Registry. "Xylene: Division of Toxicology and Environmental Medicine ToxFAQs." August 2007. http://www.atsdr.cdc.gov/toxfaqs/tfacts71.pdf.

Brown, Valerie J. "Industry Issues: Putting Heat on Gas." National Center for Biotechnology Information, February 2007. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1817691.

Bureau of Land Management. "Split Estate: Rights, Responsibilities, and Opportunities." 2007. http://www.blm.gov/pgdata/etc/medialib/blm/wo/MINERALS__REALTY__AND_RESOURCE_PROTECTION_/bmps.Par.57486.File.dat/SplitEstate07.pdf.

Bureau of Land Management. "Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development." Fourth Edition (2007). http://www.blm.gov/wo/st/en/prog/energy/oil_and_gas/best_management_practices/gold_book.html.

California Office of Environmental Health Hazard Assessment. "Health Effects of Diesel Exhaust." Accessed December 6, 2014. http://oehha.ca.gov/public_info/facts/dieselfacts.html.

Canadian Center for Occupational Health and Safety. "Chemical Profiles." Modified September 2, 2011. http://www.ccohs.ca/oshanswers/chemicals/chem_profiles.

Centers for Disease Control and Prevention. "Facts About Benzene." Updated February 2013. http://www.bt.cdc.gov/agent/benzene/basics/facts.asp.

Centers for Disease Control and Prevention. "Health-Related Quality of Life: HRQOL Concepts." Modified March 17, 2011. http://www.cdc.gov/hrqol/concept.htm.

Centers for Disease Control and Prevention. "Workplace Safety and Health Topics: Silica." Updated June 18, 2015. http://www.cdc.gov/niosh/topics/silica.

Colorado Oil and Gas Conservation Commission. "Application for Permit to Drill – Form 2." Video (8:26). Accessed December 10, 2014. https://cogcc.state.co.us/COGIS/DrillingPermits.asp.

Esswein, Eric, Max Kiefer, John Snawder, and Michael Breitenstein. "Worker Exposure to Crystalline Silica During Hydraulic Fracturing." *NIOSH Science Blog*. Updated June 12, 2015. http://blogs.cdc.gov/niosh-science-blog/2012/05/23/silica-fracking.

Federal Energy Regulatory Commission. "An Interstate Natural Gas Pipeline on My Property? What Do I Need to Know?" Updated August 2013. http://www.ferc.gov/for-citizens/citizen-guides/citz-guide-gas.pdf.

Garfield County, Colorado, Department of Public Health, "Water Treatment Decision Guide." (No date.) http://www.garfield-county.com/public-health/documents/WaterTreatmentGuide_MECH.pdf.

Indiana Department of Natural Resources, Division of Oil and Gas, Division of Reclamation, and Indiana State Department of Health. "Methane Gas & Your Water Well: A Fact Sheet for Indiana Water Well Owners." (No date.) http://www.in.gov/isdh/files/OGMethaneInWellWater_(2).pdf.

McCauley, Michael. “Air, Noise, and Light Monitoring Results for Assessing Environmental Impacts of Horizontal Gas Well Drilling Operations.” Prepared for the West Virginia Department of Environmental Protection. Morgantown, WV: West Virginia University School of Public Health, May 3, 2013. http://wvwri.org/wp-content/uploads/2013/10/a-n-l-final-report-for-web.pdf.

Milligan, Mark R. “What Are Seismic Surveys and How Much ‘Shaking’ Do They Create?” July 3, 2004. Utah Geological Survey. http://geology.utah.gov/map-pub/survey-notes/glad-you-asked/what-are-seismic-surveys.

National Energy Technology Laboratory. “Modern Shale Gas Development in the United States: An Update.” Prepared for the U.S. Department of Energy. September 2013. http://www.netl.doe.gov/File%20Library/Research/Oil-Gas/shale-gas-primer-update-2013.pdf.

National Institute for Occupational Safety and Health. “NIOSH Pocket Guide to Chemical Hazards.” Updated February 13, 2015. http://www.cdc.gov/niosh/npg/default.html.

National Park Service. “Making a Difference.” Updated April 23, 2012. http://www.nature.nps.gov/night/difference.cfm.

New York State Department of Environmental Conservation. "High-Volume Hydraulic Fracturing in NYS: 2015 Final Supplemental Generic Environmental Impact Statement (SGEIS) Documents." April 2015. http://www.dec.ny.gov/energy/75370.html.

New York State Department of Health. “A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development.” December 2014. http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf.

Occupational Safety and Health Administration. “Oil and Gas Extraction: Safety and Health Topics.” Accessed October 15, 2015. https://www.osha.gov/SLTC/oilgaswelldrilling.

Occupational Safety and Health Administration. “Oil and Gas Extraction: Standards and Enforcement.” Accessed October 15, 2015. https://www.osha.gov/SLTC/oilgaswelldrilling/standards.html.

Occupational Safety and Health Administration. “Oil and Gas Well Drilling and Servicing eTool.” Accessed October 15, 2015. https://www.osha.gov/SLTC/etools/oilandgas/index.html.

Occupational Safety and Health Administration. “OSHA Fact Sheet: Hydrogen Sulfide.” 2005. https://www.osha.gov/OshDoc/data_Hurricane_Facts/hydrogen_sulfide_fact.pdf.

Occupational Safety and Health Administration. “OSHA-NIOSH Hazard Alert: Worker Exposure to Silica during Hydraulic Fracturing.” Accessed October 15, 2015. https://www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.html.

Occupational Safety and Health Administration. “OSHA’s Proposed Crystalline Silica Rule: Overview,” September 2013. https://www.osha.gov/silica/factsheets/OSHA_FS-3683_Silica_Overview.html.

Office of Pipeline Safety. “Building Safe Communities: Pipeline Risk and Its Application to Local Development Decisions.” October 2010. http://pstrust.org/docs/PIPA-PipelineRiskReport-Final-20101021.pdf.

Ohio Department of Natural Resources, Division of Oil & Gas Resources. “Shale Drilling Animation” (4:12). Accessed October 15, 2015. http://oilandgas.ohiodnr.gov/shale#GEN.

Ohio Environmental Protection Agency. “Guidance for Temporary Housing Associated with Oil and Natural Gas Drilling Operations.” May 2012. http://epa.ohio.gov/Portals/0/general%20pdfs/Guidance%20for%20Temporary%20Housing.pdf.

Oklahoma Corporation Commission. “OCC Announces Next Step in Continuing Response to Earthquake Concerns.” July 17, 2015. http://www.occeweb.com/News/DIRECTIVE-2.pdf.

Perma-Fix Environmental Services, Inc.”Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) Study Report.” Prepared for the Pennsylvania Department of Environmental Protection. January 2015. http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-105822/PA-DEP-TENORM-Study_Report_Rev._0_01-15-2015.pdf.

Pipeline and Hazardous Material Safety Administration. "Guide for Communicating Emergency Response Information for Natural Gas and Hazardous Liquids Pipelines." 2014. http://phmsa.dot.gov/pv_obj_cache/pv_obj_id_37BB02E8C1E593B753D80B876658B908C55A5000/filename/hmcrp_rpt_014.pdf.

Pipeline and Hazardous Materials Safety Administration. "Pipeline Incidents by System Type." Data as of 11/21/14. http://www.phmsa.dot.gov/pipeline/library/datastatistics/pipelineincidenttrends.

Pipeline and Hazardous Materials Safety Administration. "Pipeline Safety Awareness." Accessed October 15, 2015. https://opsweb.phmsa.dot.gov/pipelineforum/pipeline_safety_update/image_library.html.

Pipeline and Hazardous Materials Safety Administration. "Reporting Criteria as of 2011." March 2011. http://primis.phmsa.dot.gov/comm/reports/safety/docs/IncidentReportingCriteriaHistory1990-2011.pdf.

Pipeline and Hazardous Materials Safety Administration. "State Pages." Accessed October 15, 2015. http://primis.phmsa.dot.gov/comm/States.htm?nocache=9789.

Pipelines and Informed Planning Alliance. "Partnering to Further Enhance Pipeline Safety in Communities through Risk-Informed Land-Plan Use: Final Report of Recommended Practices." November 2010. http://www.ingaa.org/File.aspx?id=11683.

State of Alaska HIA Program, Department of Health and Social Services. "Technical Guidance for Health Impact Assessment (HIA) in Alaska," Version 2. 2015. http://www.epi.alaska.gov/hia/AlaskaHIAToolkit.pdf and http://www.epi.alaska.gov/hia.

Town of Palisade and City of Grand Junction, Colorado et al. Watershed Plan for the Town of Palisade and the City of Grand Junction, Colorado. August 2007. http://www.oilandgasbmps.org/resources/casestudies/palisade.php.

Transportation Research Board. "Transmission Pipelines and Land Use: A Risk-Informed Approach." Special Report 281. 2004. http://onlinepubs.trb.org/onlinepubs/sr/sr281.pdf.

United States Department of Energy. "Memo: Stakeholder Meeting on State, Local, and Tribal Issues." August 6, 2014. http://energy.gov/sites/prod/files/2014/08/f18/20140808%20State-Local-Tribal%20Memo%20Final.pdf.

United States Department of Energy. "Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0." March 28, 2014. http://energy.gov/sites/prod/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf.

United States Department of Health and Human Services, CDC, NIOSH, and IMA-NA. "Dust Control Handbook for Industrial Minerals Mining and Processing." January 2012. http://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2012-112.pdf.

United States Department of the Interior. "Interior Releases Updated Draft Rule for Hydraulic Fracturing on Public and Indian Lands for Comment." May 16, 2013. http://www.doi.gov/news/pressreleases/interior-releases-updated-draft-rule-for-hydraulic-fracturing-on-public-and-indian-lands-for-public-comment.cfm.

United States Department of Transportation. "The State of the National Pipeline Infrastructure." 2011. https://opsweb.phmsa.dot.gov/pipelineforum/docs/Long%20Version%20Preliminary%20Report%20on%20Infrastructure%20040711draftwDecadeCauseCharts.pdf.

United States Energy Information Administration. "Natural Gas Explained: Delivery and Storage of Natural Gas." Last reviewed June 6, 2014. http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_delivery.

United States Energy Information Administration. "U.S. Expected to Become Largest Producer of Petroleum and Natural Gas Hydrocarbons in 2013," October 4, 2013. http://www.eia.gov/todayinenergy/detail.cfm?id=13251.

United States Energy Information Administration, Office of Oil and Gas. "Natural Gas Compressor Stations on the Interstate Pipeline." November 2007. http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngcompressor/ngcompressor.pdf.

United States Environmental Protection Agency. "A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon." May 2012. http://www2.epa.gov/radon/citizens-guide-radon-guide-protecting-yourself-and-your-family-radon.

United States Environmental Protection Agency. "Compilation of Air Pollutant Emission Factors." AP-42, Fifth Edition, 1995. http://www3.epa.gov/ttnchie1/ap42/ch13/final/c13s05.pdf.

United States Environmental Protection Agency. "Crude Oil and Natural Gas Waste." Updated October 7, 2015. http://www.epa.gov/osw/nonhaz/industrial/special/oil.

United States Environmental Protection Agency. "EPA Identifies Noise Levels Affecting Health and Welfare." Updated May 20, 2015. http://www2.epa.gov/aboutepa/epa-identifies-noise-levels-affecting-health-and-welfare.

United States Environmental Protection Agency. "EPA's Air Rules for the Oil and Natural Gas Industry: Summary of Key Changes to the New Source Performance Standards." Accessed October 15, 2015. http://www.epa.gov/airquality/oilandgas/pdfs/20120417changes.pdf.

United States Environmental Protection Agency. "Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations." Washington DC: October 2002. http://www3.epa.gov/epawaste/nonhaz/industrial/special/oil/oil-gas.pdf.

United States Environmental Protection Agency. "Fact Sheet: Underground Injection Control (UIC) Program Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels, UIC Program Guidance #84—Draft." May 2012. http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hfdieselfuelsfs.pdf.

United States Environmental Protection Agency. "Ground-level Ozone: Health Effect." Updated October 1, 2015. http://www3.epa.gov/ozonepollution/health.html.

United States Environmental Protection Agency. "Health Effects of Ozone in the General Population." Updated September 19, 2015. http://www.epa.gov/apti/ozonehealth/population.html#effects.

United States Environmental Protection Agency. "Health and Environmental Agencies of U.S. States and Territories." Updated October 14, 2015. http://www2.epa.gov/home/health-and-environmental-agencies-us-states-and-territories.

United States Environmental Protection Agency. "The Hydraulic Fracturing Water Cycle." Updated June 1, 2015. http://www2.epa.gov/hfstudy/hydraulic-fracturing-water-cycle#1.

United States Environmental Protection Agency. "Natural Gas Drilling in the Marcellus Shale: NPDES Program Frequently Asked Questions." Attachment to memorandum from James Hanlon, Director of EPA's Office of Wastewater Management to the EPA Regions, "Natural Gas Drilling in the Marcellus Shale under the NPDES Program." March 16, 2011. http://www.epa.gov/npdes/pubs/hydrofracturing_faq.pdf.

United States Environmental Protection Agency. "Natural Gas STAR Program." Updated October 14, 2015. http://www.epa.gov/gasstar.

United States Environmental Protection Agency. "Natural Gas STAR Program: Recommended Technologies and Practices." Updated May 30, 2014. http://www.epa.gov/gasstar/tools/recommended.html.

United States Environmental Protection Agency. "Proposed Climate, Air Quality and Permitting Rules for the Oil and Natural Gas Industry: Fact Sheet." http://www3.epa.gov/airquality/oilandgas/pdfs/og_fs_081815.pdf.

United States Environmental Protection Agency. "Radiation Doses in Perspective." Updated October 1, 2015. http://www.epa.gov/radiation/understand/perspective.html.

United States Environmental Protection Agency. "Radiation and Health." Updated October 1, 2015. http://www.epa.gov/radiation/understand/health_effects.html.

United States Environmental Protection Agency. "Radiation and Radioactivity." Updated October 1, 2015. http://www.epa.gov/radiation/understand/radiation_radioactivity.html.

United States Environmental Protection Agency. "Radionuclides in Drinking Water." Updated March 6, 2012. http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/index.cfm.

United States Environmental Protection Agency. "Radionuclides Rule: A Quick Reference Guide." June 2001. http://water.epa.gov/lawsregs/rulesregs/sdwa/radionuclides/upload/2009_04_16_radionuclides_qrg_radionuclides.pdf.

United States Environmental Protection Agency. "Radon." Updated October 7, 2015. http://www.epa.gov/radon/pubs/citguide.html.

United States Environmental Protection Agency. "Regulation of Hydraulic Fracturing under the Safe Drinking Water Act." Updated February 11, 2014. http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroreg.cfm.

United States Environmental Protection Agency. "A Regulators' Guide to the Management of Radioactive Residuals from Drinking Water Treatment Technologies." 2005. http://energy.wilkes.edu/PDFFiles/Library/EPA%20Guide%20to%20Treatment%20of%20Radionuclides%20in%20Wastewater%20Treatment.pdf.

United States Environmental Protection Agency. "Step 3: Exposure Assessment." Updated October 7, 2015. http://www2.epa.gov/risk/conducting-human-health-risk-assessment#tab-4.

United States Environmental Protection Agency. "Water: Private Wells." Updated March 6, 2012. http://water.epa.gov/drink/info/well/faq.cfm.

United States Environmental Protection Agency Office of Air and Radiation. "Particle Pollution and Your Health." September 2003. http://epa.gov/pm/pdfs/pm-color.pdf.

United States Environmental Protection Agency Office of Research and Development. "Analysis of Hydraulic Fracturing Fluid Data from the FracFocus Chemical Disclosure Registry 1.0." Washington, DC: U.S. EPA, March 2015. http://www2.epa.gov/sites/production/files/2015-03/documents/fracfocus_analysis_report_and_appendices_final_032015_508_0.pdf.

United States Environmental Protection Agency Office of Research and Development. "Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources" *(*External Review Draft). Washington, DC: U.S. EPA, June 2015. http://cfpub.epa.gov/ncea/hfstudy/recordisplay.cfm?deid=244651#_ga=1.45665120.574819698.1432322953.

United States Environmental Protection Agency Office of Research and Development. "Review of State and Industry Spill Data: Characterization of Hydraulic Fracturing-Related Spills." Washington, DC: May 2015. http://www2.epa.gov/sites/production/files/2015-05/documents/hf_spills_report_final_5-12-15_508_km_sb.pdf.

United States Geological Survey. "How Is Hydraulic Fracturing Related to Earthquakes and Tremors?" *USGS FAQs*. Modified August 19, 2015. http://www.usgs.gov/faq/categories/10132/3830.

United States Geological Survey. "Induced Earthquakes." Modified October 1, 2015. http://earthquake.usgs.gov/research/induced.

United States Geological Survey. "USGS FAQs." Modified August 19, 2015. http://www.usgs.gov/faq/categories/9833/3424.

United States Government Accountability Office. "Oil and Gas: Information on Shale Resources, Development, and Environmental and Public Health Risks." September 2012. http://www.gao.gov/assets/650/647791.pdf.

United States House of Representatives, Committee on Energy and Commerce, Minority Staff. "Chemicals Used in Hydraulic Fracturing." April 2011.

Vann, Adam, Brandon J. Murrill, and Mary Tiemann. Hydraulic Fracturing: Selected Legal Issues. Congressional Research Service Report. September 26, 2014. https://www.fas.org/sgp/crs/misc/R43152.pdf.

Wisconsin Department of Natural Resources. "Locations of Industrial Sand Mines and Processing Plants in Wisconsin." Last revised September 8, 2015. http://dnr.wi.gov/topic/Mines/ISMMap.html.

Industry

American Petroleum Institute. "Community Engagement Guidelines." ANSI/API Bulletin 100-3. First edition (July 2014). http://www.api.org/globalitems/~/media/Files/Policy/Exploration/100-3_e1.pdf.

American Petroleum Institute. "Environmental Protection for Onshore Oil and Gas Production Operations and Leases." API Recommended Practice 51R. July 2009. http://www.api.org/~/media/Files/Policy/Exploration/API_RP_51R.pdf.

American Petroleum Institute. "Hydraulic Fracturing – Well Integrity and Fracture Containment." ANSI/API Recommended Practice 100-1. October 2015. Accessed October 23, 2015. http://publications.api.org.

American Petroleum Institute. "Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines." API Guidance Document HF1. First Edition (October 2009). http://www.api.org/~/media/Files/Policy/Exploration/API_HF1.pdf.

American Petroleum Institute. "Managing Environmental Aspects Associated with Exploration and Production Operations Including Hydraulic Fracturing." ANSI/API Recommended Practice 100-2. August 2015. Accessed October 23, 2015. http://publications.api.org.

Apache Corporation. "Greener Chemicals." Accessed October 16, 2015. http://www.apachecorp.com/Sustainability/Environment/Chemicals/Greener_chemicals/index.aspx.

Appalachian Shale Recommended Practices Group. Accessed October 16, 2015. http://asrpg.org.

BG Group. "Unconventional Gas." Accessed October 16, 2015. http://www.bg-group.com/197/about-us/industry-challenges/unconventional-gas.

Canadian Association of Petroleum Producers. "What to Expect When You're Expecting a Well," June 2014. http://www.capp.ca/publications-and-statistics/publications/250098.

Chesapeake Energy. "Operations." Accessed October 16, 2015. http://www.chk.com/operations/best-management-practices/pages/information.aspx.

Chesapeake Energy. "A River Runs Through It: Environmentally Sensitive Operations in the Natural State." Spring 2008. http://www.chk.com/media/publications/theplay/pages/spring2008.aspx.

Cohen, Ken. "What Does It Mean to Frack a Well? Part 1." *ExxonMobile Perspectives*. June 15, 2015. http://www.exxonmobilperspectives.com/2015/06/15/what-does-it-mean-to-frack-a-well-part-1.

Independent Petroleum Association of America. "Induced Seismicity." Accessed October 16, 2015. http://www.ipaa.org/wp-content/uploads/downloads/2015/06/IPAA-Induced-Seismicity-Fact-Sheet_6-1-15.pdf

International Association of Oil & Gas Producers. "Our Library." Accessed October 16, 2015. http://www.iogp.org/Our-library/health-committee.

International Association of Oil and Gas Producers (OGP). "Strategic Health Management: Principles and Guidelines for the Oil and Gas Industry." Report No. 6.88/307. June 2000. http://www.ogp.org.uk/pubs/307.pdf.

International Association of Oil and Gas Producers (OGP) and International Petroleum Industry Environmental Conservation Association (IPIECA). "Drilling Fluids and Health Risk Management: A Guide for Drilling Personnel, Managers, and Health Professionals in the Oil and Gas Industry." OGP Report No. 396. London, UK: 2009. http://www.ipieca.org/publication/drilling-fluids-and-health-risk-management.

International Association of Oil and Gas Producers (OGP) and International Petroleum Industry Environmental Conservation Association (IPIECA). "A Guide to Health Impact Assessments in the Oil and Gas Industry." London, UK: 2005. http://www.ogp.org.uk/pubs/380.pdf.

International Association of Oil and Gas Producers (OGP) and International Petroleum Industry Environmental Conservation Association (IPIECA). "Managing Health for Field Operations in Oil and Gas Activities: A Guide for Managers and Supervisors in the Oil and Gas Industry." OGP Report No. 343, Version 1. London, UK: 2011. http://www.internationalsosfoundation.org/?wpfb_dl=81.

International Association of Oil and Gas Producers (OGP) and International Petroleum Industry Environmental Conservation Association (IPIECA). "Substance Misuse: A Guide for Managers and Supervisors in the Oil and Gas Industry." OGP Report No. 445. London, UK: 2010. http://www.ogp.org.uk/pubs/445.pdf.

International Council on Mining and Metals. "Community Development Toolkit." July 20, 2012. http://www.icmm.com/news-and-events/news/articles/icmm-presents-updated-community-development-toolkit.

International Council on Mining and Metals. "Good Practice Guidance on Health Impact Assessment." 2010. https://www.icmm.com/document/792 and http://www.icmm.com/document/977.

International Council on Mining and Metals. "Planning for Integrated Mine Closure: Toolkit." 2008. http://www.icmm.com/document/310.

International Council on Mining and Metals. "Water Management in Mining: A Selection of Case Studies." May 2012. http://www.icmm.com/document/3660.

Interstate Natural Gas Association of America. "How Are Natural Gas Transmission Pipelines Regulated?" Accessed October 16, 2015. http://www.ingaa.org/cms/4923.aspx.

Interstate Natural Gas Association of America Foundation. "North American Midstream Infrastructure through 2035: Capitalizing on Our Energy Abundance." Prepared by ICF International, March 18, 2014. http://www.ingaa.org/File.aspx?id=21498.

Marathon Oil Company. "Meth Education Program." Video clip. Accessed October 16, 2015. https://www.youtube.com/watch?v=nlmP2vhKn-Q.

Marcellus Shale Coalition. "Recommended Practices." Accessed October 16, 2015. http://marcelluscoalition.org/category/library/recommended-practices.

National Industrial Sand Association. "Occupational Health Program for Exposure to Crystalline Silica in the Industrial Sand Industry," 2011. http://sand.org/Silica/Occupational/Health/Program.

National Petroleum Council. "Natural Gas Pipelines: Challenges," 2011. http://www.npc.org/prudent_development-topic_papers/2-19_gas_pipeline_challenges_paper.pdf.

National Petroleum Council. "Plugging and Abandoning Oil and Gas Wells." 2011. http://www.npc.org/Prudent_Development-Topic_Papers/2-25_Well_Plugging_and_Abandonment_Paper.pdf.

Shell Oil Company. "Life of an Onshore Well." Graphic animation. Accessed October 16, 2015. https://www.youtube.com/watch?v=w9MMsEkadGw (5:52).

Shell Oil Company. "Shell's Principles for Producing Tight/Shale Oil and Gas." Accessed October 16, 2015. http://www.shell.com/global/future-energy/natural-gas/gas/shell-operating-principles.html.

Intergovernmental Bodies and International Institutions

ATSM International. "Subcommittee D-18 on Hydraulic Fracturing." Accessed October 16, 2015. http://www.astm.org/COMMIT/SUBCOMMIT/D1826.htm.

FracFocus Chemical Disclosure Registry. A project of the Ground Water Protection Council and Interstate Oil and Gas Compact Commission. Accessed October 15, 2015. www.fracfocus.org.

Ground Water Protection Council. "Injection Wells: An Introduction to Their Use, Operation, & Regulation." September 1. 2013. http://www.gwpc.org/sites/default/files/UIC%20Brochure%20Updated%209-2013_0.pdf.

Ground Water Protection Council. "State Oil & Gas Regulations Designed to Protect Water Resources." 2014. http://www.gwpc.org/sites/default/files/Oil%20and%20Gas%20Regulation%20Report%20Hyperlinked%20Version%20Final-rfs.pdf.

Ground Water Protection Council and ALL Consulting. "Modern Shale Gas in the United States: A Primer." Prepared for U.S. Department of Energy Office of Fossil Energy and the National Energy Technology Laboratory. April 2009. http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf.

Ground Water Protection Council and Interstate Oil and Gas Compact Commission. "Potential Injection-Induced Seismicity Associated with Oil & Gas Development: A Primer on Technical and Regulatory Considerations Informing Risk Management and Mitigation." 2015. http://www.gwpc.org/sites/default/files/finalprimerweb.pdf.

Ground Water Research and Education Foundation. "White Paper II Summarizing a Special Session on Induced Seismicity: Assessing and Managing Risk of Induced Seismicity by Injection," November 2013. http://www.gwpc.org/sites/default/files/files/White%20Paper%20II%20Summarizing%20a%20Special%20Session%20on%20Induced%20Seismicity-%20November,%202013%20(GWPC).pdf.

International Finance Corporation. "Guidance Note 4: Community Health, Safety and Security." January 1, 2012. http://www.ifc.org/wps/wcm/connect/dc3f4b80498007dca17ff3336b93d75f/Updated_GN4-2012.pdf?MOD=AJPERES.

International Finance Corporation. "Lessons of Experience: Peru LNG: A Focus on Continuous Improvement." No. 3, March 2013. http://www.ifc.org/wps/wcm/connect/4937c0804f612f0397f2ff0098cb14b9/IFC_LOE_PLNG.pdf?MOD=AJPERES.

International Finance Corporation. "Performance Standards and Environmental and Social Sustainability." January 1, 2012. http://www.ifc.org/wps/wcm/connect/115482804a0255db96fbffd1a5d13d27/PS_English_2012_Full-Document.pdf?MOD=AJPERES.

International Finance Corporation. "Projects and People: A Handbook for Addressing Project-Induced In-Migration." Accessed November 21, 2014. http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/learning+and+adapting/knowledge+products/publications/publications_handbook_inmigration__wci__1319576839994.

Interstate Oil and Gas Compact Commission. "Protecting Our Country's Resources: The States' Case." 2007. http://iogcc.publishpath.com/Websites/iogcc/pdfs/2008-Protecting-Our-Country's-Resources-The-States'-Case.pdf.

Interstate Oil and Gas Compact Commission. "Summary of State Statutes and Regulations." Accessed October 27, 2015. http://iogcc.publishpath.com/state-statutes.

National Association of Conservation Districts. "State Directory." Accessed October 15, 2015. http://www.nacdnet.org/about/districts/directory.

National Association of State Departments of Agriculture. "State Directory." Accessed October 15, 2015. http://www.nasda.org/9383/States.aspx.

National Conference of State Legislatures. "Compulsory Pooling Laws: Protecting the Conflicting Rights of Neighboring Landowners." October 24, 2014. http://www.ncsl.org/research/energy/compulsory-pooling-laws-protecting-the-conflicting-rights-of-neighboring-landowners.aspx.

National Conference of State Legislatures. "Natural Gas and Hydraulic Fracturing: A Policymaker's Guide." June 2012. http://www.ncsl.org/documents/energy/frackingguide_060512.pdf.

Programme on Mental Health, World Health Organization Division of Mental Health and Prevention of Substance Abuse. "Measuring Quality of Life." 1997. http://www.who.int/mental_health/media/68.pdf.

State Review of Oil and Natural Gas. "STRONGER Publishes 2015 Guidelines." Accessed October 16, 2015. http://www.strongerinc.org.

Susquehanna River Basin Commission. "Overview of Remote Water Quality Monitoring Network." Updated June 2014. http://mdw.srbc.net/remotewaterquality.

Tompkins County Council of Governments. "Community Impact Assessment: High-Volume Hydraulic Fracturing." December 2011. http://www.tompkinscountyny.gov/files/tccog/Gas_Drilling/TCCoG_Community_Impact_Assessment_12-15-11%20Final.pdf.

World Health Organization. "Health Impact Assessment." Accessed October 16, 2015. http://www.who.int/hia/en and http://www.who.int/hia/examples/en.

World Health Organization. "Night Noise Guidelines for Europe." Copenhagen, Denmark: WHO Regional Office for Europe, 2009. http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf.

Journal Articles

Adgate, John L, Bernard D. Goldstein, and Lisa M. McKenzie. "Potential Public Health Hazards, Exposures and Health Effects from Unconventional Natural Gas Development." *Environmental Science and Technology* 48, no. 15 (February 24, 2014): 8307-8320. http://www.r-cause.net/uploads/8/0/2/5/8025484/adgate_et_al_2014_ph_risks.pdf.

Allen, David T., Adam P. Pacsi, David W. Sullivan, Daniel Zavala-Araiza, Matthew Harrison, Kindal Keen, Matthew P. Fraser, A. Daniel Hill, Robert F. Sawyer, and John H. Seinfeld. "Methane Emissions from Process Equipment at Natural Gas Production Sites in the United States: Pneumatic Controllers." *Environmental Science and Technology* 49 (2015). http://pubs.acs.org/doi/pdf/10.1021/es5040156.

Bishop R.E. "Historical Analysis of Oil and Gas Well Plugging in New York: Is the Regulatory System Working?" *New Solutions* 23, no. 1 (2013). http://www.ncbi.nlm.nih.gov/pubmed/23552650.

Bunch, A.G., C.S. Perry, L. Abraham, D.S. Wikoff, J.A. Tachovsky, J.G. Hixon, J.D. Urban, M.A. Harris, and L.C. Haws. "Evaluation of Impact of Shale Gas Operations in the Barnett Shale Region on Volatile Organic Compounds in Air and Potential Human Health Risks." *Science of the Total Environment* 468-469 (2014): 832-842. http://www.sciencedirect.com/science/article/pii/S0048969713010073.

Caulton, Dana R., Paul B. Shepson, Maria O.L. Cambaliza, David McCabe, Ellen Baum, and Brian H Stirm. "Methane Destruction Efficiency of Natural Gas Flares Associated with Shale Formation Wells." *Environmental Science and Technology* 48, no. 16 (July 30, 2014): 9548-9554. http://pubs.acs.org/doi/abs/10.1021/es500511w.

Ferrar, Kyle J., Jill Kriesky, Charles L. Christen, Lynn P. Marshall, Samantha L. Malone, Ravi K. Sharma, Drew R. Michanowicz, and Bernard D. Goldstein. "Assessment and Longitudinal Analysis of Health Impacts and Stressors Perceived to Result from Unconventional Shale Gas Development in the Marcellus Shale Region." *International Journal of Occupational and Environmental Health* 19, no. 2 (2013). Abstract at http://www.maneyonline.com/doi/abs/10.1179/2049396713Y.0000000024.

Goldenberg, Shira M., Jean A. Shoveller, Aleck C. Ostry, and Mieke Koehoorn. "Sexually Transmitted Infection (STI) Testing among Young Oil and Gas Workers: The Need for Innovative Place-based Approaches to STI Control." *Canadian Journal of Public Health* 99, no. 4 (July/August 2008). http://journal.cpha.ca/index.php/cjph/article/viewFile/1666/1850.

Hammer, Monica S., Tracy K. Swinburn, and Richard L. Neitzel. "Environmental Noise Pollution in the United States: Developing an Effective Public Health Response." *Environmental Health Perspectives* 122, no. 2 (February 2014). http://ehp.niehs.nih.gov/1307272.

Jacquet, Jeffrey B. "Review of Risks to Communities from Shale Gas Development." ***Environmental Science and Technology*** 48, no. 15 (2014): 8321-33.doi: 10.1021/es404647x.

Kang, Mary, Cynthia M. Kanno, Matthew C. Reid, Xin Zhang, Denise L. Mauzerall, Michael A. Celia, Yuheng Chen, and Tullis C. Onstott. "Direct Measurements of Methane Emissions from Abandoned Oil and Gas Wells in Pennsylvania." ***Proceedings of the National Academy of Sciences*** 111, no. 51 (December 23, 2014): 18173-18177. http://www.pnas.org/content/111/51/18173.full.pdf.

Kinnard Jr., William N., Sue Ann Dickey, and Mary Beth Geckler. "Natural Gas Pipeline Impact on Residential Property Values: An Empirical Study of Two Market Areas." ***International Right of Way Association.*** June/July 1994. https://www.irwaonline.org/eweb/upload/0604d.pdf.

Macey, Gregg P, Ruth Breech, Mark Chernaik, Caroline Cox, Denny Larson, Deb Thomas, and David O Carpenter. "Air Concentrations of Volatile Compounds near Oil and Gas Production: A Community-Based Exploratory Study." ***Environmental Health*** 13 (2014): 1-18. http://www.ehjournal.net/content/13/1/82#B21.

Penning, Trevor M., Patrick N. Breysse, Kathleen Gray, Marilyn Howarth, and Beizhan Yan. "Environmental Health Research Recommendations from the Inter-Environmental Health Sciences Core Center Working Group on Unconventional Natural Gas Drilling Operations." ***Environmental Health Perspectives*** 122, no. 11 (July 18, 2014). http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4216169.

Perry, S.L. "Using Ethnography to Monitor the Community Health Implications of Onshore Unconventional Oil and Gas Developments: Examples from Pennsylvania's Marcellus Shale." ***New Solutions*** 23, no. 1 (2013): 33-53. doi: 10.2190/NS.23.1.d.

Radow, Elizabeth N. "Homeowners and Gas Drilling Leases: Boon or Bust?" ***New York State Bar Association Journal*** 83, no. 9 (November/December 2011). Reprinted at http://cce.cornell.edu/EnergyClimateChange/NaturalGasDev/Documents/PDFs/NYSBA%20Journal%20nov-dec2011.pdf.

Rawlins, Rachel. "Planning for Fracking on the Barnett Shale: Urban Air Pollution, Health Based Regulation, and the Role of Local Governments." ***Virginia Environmental Law Journal*** 31 (2013): 226-306. http://lib.law.virginia.edu/lawjournals/sites/lawjournals/files/2.%20Rawlins%20-%20Barnett%20Shale.pdf.

Schmidt, Charles W. "Blind Rush? Shale Gas Boom Proceeds Amid Human Health Questions." ***Environmental Health Perspectives*** 119, no.8 (August 2011). http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3237379.

Shonkoff, Seth, Jake Hays, and Madelon L. Finkel. "Environmental Public Health Dimensions of Shale and Tight Gas Development." ***Environmental Health Perspectives*** 122, no. 8 (August 2014). http://ehp.niehs.nih.gov/1307866.

Walsh III, F. Rall and Mark D. Zoback. "Oklahoma's Recent Earthquakes and Saltwater Disposal." ***Science Advances*** 1, no. 5 (June 18, 2015), http://advances.sciencemag.org/content/1/5/e1500195.

Webb, Ellen, Sheila Bushkin-Bedient, Amanda Cheng, Christopher D. Kassotis, Victoria Balise, and Susan C. Nagel. "Developmental and Reproductive Effects of Chemicals Associated with Unconventional Oil and Natural Gas Operations." ***Reviews on Environmental Health*** 29, no. 4 (December 5, 2014). http://wyofile.com/wp-content/uploads/2014/12/fracking-study_ew-1.pdf.

Weingarten, M., S. Ge, J.W. Godt, B.A. Bekins, and J.L. Rubinstein. "High-Rate Injection Is Associated with the Increase in U.S. Mid-Continent Seismicity," ***Science*** 348, no. 6241 (June 19, 2015). https://profile.usgs.gov/myscience/upload_folder/ci2015Jun1814143055600Weingarten_etal.pdf.

Wernham, Aaron. "Inupiat Health and Proposed Alaskan Oil Development: Results of the First Integrated Health Impact Assessment/ Environmental Impact Statement for Proposed Oil Development on Alaska's North Slope." ***EcoHealth*** 4 (2007): 500-513.

Zielinska, B., D. Campbell, V. Samburova. "Impact of Emissions from Natural Gas Production Facilities on Ambient Air Quality in the Barnett Shale Area: A Pilot Study." ***Journal of the Air Waste Management Association*** 64 (December 2014): 1369-1383, http://www.ncbi.nlm.nih.gov/pubmed/25562933.

News Media

"Agency Sends Final Fracking Rule to White House for Review." ***Energywire***, September 2014.

Associated Press. "Marcellus Shale Gas Drillers Recycling More Waste." ***The Times-Tribune*** (Scranton, PA), February 17, 2012.

Baca, Marie C. "Forced Pooling: When Landowners Can't Say No to Drilling." ***ProPublica,*** May 18, 2011. http://www.propublica.org/article/forced-pooling-when-landowners-cant-say-no-to-drilling.

Baca, Marie C. "State Laws Can Compel Landowners to Accept Gas and Oil Drilling." ***Propublica,*** May 19, 2011. http://projects.propublica.org/tables/forced-pooling.

Cama, Timothy. "Maryland Bans Fracking." The Hill, June 1, 2015. http://thehill.com/policy/energy-environment/243625-maryland-bans-fracking.

Clawson, Doug. "Hydraulic Fracturing: New International Subcommittee to Develop Needed Standards." ***Standardization News,*** November/December 2012. http://www.astm.org/sn/features/hydraulic-fracturing-nd12.html.

Davenport, Coral. "Judge Blocks Obama Administration Rules on Fracking." The New York Times, September 30, 2015. http://www.nytimes.com/2015/10/01/us/politics/judge-blocks-obama-administration-rules-on-fracking.html?_r=0.

Gleason, Rachel. "Astronomers Look to Protect Earth's Dark Skies." ***Midland Reporter Telegram.*** Updated May 8, 2014. http://www.mrt.com/top_stories/article_5f897a0e-d71d-11e3-ad5b-0019bb2963f4.html.

Gold, Russell and Tom McGinty. "Energy Boom Puts Wells in America's Backyards." ***The Wall Street Journal,*** October 25, 2013. http://www.wsj.com/articles/SB10001424052702303672404579149432365326304.

Granberg, Al. "What is Hydraulic Fracturing?" ***Propublica.*** Accessed November 23, 2014. https://www.propublica.org/special/hydraulic-fracturing-national.

"The Great Plains Oil Rush." ***National Public Radio***, originally broadcast January 29, 2014. http://www.npr.org/series/268211390/the-great-plains-oil-rush.

Gronwold, Nathaniel. "Entrepreneurs Turn to Bacteria to Fight Fracking Corrosion." ***Energywire,*** July 3, 2014.

Hirji, Zabra. "'Frac Sand' Mining Boom: Health Hazard Feared." ***Inside Climate News,*** November 5, 2013. http://insideclimatenews.org/news/20131105/frac-sand-mining-boom-health-hazard-feared-lawmakers-aim-ease-regulation.

Kaplan, Thomas. "Citing Health Risks, Cuomo Bans Fracking in New York State." The New York Times, December 17, 2014. http://www.nytimes.com/2014/12/18/nyregion/cuomo-to-ban-fracking-in-new-york-state-citing-health-risks.html?_r=0.

Kiger, Patrick J. "Green Fracking? 5 Technologies for Cleaner Shale Energy." ***National Geographic Daily News,*** March 19, 2014. http://news.nationalgeographic.com/news/energy/2014/03/140319-5-technologies-for-greener-fracking.

King, Pamela. "Industry Initiative Helps Communities Embrace Boom-Time Opportunities." ***E&E News***, May 21, 2014.

King, Pamela. "Texas Groups Strategize to Get Students Ready for Oil and Gas Jobs." ***E&E News,*** April 14, 2014.

King, Pamela. "Texas Towns Consider Deep Makeovers to Prepare for Inevitable Oil Field Bust." ***E&E News***, May 20, 2014. http://www.eenews.net/stories/1059999739.

Lee, Mike. "In North Dakota's Oil Patch, Wrecks Increase as Trucks Push onto Farm Roads." ***E&E News***, April 11, 2014.

Lee, Mike. "Nuns and Other Landowners Watching as Pennsylvania Reschedules 'Forced Pooling' Case." ***E&E News,*** July 23, 2014.

Levitan, Dave. "Algae in Glass Cases Could Determine Fracking's Toll." ***Scientific American,*** March 6, 2014. http://www.scientificamerican.com/article/algae-in-glass-cases-could-determine-frackinge28099s-toll.

McAllister, Edward. "Ohio Links Fracking to Earth Quakes, Announces Tougher Rules," ***Reuters***, April 11, 2014. http://www.reuters.com/article/2014/04/11/us-ohio-fracking-earthquakes-idUSBREA3A1J620140411.

McMahon, Jeff. "Pollution Fears Crush Home Prices near Fracking Wells." ***Forbes***, April 10, 2014. http://www.forbes.com/sites/jeffmcmahon/2014/04/10/pollution-fears-crush-home-prices-near-fracking-wells.

"New York's Highest Court Says Towns Can Ban Fracking." ***Energywire***, June 2014.

"Ohio Links Fracking to Earth Quakes, Announces Tougher Rules." ***Reuters***, April 2014. http://www.reuters.com/article/2014/04/11/us-ohio-fracking-earthquakes-idUSBREA3A1J620140411.

Petersen, Laura. "Public Lands: Drilling Boom Brings 'Light Pollution' to Southwest's Pristine Night Skies." ***E&E News,*** March 12, 2014. http://www.eenews.net/stories/1059996009.

Sadasivam, Naveena. "Boom in Unregulated Natural Gas Pipelines Posing New Risks." ***Inside Climate News,*** September 26, 2013. http://insideclimatenews.org/news/20130926/boom-unregulated-natural-gas-pipelines-posing-new-risks.

Schneider, Andrew. "In Texas, Traffic Deaths Climb Amid Fracking Boom." ***National Public Radio***, October 12, 2014. http://www.npr.org/2014/10/02/352980756/in-texas-traffic-deaths-climb-amid-fracking-boom.

Smith, Grant. "U.S. Seen as Biggest Oil Producer After Overtaking Saudi Arabia." ***Bloomberg News,*** July 4, 2014. http://www.bloomberg.com/news/2014-07-04/u-s-seen-as-biggest-oil-producer-after-overtaking-saudi.html.

Soraghan, Mike. "Oklahoma Agency Gets $1.8M to Study Seismic Links to Drilling." ***E&E News***, July 16, 2014.

Urbina, Ian. "Deadliest Danger Isn't at the Rig but on the Road." ***The New York Times***, May 14, 2012. http://www.nytimes.com/2012/05/15/us/for-oil-workers-deadliest-danger-is-driving.html.

Vaidyanathan, Gayathri. "White House Announces Plan to Slash Industry's Methane Emissions." ***E&E News***, January 14, 2015.

Wingrove, John. "Alberta's Rate of Syphilis Infection Still Rising." ***The Globe and Mail,*** updated August 23, 2012. http://www.the-globeandmail.com/life/health-and-fitness/health/conditions/albertas-rate-of-syphilis-infection-still-rising/article572646.

Wheeler, Timothy M. "Maryland Fracking Rules Proposed, but Hogan Gets Final Say." ***The Baltimore Sun***, December 12, 2014. http://www.baltimoresun.com/features/green/blog/bal-maryland-fracking-rules-proposed-20141212-story.html.

Wren, Bill. "Talk at Ten Interview: Bill Wren." Hosted by Rachel Osier Lindley, Marfa Public Radio: Windows Media Audio, originally broadcast May 24, 2012. http://marfapublicradio.org/blog/talk-at-ten/bill-wren.

Nongovernmental Organizations and Public Health Associations

Alliance of Nurses for Healthy Environments. "Assessment Tools & More." Accessed November 21, 2014. http://envirn.org/pg/pages/view/79769/assessment-tools-amp-more.

Alliance of Nurses for Healthy Environments. "Facts on Fracking: What Health Care Providers Need to Know." Accessed November 21, 2014. http://concernedhealthny.org/wp-content/uploads/2013/10/ANHE-Fact-on-Fracking-Providers.pdf.

American Public Health Association. "What Is Public Health?" Accessed December 8, 2014. https://www.apha.org/what-is-public-health.

Bonnet, Vera. "Shale Extraction and Public Health: A Resource Guide." Shale and Public Health Committee: League of Women Voters of Pennsylvania, 2013. http://shale.palwv.org/wp-content/uploads/2013/12/846114-League-of-Women-Voters-Shale-Resource-Guide.pdf.

The Breast Cancer Fund. "Environmental Epidemological Studies." Accessed August 15, 2015. http://www.breastcancerfund.org/clear-science/research-methods/enviro-epidemiological.html.

Common Ground Alliance. Accessed October 15, 2015. http://www.commongroundalliance.com.

Consumer Fraud Reporting. "State Attorney General Contact List." Updated April 16, 2015. http://consumerfraudreporting.org/stateattorneygenerallist.php.

Earthworks. "Oil and Gas at Your Door? A Landowner's Guide to Oil and Gas Development." Durango, Colorado: Oil and Gas Accountability Project, 2005. http://www.earthworksaction.org/library/detail/oil_and_gas_at_your_door_2005_edition#.UxjPSj9dWSo.

Earthworks Action. "Hydrogen Sulfide." Accessed October 17, 2015. http://www.earthworksaction.org/issues/detail/hydrogen_sulfide#.VZwpomAreFI.

Feyereisn, Wayne. "Potential Public Health Risks of Silica Sand Mining and Processing." Slide show, available as a power point presentation through the ***Sand Point Times***. Accessed December 7, 2014. http://www.sandpointtimes.com/videos.

Food and Water Watch. "The Social Costs of Fracking: A Pennsylvania Case Study." September 24, 2013. http://www.foodandwaterwatch.org/reports/the-social-costs-of-fracking.

FracDallas. "Pipeline Explosions Since 2001." Updated February 26, 2013. http://fracdallas.org/docs/pipelines.html.

FracTracker Alliance. Accessed October 16, 2015. http://www.fractracker.org/about-us.

Freyman, Monica. "Hydraulic Fracturing & Water Stress: Water Demand by the Numbers." Ceres. February 2014.

Grand Valley Citizens' Alliance. The Rifle, Silt, New Castle Community Development Plan: A Collaborative Planning Document between the RSNC Defined Area Residents, Antero Resources Corp. and Galaxy Energy. January 1, 2006. http://www.oilandgasbmps.org/docs/CO68-RSNCCommunityDevelopmentPlan.pdf and http://www.oilandgasbmps.org/resources/casestudies/RSNC-CDP.php.

International Dark-Sky Association. ***IDA Energy Brochure***. 2008. http://www.darksky.org/assets/documents/ida_energy_brochure.pdf.

Liroff, Richard, Danielle Fugere, Lucia von Reusner, and Steven Heim. "Disclosing the Facts 2014: Transparency and Risk in Hydraulic Fracturing." A Collaborative Project of As You Sow, Boston Common Asset Management, LLC, Green Century Capital Management, Inc., and the Investor Environmental Health Network. http://disclosingthefacts.org.

Look Before You Lease. Accessed September 27, 2015. http://lookbeforeyoulease.org/about.

McFeeley, Matthew. "State Hydraulic Fracturing Disclosure Rules and Enforcement: A Comparison." Natural Resources Defense Council. July 2012. http://www.nrdc.org/energy/files/Fracking-Disclosure-IB.pdf.

National Association of County and City Health Officials. "Hydraulic Fracturing: What Local Health Departments Need to Know." Issue Brief. Washington, DC: November 2014. http://eweb.naccho.org/eweb/DynamicPage.aspx?WebCode=proddetailadd&ivd_qty=1&ivd_prc_prd_key=3a169831-6bc6-4605-a89f-a61b76a7c573&Action=Add&site=naccho&ObjectKeyFrom=1A83491A-9853-4C87-86A4-F7D95601C2E2&DoNotSave=yes&ParentObject=CentralizedOrderEntry&ParentDataObject=Invoice%20Detail.

Neighbor Works America. Accessed October 16, 2015. http://nw.org/network/index.asp.

Noise Pollution Clearing House. Accessed October 16, 2015. http://www.nonoise.org/index.htm.

Noise Pollution Clearing House. "Noise Regulations and Ordinances of U.S. Cities, Counties, and Towns." Accessed October 16, 2015. http://www.nonoise.org/lawlib/cities/cities.htm.

Northern Plains Resource Council. "Good Neighbor Agreement." Accessed October 15, 2015. https://www.northernplains.org/issues/good-neighbor-agreement.

Northern Plains Resource Council. Good Neighbor Agreement Between Stillwater Mining Company and Northern Plains Resource Council, Cottonwood Resource Council, and Stillwater Protective Association, originally signed May 8, 2000; amended November 11, 2009. https://www.northernplains.org/wp-content/uploads/2013/06/2009AmendedGNA.pdf.

Northern Plains Resource Council. "Good Neighbor Agreement: A Unique Solution for Local Protection." Accessed October 16, 2015. https://www.northernplains.org/wp-content/uploads/2013/06/GNA_Citizens_Guide.pdf.

Northern Plains Resource Council. "10th Anniversary Good Neighbor Agreement Newsletter." Accessed October 16, 2015. https://www.northernplains.org/wp-content/uploads/2013/06/2010GNAjoint-newsletter.pdf.

Pipeline Safety Trust. Accessed October 16, 2015. http://pstrust.org.

Southwest Pennsylvania Environmental Health Project. "Air." Accessed October 16, 2015. http://www.environmentalhealthproject.org/health/air.

Southwest Pennsylvania Environmental Health Project. "Guideline Values for Community Noise in Specific Areas." Accessed October 16, 2015. http://www.environmentalhealthproject.org/wp-content/uploads/2014/05/WHO-community-noise-table-adapted.5.15.14.pdf.

Southwest Pennsylvania Environmental Health Project. "Noise-Light." Accessed October 16, 2015. http://www.environmentalhealthproject.org/health/noise-light.

Southwest Pennsylvania Environmental Health Project. "Water." Accessed October 16, 2015. http://www.environmentalhealthproject.org/health/water.

Wisconsin League of Conservation Voters. "Frac Sand Mining." Accessed October 16, 2015. http://conservationvoters.org/issues/frac-sand-mining.

Policy and Research Institutions

Christian-Smith, Juliet. "Improving Water Management through Groundwater Banking: Kern County and Rosedale-Rio Bravo Water Storage District." Pacific Institute. 2013. http://resources.pacinst.org/wp-content/uploads/sites/21/2013/02/groundwater_banking3.pdf.

Geological Society of America. "GSA Critical Issue: Hydraulic Fracturing." Updated March 2015. http://www.geosociety.org/criticalissues/hydraulicFracturing/index.asp.

Headwaters Economics. "Fossil Fuel Extraction as a County Economic Development Strategy: Are Energy-focusing Counties Benefiting?" September 2008. http://headwaterseconomics.org/pubs/energy/HeadwatersEconomics_EnergyFocusing.pdf.

Headwaters Economics. "Impacts of Energy Development in Colorado." November 2008. http://headwaterseconomics.org/energy/western/colorado-mesa-garfield-counties and http://headwaterseconomics.org/pubs/energy/ImpactsofEnergyDevinCO_Digest.pdf.

Headwaters Economics. "Oil and Natural Gas Fiscal Best Practices: Lessons for State and Local Governments." November 2012. http://headwaterseconomics.org/wphw/wp-content/uploads/Energy_Fiscal_Best_Practices.pdf.

Muehlenbachs, Lucija, Elisheba Spiller, and Christopher Timmins. "The Housing Market Impacts of Shale Gas Development." Resources for the Future. December 2013. http://www.rff.org/RFF/Documents/RFF-DP-13-39.pdf.

Municipal Research and Services Center. "Pipeline Safety." Updated November 3, 2014. http://www.mrsc.org/subjects/pubsafe/pipe-safety.aspx.

Paleontological Research Institution. "Water: Into the Wells." *Marcellus Shale* 7, November 2011. http://www.museumoftheearth.org/files/marcellus/Marcellus_issue7.pdf.

Paleontological Research Institution. "Water: Out of the Wells." *Marcellus Shale* 8, November 2011. http://www.museumoftheearth.org/files/marcellus/Marcellus_issue8.pdf.

Pew Charitable Trusts. "Case Study: Oil Development, North Slope of Alaska." December 30, 2006. http://www.pewtrusts.org/en/research-and-analysis/analysis/hip/hip-case-study-oil-development-north-slope-of-alaska.

Pew Charitable Trusts. "The Health Impact Project." Accessed October 16, 2015. http://www.pewtrusts.org/en/projects/health-impact-project.

Resources for the Future. "Shale Gas Development Linked to Traffic Accidents in Pennsylvania." March 2014. http://www.rff.org/RFF/Documents/RFF-Resources-185_Infographic.pdf.

Resources for the Future. "A Review of Shale Gas Regulations by State: Setback Restrictions from Buildings." Updated May 22, 2013. http://www.rff.org/centers/energy_and_climate_economics/Pages/Shale_Maps.aspx.

Richardson, Nathan, Madeline Gottlieb, Alan Krupnick, and Hannah Wiseman. "The State of State Shale Gas Regulation." Resources for the Future. June 2013. http://www.rff.org/rff/documents/RFF-Rpt-StateofStateRegs_Report.pdf.

Sperger, Courtney, Kristin Cook, and Kenneth Klemow. "Does Marcellus Shale Pose a Radioactivity Risk?" Institute for Energy and Environmental Research of Northeastern Pennsylvania. August 1, 2012. http://energy.wilkes.edu/pages/184.asp.

APPENDIX B: WORKING GROUP MEMBER BIOS

Dave Baker, Working Group Chair and RESOLVE Board Member

Dave Baker's career has spanned 38 years in the mining industry. He recently retired after 32 years with Newmont Mining Corporation. He joined Newmont in 1980 as a geologist where in 1985, he moved to Newmont's fledgling Environmental Department. He was elected Vice President, Environmental Affairs in 1991. Mr. Baker spent a significant amount of his career addressing the regulatory implications on mining operations with extensive experience in the permitting and development of major mining projects in the United States, Africa, Indonesia, Peru, Ghana, Australia, Canada and Uzbekistan. He has also been involved in financing major mining projects through the IFC, the United States Export/Import Bank and the European Bank for Reconstruction and Development, among others. He participated in the Global Mining Initiative and the Mining, Metals and Sustainable Development (MMSD) and the founding of the International Council on Mining and Metals (ICMM).

Mr. Baker served as Newmont's first Chief Sustainability Officer, where he had broad responsibility for developing and implementing Newmont's global strategy for sustainability during an era of increasing stakeholder focus and expectations on corporate transparency, substantive community engagement, and the broader issues around sustainability, value creation and shared value.

Mr. Baker received his Bachelor of Science degree in Earth Sciences—Geology from the University of Arizona and completed the Harvard Business School's Advanced Management Program for International Managers in 1997.

Mr. Baker has been actively involved in the evolution of the mining industry's environmental and social responsibility and sustainability philosophy and approach, including the Global Mining Initiative and others.

Stephen D'Esposito, President, RESOLVE

Stephen D'Esposito is President of RESOLVE. RESOLVE is an independent organization with an over thirty-year track record of success helping diverse interests engage in dialogue, collaborative decision-making and action. RESOLVE strengthens the capacity of others to act as collaborative leaders. The Solutions Network (www.solutions-network.org) is a RESOLVE initiative designed to catalyze, incubate and reward solutions to urgent environmental challenges.

From 1997 through September 2008, Steve was President and

CEO of EARTHWORKS, a nonprofit organization dedicated to protecting communities and the environment from the adverse impacts of mineral and energy development while promoting sustainable solutions. Steve built EARTHWORKS into the leading independent NGO on mining, oil and gas issues, enhancing its reputation for providing policy and technical support to community groups, expanding to address international issues, strengthening its policy and science capacity, and launching new initiatives to engage directly with leading companies in the sector.

From 1993 through 1995, Steve was Deputy Director and then head of the Executive Committee of Greenpeace International, based in Amsterdam, the Netherlands, where he helped strengthen a number of national offices and programs and worked to integrate corporate engagement strategies into advocacy campaigns. During his tenure at Greenpeace International, Steve was a key decision-maker on the Brent Spar campaign, which many think led to a shift in corporate strategy and response to environmental campaigns as well as lessons-learned for NGOs.

Steve received a bachelor's degree in political science from Tulane University in New Orleans in 1982. He currently serves on an advisory council to the World Economic Forum; the board of Center for Science in Public Participation; the steering committee for the Responsible Mineral Development Initiative (of the World Economic Forum); the board of Resource Media; the steering committee for the Responsible Minerals Sector Initiative at Simon Fraser University; and the Advisory Panel, Kinross Professorship and Chair, Department of Mining Engineering, Queens University, Kingston.

David Dyjack, Executive Director, National Environmental Health Association

David T. Dyjack, Dr.PH, CIH, is Executive Director of the National Environmental Health Association, the largest professional association in the world dedicated to the practice of environmental health, a position he recently accepted. Prior to this, he was the Associate Executive Director for Programs at the National Association of County and City Health Officials (NACCHO) where he led the organization's grant and contract portfolio and 75 health professionals in support of the nation's 2800 local health departments. In this role he supervised projects in emergency preparedness and response, public health informatics, infectious disease, workforce development, governmental infrastructure, environmental health, maternal and child health, health equity, and chronic disease.

Throughout a 30-year career he has led workforce capacity building efforts in excess of 40 states and 60 countries. He has been Principal Investigator for a CDC-funded Center for Public Health Preparedness, where he led efforts to enhance the knowledge, skills, and abilities of local, tribal, state and ministerial governmental public health workforce throughout the Western United States and Pacific Rim, with emphasis on environmental health. Dyjack created an environmental health emergency preparedness training program in partnership with the California Conference of Directors of Environmental Health, has been an instructor for CDC's Environmental Health Training in Emergency Response (EHTER), and been instrumental in community resilience research bridging at-risk communities and governmental environmental health.

Additionally, he has provided management and leadership in varied public health activities since the mid-1980s. These efforts include work supported by the National Institutes of Health, the U.S. Health Resources and Services Administration, the U.S. Centers for Disease Control & Prevention, the U.S. Department of Labor, the U.S. Department of Defense, the U.S. Agency for International Development, the International Labor Organization (ILO), and the California Department of Health Services. He earned a doctorate in public health from the University of Michigan, an MSPH from the University of Utah, and is a board certified industrial hygienist (CIH).

Aaron Wernham, President and CEO, Montana Healthcare Foundation

Aaron Wernham, MD, MS, is the first President and CEO of the Montana Healthcare Foundation, which makes grants to improve the health and wellbeing of all Montanans largely by strengthening public health services and increasing the quality and accessibility of healthcare services across the state. Most recently, Dr. Wernham founded and directed the Health Impact Project, a collaboration of the Robert Wood Johnson Foundation and The Pew Charitable Trusts, established to promote and support the use of Health Impact Assessment (HIA) in the United States.

Dr. Wernham was a member of the National Research Council's Committee on HIA, led multiple HIAs and HIA trainings, and collaborated with and advised numerous state and federal agencies on HIA. Dr. Wernham also served as a senior policy analyst with the Alaska Native Tribal Health Consortium, where he headed a joint state-tribal-federal working group that developed HIA guidance for federal and state environmental regulatory and permitting efforts.

Dr. Wernham received his medical degree from the University of California, San Francisco and his master's degree in health and medical sciences from the University of California, Berkeley. He is board certified in family medicine, and served as clinical faculty in a University of California, Davis family practice residency program.

Shell Oil Company

Shell staff also participated on the Working Group and provided input and feedback on the guidebook.

APPENDIX C: OVERVIEW OF THE U.S. LEGAL AND REGULATORY FRAMEWORK FOR SHALE DEVELOPMENT

Legal and regulatory issues are in flux for this rapidly expanding and evolving industry, with many unsettled questions pertaining to environmental protection, technical applications, nuisance laws, the role of local governments, zoning, split estates, forced pooling, and landowner rights. In September 2014, the Congressional Research Service examined some of the legal issues related to hydraulic fracturing and found both gaps and uncertainties in policy that are, in some instances, being addressed through litigation.[1] Below is an overview of current policy related to some of the key issues, as of mid-2015.

U.S. Federal Legislation & Regulation

The United States Environmental Protection Agency (EPA) has responsibility for most of the key federal laws relevant to shale development, including the Clean Air Act (CAA), the Clean Water Act (CWA), and the Safe Drinking Water Act (SDWA). Several other federal laws also apply to shale development, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund), which authorizes the EPA to respond to releases or potential releases of hazardous substances that threaten human health and the environment; the Resource Conservation and Recovery Act (RCRA), which regulates the generation, transport, treatment, storage, and disposal of hazardous wastes; and the National Environmental Policy Act (NEPA), which requires federal agencies to integrate environmental impact statements (EIS) and recommendations for mitigation into their project planning. Oil and gas development on federally owned lands is managed by the U.S. Department of the Interior's Bureau of Land Management (BLM) and the U.S. Forest Service (USFS), an agency within the U.S. Department of Agriculture. For information on pipeline regulation, see Appendix E.

1 Adam Vann, Brandon J. Murrill, and Mary Tiemann, Hydraulic Fracturing: Selected Legal Issues, Congressional Research Service Report (September 26, 2014), https://www.fas.org/sgp/crs/misc/R43152.pdf.

AIR QUALITY

In 2012, the EPA issued enhanced regulations under the CAA, requiring that natural gas emissions from new hydraulically fractured and re-stimulated shale gas wells be *flared* (burned), as opposed to vented, thus reducing the level of toxic emissions when the well is prepared for production. Beginning in January 2015, 95 percent of all volatile organic compounds (VOCs) emitted during the well completion stage must be captured through a process known as ***green completion***, whereby commercially useful gas and liquid hydrocarbons are separated from flowback in a closed-system technology.[2]

In August 2015, the EPA issued proposed rules to reduce methane emissions under the CAA, with the goal of reducing emissions by 40 to 45 percent below 2012 levels by 2025.[3] Building on the 2012 standards for natural gas wells, the proposed rules will require reductions of methane emissions from shale oil wells and more ***downstream*** (associated with natural gas transmission) equipment and infrastructure. The proposed rules require operators to locate and plug leaks from equipment and infrastructure, including pneumatic pumps, pneumatic controllers, and compressor stations, which can be a significant source of emissions.[4] Operators of shale oil wells will be required to implement green completions, which capture both VOCs and methane. These rules will apply only to sources newly constructed or modified after the date of proposed rule publication in the Federal Register (September 18, 2015). In addition, the agency offers guidelines for states to reduce VOC emissions from existing oil and gas sources in areas with smog problems. The proposed rules have been issued with a 60-day comment period, and the agency intends to have the final rules in place in 2016.

WATER QUALITY

At the request of Congress, the EPA has been studying the potential impact of shale development operations on drinking water resources. The agency released a draft assessment summarizing existing science and new EPA research in June 2015.[5] The draft is currently undergoing review by EPA's Science Advisory Board. Once finalized, it is anticipated to serve as a resource for the protection of drinking water resources.[6]

Safe Drinking Water Act

The EPA protects underground sources of drinking water (USDW) through its regulatory authority under the SDWA. The Underground Injection Control (UIC) Program is the principal means of protecting USDWs, which requires permits for the use of underground injection as a means of waste disposal. States that have demonstrated an ability to meet EPA's requirements for enforcement of the UIC program have been granted

2 U.S. Environmental Protection Agency (EPA), "EPA's Air Rules for the Oil and Natural Gas Industry: Summary of Key Changes to the New Source Performance Standards," accessed November 21, 2014, http://www.epa.gov/airquality/oilandgas/pdfs/20120417changes.pdf

3 U.S. EPA, "Proposed Climate, Air Quality and Permitting Rules for the Oil and Natural Gas Industry: Fact Sheet," 1, http://www3.epa.gov/airquality/oilandgas/pdfs/og_fs_081815.pdf.

4 U.S. EPA, "Proposed Climate, Air Quality and Permitting Rules for the Oil and Natural Gas Industry: Fact Sheet," 1.

5 U.S. EPA Office of Research and Development, Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources: Executive Summary (External Review Draft) (Washington, DC: June 2015), www.epa.gov/hfstudy.

6 U.S. EPA, "Questions and Answers about EPA's Hydraulic Fracturing Study" last updated October 8, 2015, http://www2.epa.gov/hfstudy/questions-and-answers-about-epas-hydraulic-fracturing-study#28.

primary enforcement authority, called ***primacy***. These states have established regulations for the protection of USDWs for Class II injection wells, including on injection pressure and monitoring, well testing, and reporting. In states that have not received primacy, the EPA directly implements the regulations.

There are six categories (or classes) of UIC injection wells, depending on the kind of fluid and depth at which the fluid is injected. The oil and gas industry uses Class II injection wells to 1) permanently dispose of wastewater; 2) reinject it at the site of a production well in order to improve the recovery of the resource; and 3) to store hydrocarbons beneath the surface to be pumped out later for processing and use. As of September 2013, the Ground Water Protection Council estimated that 31 states host approximately 168,000 Class II injection wells.[7]

Prior to well construction, the site is evaluated to ensure that the injected fluids will be appropriately isolated from drinking water sources and that construction and operation procedures will be protective of USDWs. Well construction techniques use layers of steel casing and cement to prevent any subsurface fluid migration. Once constructed, the wells are tested prior to injection. After the wells enter into operation, they are monitored for injection pressures and volumes to ensure proper operation and to allow for the identification of any problems. Wells must also be tested at least once every five years to check the performance of the well and the subsurface conditions. When operations cease, wells must be closed in a manner that protects USDWs and are typically sealed with a series of cement plugs.

Is hydraulic fracturing considered underground injection?

Some stakeholders have raised the question of whether hydraulic fracturing constitutes underground injection and should be regulated under the UIC program.[8] In response to such questions, Congress declared in the Energy Policy Act of 2005 that the injection of hydraulic fracturing fluids for oil and gas development activities (except those containing diesel fuel) is not considered underground injection and is therefore excluded from regulation under the SDWA.[9] Following on this decision, in May 2012 the EPA issued draft guidance indicating that when operators use hydraulic fracturing fluids containing diesel fuel, they are required to obtain a permit under the UIC program.[10]

Clean Water Act

The discharge of oil and gas wastewaters into the surface waters of the United States is regulated by the EPA under the CWA. The CWA controls industrial discharges directly to surface waters (e.g., through stormwater systems) and industry's indirect discharges to publicly owned treatment works (POTWs). Any discharges to surface waters must be below the limits set under the CWA National Pollutant Discharge Elimination System (NPDES). NPDES may authorize a permit that allows

7 Ground Water Protection Council (GWPC), "Injection Wells: An Introduction to Their Use, Operation, & Regulation" (September 1. 2013), 13, http://www.gwpc.org/sites/default/files/UIC%20Brochure%20Updated%209-2013_0.pdf.

8 GWPC, "Injection Wells," 28.

9 U.S. EPA, "Regulation of Hydraulic Fracturing under the Safe Drinking Water Act," last updated February 11, 2014, http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/wells_hydroreg.cfm.

10 U.S. EPA, "Fact Sheet: Underground Injection Control (UIC) Program Permitting Guidance for Oil and Gas Hydraulic Fracturing Activities Using Diesel Fuels, UIC Program Guidance #84 – Draft" (May 2012), http://water.epa.gov/type/groundwater/uic/class2/hydraulicfracturing/upload/hfdieselfuelsfs.pdf.

discharging of chemicals into U.S. waters, provided that they are below EPA standard limits.[11] Permitting generally occurs at the federal level; however, NPDES has authorized some states to issue permits directly.

Waste Disposal

As with other oil and gas wastes, shale development wastes are classified as "special waste" and are therefore exempt from hazardous waste regulations under Subtitle C of the Resource Conservation and Recovery Act (RCRA).[12] While exempt from RCRA Subtitle C pertaining to hazardous wastes, wastes from shale development are still subject to other federal regulations (e.g., CWA, SDWA), RCRA Subtitle D solid waste regulations, and state regulations.[13] If hazardous substances from shale development contaminate a site and pose a threat to public health or the environment, operators can potentially be liable under CERCLA for natural resource damages, cleanup costs, and the cost of public health studies.[14]

Shale Development on Federal and Tribal Lands

In March 2015, the BLM issued new standards for shale development on federal and tribal lands. The BLM controls 700 million acres of federal subsurface minerals and is the regulatory agency for an additional 56 million acres of tribal subsurface minerals.[15] To date, there are over 100,000 oil and gas wells on federal lands, with 90% of the wells currently being drilled using hydraulic fracturing techniques.[16] The new rule includes new requirements for ensuring well integrity, the disclosure of the chemicals used in hydraulic fracturing, higher standards for wastewater storage, and a requirement that operators provide additional information on preexisting wells, with the goal of reducing the potential for cross-well contamination. In September 2015, however, a federal judge issued an injunction blocking the implementation of the new regulations until an industry challenge to the regulations can be heard in court later in the year.[17]

Tribal Governments

Native American lands are often held in trust by the federal government, and therefore potential energy development on or near tribal lands involves coordination and negotiation with both the tribal government and relevant federal government agencies, including the Bureau of Indian Affairs. There can also be unique laws and regulations pertaining to energy development on tribal lands.

11 U.S. EPA, "Natural Gas Drilling in the Marcellus Shale: NPDES Program Frequently Asked Questions," attachment to memorandum from James Hanlon, Director of EPA's Office of Wastewater Management to the EPA Regions titled, "Natural Gas Drilling in the Marcellus Shale under the NPDES Program" (March 16, 2011): 6, http://www.epa.gov/npdes/pubs/hydrofracturing_faq.pdf.

12 U.S. Environmental Protection Agency, "Crude Oil and Natural Gas Waste," last updated 4/7/14, http://www.epa.gov/osw/nonhaz/industrial/special/oil.

13 U.S. EPA, "Exemption of Oil and Gas Exploration and Production Wastes from Federal Hazardous Waste Regulations," 5, 20, http://www3.epa.gov/epawaste/nonhaz/industrial/special/oil/oil-gas.pdf.

14 Adam Vann, Brandon J. Murrill, and Mary Tiemann, Hydraulic Fracturing.

15 U.S. Department of the Interior Bureau of Land Management (BLM), "Interior Department Releases Final Rule to Support Safe, Responsible Hydraulic Fracturing Activities on Public and Tribal Lands" (March 20, 2015), http://www.blm.gov/wo/st/en/info/newsroom/2015/march/nr_03_20_2015.html.

16 BLM, "Interior Department Releases Final Rule."

17 Coral Davenport, "Judge Blocks Obama Administration Rules on Fracking," The New York Times (September 30, 2015), http://www.nytimes.com/2015/10/01/us/politics/judge-blocks-obama-administration-rules-on-fracking.html?smid=nytcore-ipad-share&smprod=nytcore-ipad&_r=0.

State Legislation & Regulation

States regulate shale gas development and production on their territory and are often the primary administrators of relevant federal laws. They regulate well permitting, potential environmental impacts, and certain pipelines through their state public service commissions (see Appendix E). As is the case federally, many states have been updating legislation, with more than 100 bills passed in 19 states between 2010 and 2013.[18] State legislatures are particularly focused on severance taxes, impact fees, well spacing, well pad setbacks, waste treatment and disposal, and disclosure of the chemicals used in hydraulic fracturing.

A Resources for the Future study of state regulations found a significant amount of divergence in the ways that states are regulating shale development.[19] In a 2014 review of state oil and gas regulations relevant to groundwater protection, the Ground Water Protection Council (GWPC) noted that states have been revising their regulations since its initial 2009 review.[20] The GWPC identified some trends in new regulations, including increased requirements for disclosure of hydraulic fracturing fluid ingredients, increased mechanical integrity testing, and improved requirements for wastewater disposal pits and liners.

While many states have been updating their oil and gas regulations in response to shale development, some states have declared moratoria while policy reviews are underway. In December 2014, after the release of a seven-year review of the potential environmental and health impacts of shale development in New York, the governor instituted a ban on shale development in the state.[21] In June 2015, Maryland established a two-year moratorium on shale development while the state writes appropriate regulations.[22]

DISCLOSURE

In a February 2014 report, the U.S. Department of Energy recommended enhancements to the largely voluntary FracFocus database that tracks materials used in shale development. The recommended changes would include mandatory "full disclosure of all known constituents added to fracturing fluid" as well as the possible inclusion of area well water data pre-stimulation and post-production.[23] According the GWPC review cited above, chemical disclosure has recently been a common focus of state rulemaking, with almost every major oil-and-gas producing state considering the issue.[24]

18 National Conference of State Legislatures website, accessed November 22, 2014, http://www.ncsl.org.

19 Nathan Richardson, Madeline Gottlieb, Alan Krupnick, and Hannah Wiseman, ***The State of State Shale Gas Regulation,*** Resources for the Future, June 2013, http://www.rff.org/rff/documents/RFF-Rpt-StateofStateRegs_Report.pdf.

20 GWPC, State Oil & Gas Regulations Designed to Protect Water Resources (2014), 6, http://www.gwpc.org/sites/default/files/Oil%20and%20Gas%20Regulation%20Report%20Hyperlinked%20Version%20Final-rfs.pdf.

21 Thomas Kaplan, "Citing Health Risks, Cuomo Bans Fracking in New York State," The New York Times (December 17, 2014), http://www.nytimes.com/2014/12/18/nyregion/cuomo-to-ban-fracking-in-new-york-state-citing-health-risks.html?_r=0.

22 Timothy Cama, "Maryland Bans Fracking," The Hill (June 1, 2015), http://thehill.com/policy/energy-environment/243625-maryland-bans-fracking.

23 U.S. Department of Energy, ***Secretary of Energy Advisory Board Task Force Report on FracFocus 2.0*** (March 28, 2014), http://energy.gov/sites/prod/files/2014/04/f14/20140328_SEAB_TF_FracFocus2_Report_Final.pdf

24 GWPC, State Oil & Gas Regulations Designed to Protect Water Resources (2014), 8, http://www.gwpc.org/sites/default/files/Oil%20and%20Gas%20Regulation%20Report%20Hyperlinked%20Version%20Final-rfs.pdf.

Local Governments

Local county and municipal governments often play a regulatory role in or near populated areas, where they may manage issues such as noise levels, traffic flow, and setbacks from residences. The primary tool for local governments to control oil and gas development in their area is through zoning laws and other land use regulations. With the growth of shale development, some local residents and communities have expressed concerns about potential health, environmental, and property value impacts and have attempted to impose increased regulations on shale development activities.

In some of these cases, local governments' efforts to regulate the industry and land use have come into conflict with the state's authority to manage the development of its natural resources, raising the question of when states can overrule (or *preempt*) local land use and zoning authority. Some of these cases are playing out in the state courts. To date, the state courts have tended to uphold local laws when they pertain to zoning and land use, as a New York court concluded when two municipalities imposed zoning restrictions on the oil and gas industry within their boundaries.[25] When local laws have attempted to regulate oil and gas procedures and operations, however, the courts have determined that the state's authority pre-empts local laws. For example, when the city of Longmont, Colorado, imposed a ban on hydraulic fracturing, a Colorado district court ruled that the ban interfered with the state's regulatory authority to permit hydraulic fracturing.[26]

Selected Resources

OVERVIEW

- Ground Water Protection Council and ALL Consulting, "Modern Shale Gas Development in the United States: A Primer", prepared for the U.S. Department of Energy and the National Energy Technology Laboratory (April 2009), http://energy.gov/sites/prod/files/2013/03/f0/ShaleGasPrimer_Online_4-2009.pdf. This 2009 primer on shale gas development in the United States includes an overview of the applicable federal, state, and local regulatory environments on pages 25–42. In 2013, the National Energy Technology Laboratory issued an update to this primer, "Modern Shale Gas Development in the United States: An Update" (http://www.netl.doe.gov/File%20Library/Research/Oil-Gas/shale-gas-primer-update-2013.pdf), to address evolving concerns and regulations. The regulatory framework is covered on pages 55–57.
- Adam Vann, Brandon J. Murrill, and Mary Tiemann, "Hydraulic Fracturing: Selected Legal Issues," Congressional Research Service Report (September 26, 2014), https://www.fas.org/sgp/crs/misc/R43152.pdf. Report by the Congressional Research Services gives an overview of the legal issues pertaining to hydraulic fracturing, including applicable federal laws such as the SDWA, the CAA,

25 Adam Vann, Brandon J. Murrill, and Mary Tiemann, Hydraulic Fracturing: Selected Legal Issues, 27.
26 Adam Vann, Brandon J. Murrill, and Mary Tiemann, Hydraulic Fracturing: Selected Legal Issues, 28-9.

and RCRA; the issue of disclosure of hydraulic fracturing fluid ingredients; state preemption of local laws, state tort law, and legislation before the 113th Congress.

TRACKING LEGISLATION & REGULATION

As indicated above, the legal and regulatory framework for shale development is continually evolving. There are several organizations tracking these developments that can serve as resources for legal and regulatory information on oil and gas development, as well as shale development specifically:

- FracFocus, the chemical disclosure registry, has a database of oil and natural gas regulations by state: http://fracfocus.org/regulations-state.
- Fracking Insider, an environmental law and energy blog: www.frackinginsider.com.
- The National Conference of State Legislatures (NCSL) has a guidebook for state lawmakers, "Natural Gas and Hydraulic Fracturing: A Policymaker's Guide" (June 2012), http://www.ncsl.org/documents/energy/frackingguide_060512.pdf. NCSL also has a webpage on the topic of compulsory or forced pooling, "Compulsory Pooling Laws: Protecting the Conflicting Rights of Neighboring Landowners" (http://www.ncsl.org/research/energy/compulsory-pooling-laws-protecting-the-conflicting-rights-of-neighboring-landowners.aspx). It describes forced pooling, gives definitions of relevant terms, and describes the different state approaches to compulsory pooling. It also has a map and table of state compulsory pooling laws.
- Resources for the Future, an independent nonprofit research organization, conducted a review of shale gas regulations in 31 states with current or potential shale development operations. There is a report, comparative tables, and maps on the website at http://www.rff.org/centers/energy_and_climate_economics/Pages/Shale_Maps.aspx.
- The University of Colorado Law School's Intermountain Oil and Gas BMP website hosts several relevant resources:
  - oil and gas law & policy page: http://www.oilandgasbmps.org/laws
  - hydraulic fracturing page: http://www.oilandgasbmps.org/resources/fracing.php
  - a database of comparative water quality, water quantity, and air quality laws relating to shale development: http://www.lawatlas.org/oilandgas

STATE ASSISTANCE AND GUIDANCE

The following are organizations that provide assistance and guidance to states in developing oil and gas policy:

- The Interstate Oil and Gas Compact Commission (http://iogcc.publishpath.com), is an organization representing the governors of member states on the responsible development of oil and gas resources.
- The State Review of Oil & Natural Gas Environmental Regulations (http://www.strongerinc.org), or STRONGER, is "a non-profit, multi-stakeholder organization whose purpose is to assist states in documenting the environmental regulations associated with the exploration, development and production of crude oil and natural gas." STRONGER's guidelines for state oil and gas exploration and production waste regulatory programs can be found here: http://www.strongerinc.org/guidelines. The guidelines also contain a section relating to hydraulic fracturing.

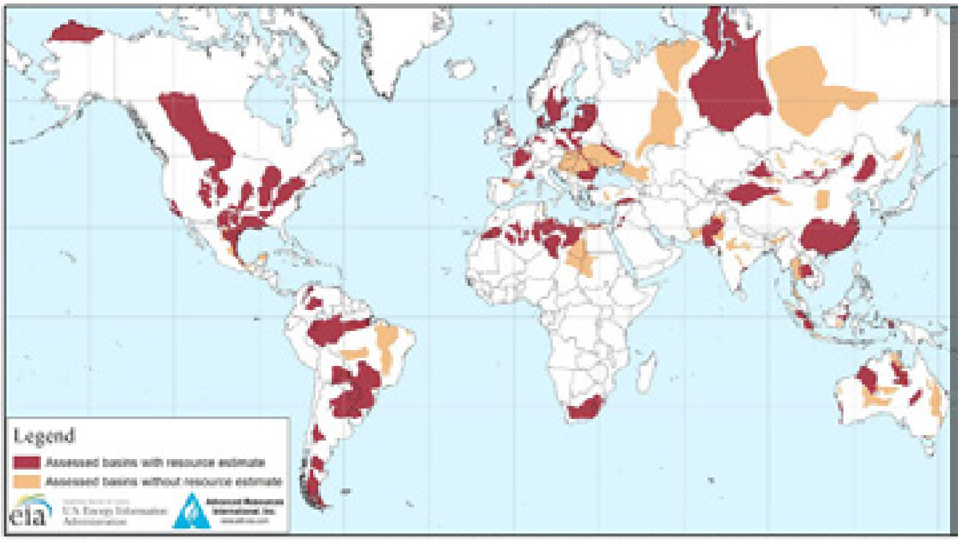
APPENDIX D: VOLUNTARY PRINCIPLES AND STANDARDS FOR SHALE DEVELOPMENT OPERATIONS

International

Over the last decade, shale gas exploration and production have increased dramatically in the United States.[1] International interest is also growing, especially in China and parts of Eastern Europe, although every continent on earth has potential shale gas basins that could be exploited in coming years (see Figure 7). In fact, over the next two decades, shale gas production worldwide is projected to increase threefold.[2]

On an international level, principles of responsible natural resource development have increasingly been incorporated into voluntary standards and guidance documents. The International Finance Corporation (IFC) of the World Bank, for example, has established a set of Environmental and Social Performance Standards, which are part of the organization's approach to risk management with regard to its investments and represents the standards that its clients must meet throughout an IFC-funded project (http://www.ifc.org/wps/wcm/connect/115482804a0255db96fbffd1a5d13d27/PS_English_2012_Full-Document.pdf?MOD=AJPERES). Performance Standard #4 Community

Figure 7. Map of basins with assessed shale oil and gas formations, as of May 2013



Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.

1 U.S. Department of Energy, ***Modern Shale Gas Development in the United States: An Update*** (National Energy Technology Laboratory: September 2013), http://www.netl.doe.gov/File%20Library/Research/Oil-Gas/shale-gas-primer-update-2013.pdf, Shale Gas Geographical Distribution pp. 19–46.

2 ATSM International. "Subcommittee D-18 on Hydraulic Fracturing," http://www.astm.org/COMMIT/SUBCOMMIT/D1826.htm, accessed November 21, 2014.

Health, Safety, and Security is particularly relevant for community health issues. Guidance notes on the implementation of Performance Standard #4 are also available (http://www.ifc.org/wps/wcm/connect/dc3f4b80498007dca17ff3336b93d75f/Updated_GN4-2012.pdf?MOD=AJPERES).

With regard to the technologies used in hydraulic fracturing, the American Society for Testing and Materials (now ASTM International), has set out to develop an internationally applicable set of best practices and standards. The ASTM Subcommittee D18.26 on Hydraulic Fracturing is composed of representatives of industry, environmental groups, engineers, federal regulators, state and local government, permitting bodies, and academics who are working together to develop standards and principles that will apply specifically to the technology of hydraulic fracturing. The subcommittee's proposed and active standards can be found here: http://www.astm.org/COMMIT/SUBCOMMIT/D1826.htm.

United States

In the United States, where shale gas development has principally been taking place to date, some organizations have begun to offer guidance on best practices for the use of hydraulic fracturing and horizontal drilling:

- The State Review of Oil & Natural Gas Environmental Regulations (STRONGER) is "a non-profit, multi-stakeholder organization whose purpose is to assist states in documenting the environmental regulations associated with the exploration, development and production of crude oil and natural gas": http://www.strongerinc.org.
- The Center for Sustainable Shale Development, a collaboration among industry, environmental, and philanthropic organizations, aims to develop innovative best practices for sustainable shale development through the establishment of performance standards and a certification process that evaluates whether companies achieve those standards: https://www.sustainableshale.org.

Industry Principles and Standards

The oil & gas industry has long established principles and guidance for best practices with regard to community health, recognizing that good stakeholder engagement can help to reduce project risks. The International Association of Oil & Gas Producers (OGP) and the International Petroleum Industry Environmental Conservation Association (IPIECA), a global oil and gas industry association for environmental and social issues have produced several relevant guidance documents, including:

- "Good Practice Guidelines for the Development of Shale Oil and Gas" (December 2013), http://www.ipieca.org/publication/ogp-ipieca-good-practice-guidelines-development-shale-oil-and-gas

- "Managing Health for Field Operations in Oil and Gas Activities" (2011), http://www.internationalsosfoundation.org/?wpfb_dl=81

The American Petroleum Institute (API), an industry association, has produced several industry guidance documents and recommended practices on shale development operations:

- “Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines,” API Guidance Document HF1, First Edition (October 2009), http://www.api.org/~/media/Files/Policy/Exploration/API_HF1.pdf
- “Hydraulic Fracturing—Well Integrity and Fracture Containment” (ANSI/API Recommended Practice 100-1)
- “Managing Environmental Aspects Associated with Exploration and Production Operations Including Hydraulic Fracturing” (ANSI/API Recommended Practice 100-2)

The recommended practice documents 100-1 and 100-2 are newly released documents that are available for free public viewing (or for sale to download) on the API website: http://publications.api.org. To access, register, select “Browse read-only documents now,” then select “Exploration and Production,” and scroll to recommended practices 100-1 and 100-2.

Other industry associations that have developed recommendations for best practices on shale gas development include:

- The Appalachian Shale Recommended Practices Group, a consortium of the 11 largest natural gas and oil producers operating in the Appalachian Basin: http://asrpg.org.
- Marcellus Shale Coalition, an industry association focused on the Marcellus and Utica shale plays, has developed a set of recommended practices on specific issues related to shale development: http://marcelluscoalition.org/category/library/recommended-practices.

Many individual operators have elaborated their own sets of principles with regard to shale development. Some examples can be found here:

- BG Group: http://www.bg-group.com/197/about-us/industry-challenges/unconventional-gas
- Chesapeake Energy: http://www.chk.com/responsibility
- Shell Oil Company: http://www.shell.com/global/future-energy/natural-gas/gas/shell-operating-principles.html

APPENDIX E: PIPELINES—TRANSPORTING SHALE GAS TO MARKETS

A complex distribution system for natural gas has been in place for decades in the United States, which—until recently—principally carried gas from the Southwest to other regions of the country. With the advent of shale gas development, additional distribution infrastructure is needed. In response, pipeline companies are hurrying to meet demand, with plans for pipeline construction that have the potential to impact many more communities and property owners than do the shale gas wells themselves. Projections suggest that, through 2035, the country's natural gas pipeline infrastructure will triple.[1]

As the development of this network will have health and other impacts around the country, this section offers an overview of the pipeline system, how it is regulated, potential community health effects, and management options.

Pipeline under construction in WV. By Samantha Malone 2013.

1 Interstate Natural Gas Association of America (INGAA) Foundation, "North American Midstream Infrastructure through 2035: Capitalizing on Our Energy Abundance," prepared by ICF International: March 18, 2014, http://www.ingaa.org/File.aspx?id=21498.

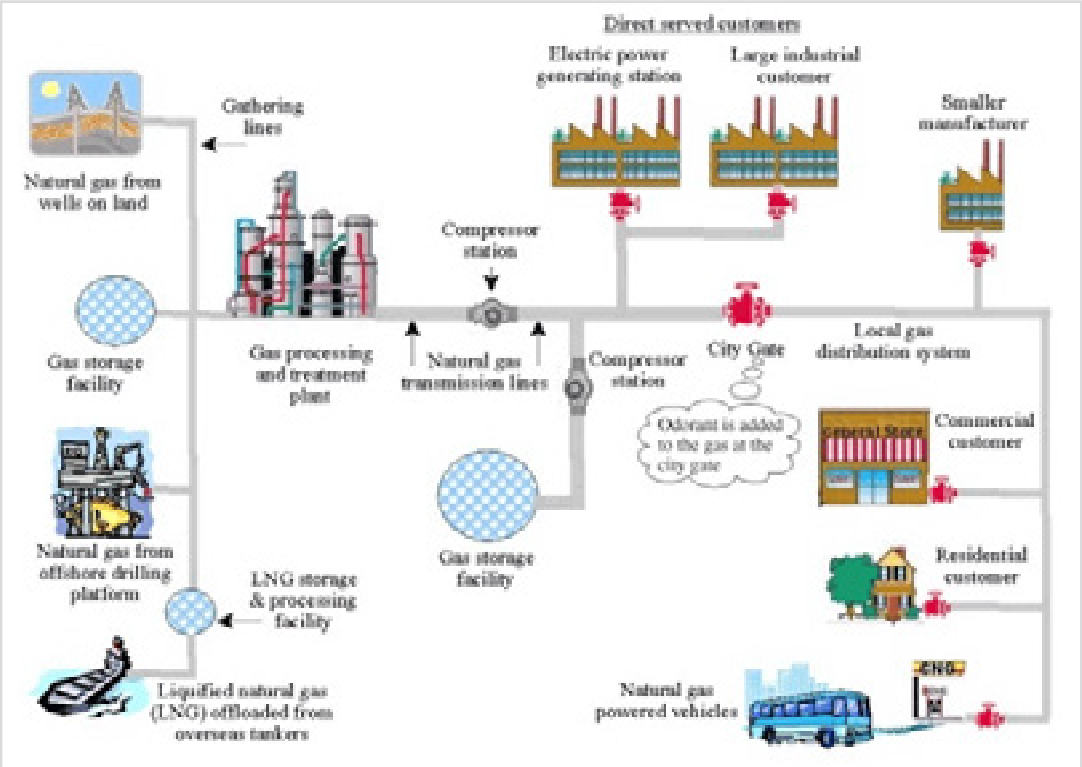
The Pipeline Network—What Is It?

Gas produced at the wellhead is transported to markets through a series of pipelines:

- *flowlines* carry raw gas and fluids at or near the wellhead and within a production facility
- *gathering lines* bring the gas from a production facility to a central collection point
- *transmission lines* are the long-distance haulers, transporting processed gas to and from storage facilities and compressor stations, and to distribution lines
- *distribution lines,* or *mains*, carry gas under reduced pressure from large high-pressure transmission lines to low-pressure customer service lines

The pipeline network is illustrated in Figure 8 below.

Figure 8. Illustration of natural gas pipeline systems



Source: PHMSA, "Pipeline Safety Awareness," https://opsweb.phmsa.dot.gov/pipelineforum/pipeline_safety_update/image_library.html.

Who Oversees and Regulates Pipelines?

Federal agencies: The Federal Energy Regulatory Commission (FERC) approves the construction, siting, and operation of interstate transmission lines. It also manages abandonment of interstate pipelines. The **Office of Pipeline Safety** (OPS), which is part of the Pipeline and Hazardous Materials Safety Administration (PHMSA), regulates interstate transmission lines, intrastate pipelines for a few states, gathering lines in populated areas, and some distribution lines that deliver gas to customers. Their primary responsibility is assuring pipeline integrity from a public safety and environmental perspective. Emergency response is also one of their mandates. The National Transportation Safety Board (NTSB), the U.S. Environmental Protection Agency (EPA), and the U.S. Fish and Wildlife Service (USFWS) also play regulatory roles related to their specific mandates.

Tribal governments: For approval of **interstate** pipelines traversing tribal lands, FERC must coordinate with the federal Bureau of Indian Affairs (BIA), and the federal agencies must engage in government-to-government consultation with tribal authorities during the pipeline planning and review process. **Intrastate pipelines** that cross tribal lands must be approved by the federal government (regarding environmental and cultural impacts) and by the Bureau of Indian Affairs. Pipeline safety and emergency management are also the responsibility of tribal governments, with training and technical support from OPS. As more pipeline infrastructure is needed, there is an increasing need for improved coordination between the federal government, states, and tribal authorities.[2]

State agencies: States regulate flowlines at production facilities (i.e., well pads, processing plants, compressor stations, storage facilities) and gathering lines in rural areas. This is generally done through the permitting process. Most states regulate intrastate pipelines with OPS guidance, often to a more stringent standard than required by the federal government.[3] Many states also regulate distribution lines with OPS guidance.

Regulatory capacity: The pipeline network is currently managed by multiple state and federal agencies, yet these entities do not always have the resources to provide for robust management.[4] For example, PHMSA has funding for only 137 inspectors to inspect the 2.5 million miles of natural gas pipelines operated by about 3,000 companies throughout the country.[5]

Gathering lines—90% of which are rural and are therefore regulated by states—have recently emerged as a cause for concern. Newly installed lines for servicing shale gas are usually larger and carry gas at higher pressure than traditional gathering lines, presenting the possibility of more serious incidents. State officials are often not aware of the location of many of these rural gathering lines, particularly older pipelines; and when an incident occurs, operators are often not required to report it.[6]

2 U.S. Department of Energy, "Stakeholder Meeting on State, Local, and Tribal Issues" (memo, Washington, DC, August 6, 2014), http://energy.gov/sites/prod/files/2014/08/f18/20140808%20State-Local-Tribal%20Memo%20Final.pdf.
3 Interstate Natural Gas Association of America (INGAA), "How Are Natural Gas Transmission Pipelines Regulated?" accessed November 20, 2014, http://www.ingaa.org/cms/4923.aspx.
4 The National Petroleum Council, "Natural Gas Pipelines: Challenges," 2011, http://www.npc.org/prudent_development-topic_papers/2-19_gas_pipeline_challenges_paper.pdf
5 FracDallas, "Pipeline Explosions Since 2001," updated February 26, 2013, http://fracdallas.org/docs/pipelines.html
6 Novena Sadasivam, "Boom in Unregulated Natural Gas Pipelines Posing New Risks," Inside Climate News (September 26, 2013), http://insideclimatenews.org/news/20130926/boom-unregulated-natural-gas-pipelines-posing-new-risks

What health considerations are there?

Given that a certain amount of methane leakage occurs throughout the pipeline network, health impacts for people living, working, and recreating near pipelines need to be considered.

AIR QUALITY

For health impacts of natural gas emissions, refer to the Air Quality section under Stage 3.

SAFETY

Pipelines carry hazardous materials and therefore entail safety risks. Typically, natural gas pipeline accidents that cause explosions and/or fires are most frequently due to excavation and pipeline corrosion or defects.[7] According to PHMSA, from 2004 to 2013, the ten-year incident average for natural gas pipelines was as follows: 117 incidents on transmission lines; 16 on gathering lines (rural gathering lines do not require incident reporting)[8]; and 137 on distribution lines.[9]

QUALITY OF LIFE—ECONOMIC IMPACTS

Eminent domain is a legal process by which a state, municipality, private person, or corporation can acquire rights to private property for public use. Allowed under the Fifth Amendment of the Constitution of the United States and referenced in most state constitutions, eminent domain is specifically granted for interstate natural gas transmission pipelines under the 1938 Natural Gas Act. Good faith negotiations should precede the exercise of eminent domain, and property owners should receive just compensation.

Other types of pipelines—intrastate, gathering, and distribution—may or may not fall under eminent domain, depending on the constitution of the state involved. States vary significantly in their application of eminent domain to natural gas pipelines, in granting private companies the privilege to use eminent domain, and in what is considered just compensation to property owners.

In terms of potential benefits to communities, pipeline companies pay taxes to the municipalities in which they operate. A pipeline construction project also generates temporary economic activity for a community and could create a few permanent jobs. In some cases, natural gas may be made available to communities along the pipeline route if they are not presently being serviced by a gas utility company.

Research suggests that real estate values and insurance rates are generally not affected by the presence of a natural gas pipeline on or near the property.[10] Property owners receive financial compensation (or an ***easement***), in the form of an

---

7 U.S. Department of Transportation, "The State of the National Pipeline Infrastructure" (2011), https://opsweb.phmsa.dot.gov/pipelineforum/docs/Secretarys%20Infrastructure%20Report_Revised%20per%20PHC_103111.pdf.

8 Pipeline and Hazardous Materials Safety Administration (PHMSA), "Pipeline Incidents by System Type," data as of 11/21/14, http://www.phmsa.dot.gov/pipeline/library/datastatistics/pipelineincidenttrends.

9 Incidents that are recorded by OPS involve a release of gas that results in death or in-patient hospitalization, and/or property damage of $50,000 or more. (PHMSA, "Reporting Criteria as of 2011," March 2011, http://primis.phmsa.dot.gov/comm/reports/safety/docs/IncidentReportingCriteriaHistory1990-2011.pdf.)

10 William N. Kinnard, Jr., Sue Ann Dickey, and Mary Beth Geckler, "Natural Gas Pipeline Impact on Residential Property Values: An Empirical Study of Two Market Areas," ***International Right of Way Association*** (June/July 1994), https://www.irwaonline.org/eweb/upload/0604d.pdf.

up-front payment per linear foot, with a signing bonus added on occasion; property owners continue to pay taxes on the easement unless they can show cause for tax abatement. If the easement is in an agricultural area, farming can continue to take place, but other activities may be restricted (e.g., cattle grazing may require fencing and arrangements for access by the pipeline operator).

QUALITY OF LIFE—PSYCHOLOGICAL IMPACTS

When communities and property owners first learn about a proposed natural gas pipeline, they often have concerns about the project. Their concerns tend to cluster around issues of land value, eminent domain, and the safety of living near a natural gas line. The company and FERC invite potentially impacted landowners to public meetings for clarification and input on the process. FERC and the operator may take certain environmental or safety concerns raised by community members into consideration (e.g., land subsidence over abandoned mine sites), which can result in the alteration of the proposed route.[11]

QUALITY OF LIFE—VISUAL IMPACTS

During construction, the right-of-way for a transmission line may be 75 to 100 feet or more, depending on soil conditions and topography. Trees are cut and vegetation is removed. While grassy vegetation is planted after construction is complete, no trees are permitted for fear of tree roots damaging the pipeline, as well as to allow for aerial inspection of the route. The permanent easement is usually 50 feet wide, which the operator maintains. Above-ground components such as valves may remain visible.[12]

What can be done to address health concerns? What have others done?

SAFETY

Most excavation incidents occur when an entity other than the operator is digging near pipelines, and these incidents lead to the largest number of personal injuries and fatalities. Excavation risks therefore need to be managed by multiple stakeholders—including operators, regulators, municipal planners, property owners, and private excavators.

Pipeline operators: Damage to pipelines due to excavation has been decreasing in recent years, thanks to one-call centers, or "call before you dig" phone banks. Pipeline markers are also

11 Federal Energy Regulatory Commission, "An Interstate Natural Gas Pipeline on My Property? What Do I Need to Know?" updated August 2013, http://www.ferc.gov/for-citizens/citizen-guides/citz-guide-gas.pdf.

12 Pennsylvania State University Extension Agency, "Negotiating Pipeline Rights-of-Way in Pennsylvania," accessed December 6, 2014, http://extension.psu.edu/natural-resources/natural-gas/publications/negotiating-pipeline-rights-of-way-in-pennsylvania.

important in preventing excavation damage, but they are not exact indicators of pipeline locations, so contacting a one-call center is still necessary before excavation begins.

Pipeline companies are using improved technology and detection techniques, such as handheld infrared scanners, to address potential problems due to corrosion or pipeline defects.[13] Some experts have recommended more frequent replacement of aging pipelines to prevent potential problems and that all pipelines, including rural gathering lines, be regulated by OPS.

OPS requires operators to conduct public awareness programs regarding pipeline safety. Activities include disseminating materials on the use of one-call centers; communicating with stakeholders on pipeline locations and the detection of any leaks; and trainings for first responders.[14]

Local governments: While local governments traditionally have jurisdiction over land use, they have infrequently addressed pipeline issues, or have done so in the absence of risk- or site-based data.[15] Following several major pipeline incidents in 2004, the Transportation Research Board (TRB) recommended that the federal government provide risk-based guidance on land use near pipelines.[16, 17] As a result, the Pipelines and Informed Planning Alliance (PIPA) was created under OPS to provide guidance to local communities, pipeline operators, property developers/owners, and real estate commissions. These guidelines include siting considerations; width of pipeline corridors and easements; appropriate land use, human activities, and structures in the vicinity of the easement; setbacks to protect people and property; and model ordinances. The guidelines were developed for transmission pipelines only and are not mandatory.[18]

Therefore, in terms of considerations for improving pipeline safety, local planning commissions could make risk-based determinations on the above considerations according to the needs of their communities. They could also include pipeline locations on local *plats* and planning documents. Local governments could require real estate transactions to disclose pipelines within 600 feet of the property line.[19]

Property owners and private excavators: Prior to conducting excavation activities, it is important to check for pipeline markers and make use of one-call centers to determine the exact location of any pipelines on or near the property.

QUALITY OF LIFE

Property owners: If your property might be impacted by the construction of an **interstate pipeline**—and thereby be subject to eminent domain—you will receive information on the process from FERC and from the pipeline operator, and will have the opportunity to participate in informational meetings to learn

13 Pennsylvania State University Extension Agency, http://extension.psu.edu/natural-resources/natural-gas/publications/negotiating-pipeline-rights-of-way-in-pennsylvania.

14 INGAA, "How Are Natural Gas Transmission Pipelines Regulated?" (2014), http://www.ingaa.org/cms/4923.aspx.

15 The Transportation Research Board, "Transmission Pipelines and Land Use: A Risk-Informed Approach" (Special Report 281, Washington, DC, 2004), viii, http://onlinepubs.trb.org/onlinepubs/sr/sr281.pdf.

16 Office of Pipeline Safety, "Building Safe Communities: Pipeline Risk and Its Application to Local Development Decisions" (October, 2010), http://pstrust.org/docs/PIPA-PipelineRiskReport-Final-20101021.pdf.

17 The Transportation Research Board, "Transmission Pipelines and Land Use: A Risk-Informed Approach" (Special Report 281, Washington, DC, 2004), http://onlinepubs.trb.org/onlinepubs/sr/sr281.pdf.

18 Pipelines and Informed Planning Alliance, "Partnering to Further Enhance Pipeline Safety in Communities through Risk-Informed Land-Plan Use: Final Report of Recommended Practices" (November 2010), http://www.ingaa.org/File.aspx?id=11683.

19 Municipal Research and Services Center, last updated November 3, 2014, http://www.mrsc.org/subjects/pubsafe/pipesafety.aspx.

more about the proposed pipeline. Residents and municipalities can inform themselves about their options during the permitting process, and landowners can learn about negotiating an easement with the company (see the resources section below).

When eminent domain does not apply to the proposed pipeline, as with **gathering lines** in many states, property owners can accept or deny easement rights, with a certain amount of leverage in negotiating terms. Given the concerns about state capacity to regulate most gathering lines, property owners should carefully attend to matters of construction, inspection, and safety.

What resources can provide further information?

SAFETY

- The Common Ground Alliance (http://www.commongroundalliance.com, accessed December 6, 2014) is a government/industry alliance charged with tracking damage to underground infrastructure and developing better prevention measures.
- Pipeline and Hazardous Material Safety Administration (PHMSA), "Guide for Communicating Emergency Response Information for Natural Gas and Hazardous Liquids Pipelines" (2014), http://phmsa.dot.gov/pv_obj_cache/pv_obj_id_37BB02E8C1E593B753D80B876658B908C55A5000/filename/hmcrp_rpt_014.pdf. This guide offers suggestions for pre-incident planning for communication between local emergency responders and pipeline operators.
- The Pipeline Safety Trust (http://pstrust.org,) is an education and advocacy group dedicated to pipeline safety.
- Pipelines and Informed Planning Alliance (PIPA), "Partnering to Further Enhance Pipeline Safety in Communities through Risk-Informed Land-Plan Use: Final Report of Recommended Practices" (November 2010), http://www.ingaa.org/File.aspx?id=11683. This final report of the PIPA recommended practices workshop contains recommendations to help improve the safety of communities in proximity to transmission pipelines. They are intended as guidance to local governments, property developers and owners, transmission pipeline operators, and real estate boards.

QUALITY OF LIFE

- Federal Energy Regulatory Commission, "An Interstate Natural Gas Pipeline on My Property? What Do I Need to Know?" updated August 2013, http://www.ferc.gov/for-citizens/citizen-guides/citz-guide-gas.pdf. The FERC oversees approval, permitting, and siting of interstate transmission lines. This brochure provides information for potentially affected property owners.
- Law Offices of Carolyn Elefant, "Knowing and Protecting Your Rights when an Interstate Gas Pipeline Comes to Your Community" (May 17, 2010), http://lawofficesofcarolynelefant.com/wp-content/uploads/2010/06/FINALTAGguide.pdf. A former FERC attorney's advice to municipalities and landowners on navigating FERC's pipeline certification process.

- Municipal Research and Services Center, a Seattle-based nonprofit dedicated to supporting effective local government, maintains web pages on pipeline safety, including safety regulations, model ordinances, and recommended practices for planning near pipelines: http://www.mrsc.org/subjects/pubsafe/pipesafety.aspx (updated May 2012).
- Pennsylvania State University Extension Agency, "Negotiating Pipeline Rights-of-Way in Pennsylvania," accessed December 6, 2014, http://extension.psu.edu/natural-resources/natural-gas/publications/negotiating-pipeline-rights-of-way-in-pennsylvania. A guide for landowners who are considering allowing a pipeline easement on their property.
- Pipeline Safety Trust, "Landowner's Guide to Pipelines," July 2014, http://pstrust.org/wp-content/uploads/2014/07/pst_LandOwnersGuide_2014_forweb.pdf.

Gathering pipeline construction, PA. Photo by Bob Donnan, 2014.


Construction of oilgas pipeline in ND.
Photo by the National Parks Conservation Association, 2014.

COMMUNITY HEALTH AND SHALE DEVELOPMENT GUIDEBOOK
Version 1.0—November 2015

RESOLVE
1255 23rd Street, NW, Suite 275
Washington, DC 20037, USA
202.944.2300 / 202.338.1264 Fax

CONTACT
Dana Goodson—Project Director
(+1) 202.965.6209
communityhealthguide@resolv.org

WEB VERSION
http://www.solutions-network.org/site-communityhealthguidebook