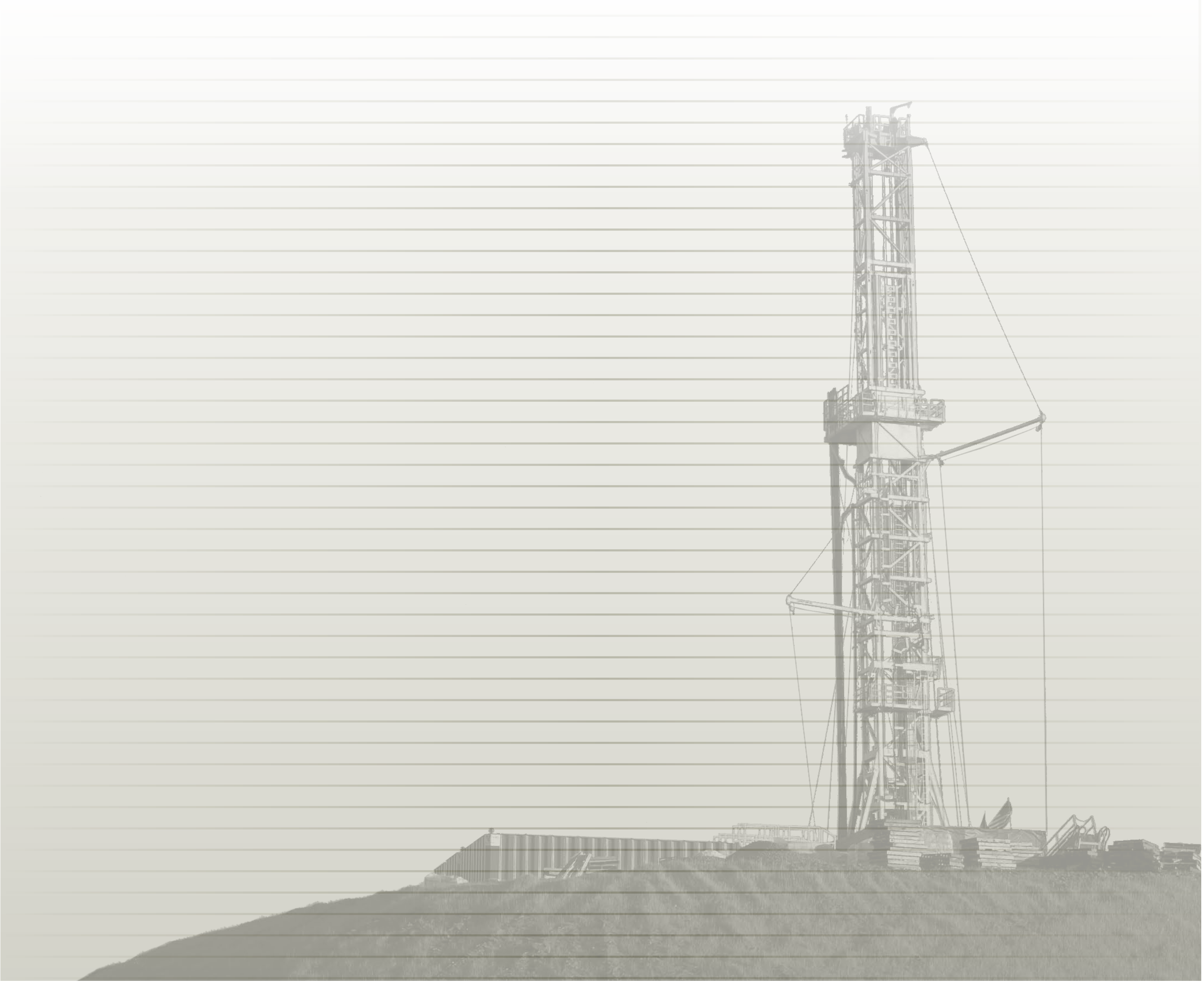
FEBRUARY 2012

Fact-Based Regulation for Environmental Protection in Shale Gas Development



A REPORT BY

energy institute

THE UNIVERSITY OF TEXAS AT AUSTIN

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Fact-Based Regulation for Environmental Protection in Shale Gas Development

Summary of Findings

Charles G. Groat, Ph.D.
Principal Investigator

Thomas W. Grimshaw, Ph.D.
Co-Principal Investigator

The Energy Institute
Flawn Academic Center, FAC 428
2 West Mall, C2400
The University of Texas at Austin
Austin, TX 78712

http://energy.utexas.edu/

512.475.8822

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Preface

The discovery of large reserves of natural gas in shale formations – shale gas – has been a major positive development for the energy picture of the US and the world. Yet a number of controversies over shale gas development have emerged that must be resolved in order for the full potential of this valuable resource to be realized. The Energy Institute has launched a series of initiatives to help deal with these issues and ensure responsible development of shale gas.

This Summary of Findings is from one of these initiatives that seek to help policymakers and regulators deal with shale gas issues in a rational manner based on factual information. The full report may be found on the Energy Institute website at:

http://energy.utexas.edu/

The Senior Contributors to the report are shown below with their respective areas of contribution:

Matt Eastin	News Coverage and Public Perceptions of Hydraulic Fracturing
Ian Duncan	Environmental Impacts of Shale Gas Development
Hannah Wiseman	Regulation of Shale Gas Development
Hannah Wiseman	State Enforcement of Shale Gas Development Regulation

The investigations continue, and findings will be updated and supplemented as progress is made. Future initiatives are planned to gather more field and laboratory information to improve the scientific basis for development of shale gas resources with adequate control and regulation.

1 Introduction

Natural gas produced from shale formations, commonly referred to as "shale gas", has become increasingly important in the energy supply picture for US and worldwide. Obtaining natural gas from shale units was until recently not considered economically feasible because of low permeability of shales. Economic utilization has been made possible by application and refinement of two previously-developed methods in the oil and gas industry – horizontal drilling and hydraulic fracturing.

The current estimate of the shale gas resource for the continental US is about 862 trillion cubic feet (TCF). This estimate doubled from 2010 to 2011 and is expected to continue to grow with additional resource information. Annual shale gas production in the US increased almost five-fold, from 1.0 to 4.8 trillion cubic feet between 2006 and 2010. The percentage of contribution to the total natural gas supply grew to 23% in 2010; it is expected to increase to 46% by 2035. With these dramatic increases in resource estimates and production rates, shale gas is widely considered a "game changer" in the energy picture for US.

Most would consider this greatly increased availability of natural gas as a highly favorable development for the public interest. Yet a number of controversies have emerged that must be resolved in order for the full benefit of shale gas to be fully realized. The US and the world are in great need of the energy from shale gas resources. In particular, the energy security of the US is greatly enhanced by the full availability of shale gas. At the same time, the resource must be developed with due care for human health and the environment. Meeting these requirements – and addressing controversies – requires carefully-crafted policies and regulations to enhance the public interest in shale gas development.

The Energy Institute at The University of Texas at Austin has funded the initiative leading to this report to promote shale gas policies and regulations that are based on facts – that are well grounded in scientific understanding – rather than claims or perceptions. The initiative is focused on three of the principal shale gas areas of the US – the Barnett shale in Texas, the Haynesville shale in East Texas and Louisiana, and the Marcellus shale in several states in the eastern US.

The overall approach of the initiative was to develop a solid foundation for fact-based regulation by assessing media coverage and public attitudes, reviewing scientific investigations of environmental impacts, and summarizing applicable state regulations and regulatory enforcement. The results are oriented toward energy policy makers in both the public and private sectors – legislators and their staff, state and federal regulators, energy company executives, and non-governmental organizations.

The findings of this initiative have been developed from the professional opinions of a team of energy experts primarily from The University of Texas at Austin. The team was established to incorporate different perspectives and includes representatives from:

- UT Jackson School of Geosciences
- UT Bureau of Economic Geology
- University of Tulsa College of Law (Team member now at Florida State University)
- UT School of Communications
- UT Energy Institute

The team consists of Senior Participants who are faculty members or research scientists conducting state-of-the-art energy research in their respective fields. Staff of the Environmental Defense Fund (EDF) have participated as full members of the project team by assisting with planning the project and providing expert review of the White Papers and project report.

To accomplish the objectives of this initiative, the Senior Participants prepared a set of White Papers covering the major topics relevant to fact-based shale gas regulation:

- News Coverage and Public Perceptions of Hydraulic Fracturing
- Environmental Impacts of Shale Gas Development
- Regulation of Shale Gas Development
- State Enforcement of Shale Gas Development Regulations

The White Papers have been consolidated into the project report. This Summary of Findings provides the highlights of the report for ease of reference by policymakers. The findings are presented for each of the four topical areas and are derived almost entirely from the respective sections. In many cases, almost the exact wording, as well as references to sources, are utilized directly without attribution.

Natural gas resources – and shale gas specifically – are essential to the energy security of the US and the world. Realization of the full benefit of this tremendous energy asset can only come about through resolution of controversies through effective policies and regulations. Fact-based regulation and policies based on sound science are essential for achieving the twin objectives of shale gas resource availability and protection of human health and the environment.

2 Overview of Shale Gas – and Its Controversies

Shale gas is considered an unconventional gas resource because in conventional exploration and development it is understood that natural gas originates in shale as a "source rock" but that it must migrate into porous and permeable formations (termed "reservoirs"), such as sandstones, in order to be produced economically. Shale gas production involves going directly to the source rock to access the resource. Such production from shale units was not considered economically feasible before application and refinement of horizontal drilling and hydraulic fracturing.

Shale units capable of producing natural gas in large quantities are found in five regions of the continental US. They are shown below with the shale plays and percent of US resources:

- Northeast: primarily the Marcellus (63%)
- Gulf Coast: Haynesville, Eagle Ford (13%)
- Southwest: Barnett and Barnett-Woodford (10%)
- Mid-Continent: Fayetteville, Woodford (8%)
- Rocky Mountain: primarily Mancos and Lewis (6%)

The use of hydraulic fracturing to increase production from conventional oil and gas wells grew rapidly starting in the late 1940s and continues to be used routinely for reservoir stimulation. Since its initiation, hydraulic fracturing has been used to stimulate approximately a million oil and gas wells. Improvements in horizontal drilling technologies, such as downhole drilling motors and telemetry equipment, led to its increased application in conventional drilling starting in the early 1980s. A partnership between agencies of the US government, a gas industry consortium, and private operators beginning in the 1970s led to the development of horizontal drilling and multi-stage hydraulic fracturing, which were critical to economic production of shale gas. The development efforts of Mitchell Energy Corporation in the Barnett shale in Texas during the 1980s and 1990s were critical in the commercial success of shale gas production.

Shale gas has become embroiled in controversy over alleged impacts on public health and the environment. Some segments of the public have become deeply suspicious of the veracity and motives of gas companies. These suspicions were intensified by the natural gas producers and gas field service companies initially refusing to disclose the chemical makeup of fluids used to enhance hydraulic fracturing. Many outside observers have concluded that it is “likely”, “highly likely” or “definitively proven” that shale gas extraction is resulting in widespread contamination of groundwater in the US. For example[1], one study of the impacts of shale gas exploitation in the US asserted that “there is considerable anecdotal evidence from the US that contamination of both ground and surface water has occurred in a range of cases”. In another example, a university professor stated in a written submission to the EPA that “Shale gas development clearly has the potential to contaminate surficial groundwater with methane, as shown by the large number of incidences of explosions and contaminated wells in Pennsylvania, Wyoming, and Ohio in recent years.” and that “… shale gas development has clearly contaminated groundwater and drinking water wells with methane…”.

The response from the gas industry and its supporters has generally been denial – not only that any such problems exist but also that if they did exist they are not real risks. For example[2], one industry website denied that the migration of fracturing fluid underground is among the “environmental and public health risks” of hydraulic fracturing and shale development. In another example, a university professor who is a shale gas proponent told a Congressional Committee that “the hydraulic fracturing process is safe, already well regulated by the various States” and that “the hysterical outcry over this process is completely unjustified”.

The debate between protagonists and antagonists of shale gas development has in some cases become strident and acrimonious. Negative perceptions and political consequences have led to the prohibition of shale gas development in a number of instances, at least temporarily. Realization on the part of all stakeholders of the large national energy security and other benefits of shale gas resource – when developed with adequate protection of public health and the environment – may provide "common cause" for seeking solutions.

[1] The examples cited are from the report section on Environmental Impacts of Shale Gas Development.

[2] The examples cited are from the report section on Environmental Impacts of Shale Gas Development.

The most rational path forward is to develop fact-based regulations of shale gas development based on what is currently known about the issues and, at the same time, continue research where needed for information to support controls in the future. Additional or improved controls must not only respond to the issues of controversy, but also address the full scope of shale gas development. Priorities must be set on the most important issues as well as on public perceptions. The path ahead must take advantage of the substantial body of policies and regulations already in place for conventional oil and gas operations. Enforcement of current and future regulations must also be ensured to meet the twin objectives of protection of environment and other resources and gaining public acceptance and support.

3 Media Coverage and Public Perception

The controversies surrounding shale gas development have received considerable media coverage. Public perceptions have been influenced by the controversies and media coverage. For these reasons, both media coverage and public perception of shale gas development have been investigated. All three shale gas areas were assessed for media coverage. Public perception was determined for the Barnett Shale area.

3.1 Media Coverage

Media coverage of hydraulic fracturing, a critical and distinctive component of shale gas development, was assessed for tonality (negative or positive) and reference to scientific research. The assessment covered the period from June 2010 to June 2011 and included three areas:

- Barnett shale area (Dallas, Tarrant, and Denton counties, Texas)
- Haynesville shale area (Shreveport, Louisiana)
- Marcellus shale area (six states)

The six Marcellus locations were Pennsylvania (Pittsburgh), New York (Buffalo), West Virginia (Charleston), Maryland (Hagerstown), Ohio (Cleveland), and Virginia (Roanoke). Four types of media – newspapers (national and metropolitan), television (national and local), radio (national and local), and online (Google News) – were included using searches for keywords for hydraulic fracturing in 14 groups as follows:

Well Blowout	Pipeline Leaks
Water Well Contamination	Regulatory Enforcement
Frac Fluid (and Frack Fluid)	Local Government Response
Surface Spills or Accidental Release	Public Interest and Protest Groups
Flow-Back Water	Barnett Shale Groups
Water Disposal Wells	Wyoming Groups
Atmospheric Emissions and Air Quality	Marcellus Group

Media coverage of shale gas development was assessed in the Marcellus, Haynesville, and Barnett shale areas. The analysis of the tonality of articles and broadcasts included 13 newspapers (three national and 10 metropolitan), 26 broadcast media (seven national and 18 metropolitan television stations and one national radio station), and one online news source.

For the nation as a whole, the attitudes were found to be uniformly about two-thirds negative.

	Negative	Neutral	Positive
National Newspapers (3)	64%	25%	12%
Metropolitan Newspapers (10)	65%	23%	12%
National Television & Radio (7)	64%	19%	18%
Metropolitan Television (18)	70%	27%	3%
Online News (1)	63%	30%	7%

The local media coverage for each of the shale areas shows similarity to the national results for the Barnett and Marcellus shale areas; the Haynesville area may be anomalous because only one newspaper and one television source were available.

		Barnett Shale Area	
	Negative	Neutral	Positive
Newspapers (3)	79%	6%	16%
Television (6)	70%	30%	0%
		Marcellus Shale Area	
Newspapers (6)	67%	25%	8%
Television (11)	74%	20%	6%
		Haynesville Shale Area	
Newspapers (1)	8%	46%	46%
Television (1)	0%	100%	0%

With respect to reference to scientific research, the search found that few articles referenced research on the topic of hydraulic fracturing:

	Percent Referencing Scientific Research
Newspaper Articles	18%
Television Reports	25%
Radio Coverage	15%
Online Coverage	33%

3.2 Public Perception and Knowledge

Public perception of hydraulic fracturing was assessed specifically in the Barnett shale area utilizing an online survey method that included 75 questions in six categories:

Thoughts about hydraulic fracturing	Perceptions about hydraulic fracturing
Knowledge of hydraulic fracturing	Behaviors
Media use	Demographics

The area included was expanded to 26 counties in Texas, and the survey included almost 1500 respondents. The results of the survey indicate a generally positive attitude toward hydraulic fracturing, with more favorable responses for the following descriptors: good for the economy, important for US energy security useful, important, effective, valuable, and productive. Attitudes were neutral to slightly positive as indicated by response to several descriptors for hydraulic fracturing: importance for US energy security, safety, beneficial or good, wise, and helpful. There was a more negative attitude, however, about environmental concerns. Hydraulic fracturing was felt to be bad for the environment by about 40% of the respondents. Another 44% were neutral and only 16% were positive.

With respect to knowledge of hydraulic fracturing, many respondents were found to have some general knowledge about the process of hydraulic fracturing, but they tend to lack an understanding of regulation and the cost-benefit relationship of production:

- Most respondents overestimate the level of hydraulic fracturing regulation; for example, 71% were not aware that the Railroad Commission does not regulate how close a gas well can be drilled to a residential property.
- Many respondents (76%) overestimate annual water consumption for shale gas usage and underestimate (75%) the amount of electricity generated from natural gas.
- Most generally understand the process of fracturing and gas development surrounding the fracturing of wells, but the scope and technical aspects of fracturing are less well understood. For example, 49% were unaware of proppants, and 42% overestimated scientific evidence surrounding the issue of hydraulic fracturing and water contamination.

- Knowledge of policy issues related to groundwater contamination, such as the disclosure of chemicals used in fracturing and active groups affiliated with groundwater issues, was high.
- Knowledge of the occurrence of well blowouts in hydraulic fracturing was high (73%), as well as the impact of blowouts comparison to surface spills (72%). And 54% understand the frequency that blowouts have occurred in the Barnett shale.

Hydraulic fracturing knowledge was also assessed for the following five areas:

- Awareness of Hydraulic Fracturing. 50% of the respondents consider themselves to be somewhat aware or very aware hydraulic fracturing. The other 50% were not very aware or were not aware at all.
- Concern about Water Quality. 35% indicated they were very concerned, and 40% were somewhat concerned. 24% were not very concerned or not at all concerned.
- Disclosure of Chemicals Used in Hydraulic Fracturing. Regarding whether state and national officials are doing enough to require disclosure, 12% thought that the officials are doing everything they should, and 32% indicated that officials were doing some of what they should. 47% indicated not as much as should be done was being done. 9% thought that nothing at all was being done.
- Message to Politicians. When asked about relative priorities of energy production on the one hand and public health and the environment on the other, 67% indicated higher priority on public health and the environment.
- America's Future Energy Production. When asked to prioritize between meeting energy needs (and override concerns about water shortages and pollution) on the one hand and focusing on energy sources that require the least water and minimal water pollution impacts on the other hand, 86% placed higher priority on the second option.

The survey also included an assessment of the degree of willingness to get involved in community efforts, such as organizing, protesting, calling legislators, and petitioning. The results indicate that people are either undecided or ambivalent, or they sense two equal points of view and aren’t sure which one to accept. It also appears that respondents sense that it is not desirable to get involved – they are mostly unwilling to participate in any events in support of or against hydraulic fracturing. This could be related to their ambiguous attitudes.

3.3 Regulation or Policy Topics: Media Coverage and Public Perception

- Media coverage in the Barnett, Haynesville, and Marcellus shale areas is overwhelmingly negative, with about two-thirds of coverage – including all media and all shale areas – on the negative side
- Much of the coverage has focused on environmental issues such as groundwater contamination.
- Most residents understand the general process of hydraulic fracturing but lack a strong comprehension of its cope and technical aspects, such as the depth of wells and the role of proppants.
- Reference to shale gas research is understated in the media, with only 15 to 30% of articles and reports containing such references.
- Public perception in the Barnett shale area is somewhat more balanced on the positive and negative side, but a view is held by many (40%) that hydraulic fracturing is bad for the environment. Only 16% have a favorable view.
- Residents in the Barnett shale area are generally informed about hydraulic fracturing, but they tend to overestimate existing regulations and the amount of water used and under estimate the importance of natural gas in electric power production.
- Negative media reporting and public perceptions must be addressed by both regulators and the shale gas industry as regulations are developed or added.
- Comparison of the assessment of public knowledge of hydraulic fracturing in the Barnett shale area with a national survey found that more residents perceived themselves to be more aware of hydraulic fracturing than is the case nationally. But the Barnett area residents and national survey populations are similar in their concerns about water quality and what politicians are doing about the issue.

4 Environmental Impacts of Shale Gas Development

Shale gas development, as with all types of resource utilization, should take place with adequate protective measures for human health and the environment. Although many of the shale gas controversies have arisen over concerns about adverse impacts of hydraulic fracturing, all phases of shale gas operations and their potential impact should be addressed. The various phases of the shale gas development life cycle and their associated issues have been organized for the assessment as follows:

- Drill Pad Construction and Operation
- Hydraulic Fracturing and Flowback Water Management
- Groundwater Contamination
- Blowouts and House Explosions
- Water Consumption and Supply
- Spill Management and Surface Water Protection
- Atmospheric Emissions
- Health Effects

These shale gas phases and their impacts have been assessed based on a review of scientific and other literature on shale gas development.

4.1 Drill Pad Construction and Operation

During the construction phase for a well pad and associated infrastructure such as unimproved or gravel roads, the quality of surface water resources may be impacted by runoff, particularly during storm events. Soil erosion and transport of sediment into streams and other water bodies must be managed not only to protect water quality but also to prevent damage to ecological habitats. During both construction and operation, protection must also be provided against leaks and spills of oil and grease, VOCs, and other contaminants.

Regulations under the Clean Water Act require Storm Water Management Plan (SWMPs) to protect water quality during high precipitation events. The requirements of an SWMP may not highly specific but instead call for Best Management Practices (BMPs), which include erosion and sediment control measures such as seeding, filter fences, terraces, check dams, and straw bales. Studies of sediment yields from well pad sites during storm events indicate a comparable yield to typical construction sites – from 15 to 40 tons per hectare per year. The US DOE National Energy Technology Laboratory (NETL) sponsors a wide range of research into water quality and ecological impacts and mitigative measures for drill pads and access roads, including improved road designs, impacts on sensitive birds, and impacts on wildlife in streams (particularly large invertebrates).

Shale gas development will affect forests and ecological habitat at a large scale as well. Studies of development in the Marcellus shale area indicate that two thirds of well pads will be constructed in forest clearings, resulting in the clearing of 34,000 to 83,000 acres for pads and an additional 80,000 to 200,000 acres of habitat impacts from pads and associated road infrastructure.

4.2 Hydraulic Fracturing and Groundwater Contamination

Of all the issues that have arisen over shale gas development, hydraulic fracturing and its claimed effects on groundwater are without doubt the most contentious. The term has become such a lightning rod that it is equated in the eyes of many with the entire cycle of shale gas operations – from drilling to fracturing, completion, and production. Many allegations have been made about contamination of groundwater caused by hydraulic fracturing, with particular emphasis on impacts on water wells. A contributing factor to the level of controversy may well be the location of portions of shale gas plays in proximity to urban centers and other highly densely populated areas, resulting in closer contact with the general public than in previous in oil and gas operations.

The concerns over hydraulic fracturing and related activities have a number of dimensions, but they can be summed up with a few relevant questions:

1. Does the composition of additives to the fracturing fluid pose extraordinary risk drinking water?
2. Does fracturing fluid escape from the shale formation being treated and migrate to aquifers?
3. Are claims of hydraulic fracturing impacts on water wells valid?

4. Does the flowback and produced water after fracturing have a negative impact?
5. Does hydraulic fracturing lead to well blowouts and house explosions?

The last two questions are addressed in subsequent sections of this Summary of Findings.

Fracturing Fluid Additives

The overall composition of the fluid used for hydraulic fracturing varies among companies and the properties of the shale being treated. In general the fluid is about 90% water, 9.5% proppant particles, and 0.5% chemical entities (the latter percentage is variable but is less than 1%). The additives have a number of purposes, including reducing friction (as the fluid is injected), biocide (to prevent bacterial growth), scale inhibition (to prevent mineral precipitation), corrosion inhibition, clay stabilization (to prevent swelling of expandable clay minerals), gelling agent (to support proppants), surfactant (to promote fracturing), and cleaners. Estimates of the actual chemicals utilized range as high as 2500 service company products containing 750 chemical compounds.

The detailed composition of the additives has been controversial because until recently the companies that manufacture fracturing fluid components have insisted that the exact composition was proprietary. But over the last two years, voluntary disclosures and state-based disclosure laws (e.g., Texas) have resulted in increased openness on the details of the composition of the chemical components of fracturing fluids. In spite of the much broader disclosure of the ingredients of the additives, there is not yet a clear understanding of what are the key chemicals of concern for environmental toxicity or their chemical concentration in the injected fluid.

The Waxman Committee Report[3] is the most comprehensive publicly available study of the chemical makeup of additives used in hydraulic fracturing fluids. Many of the chemicals listed are no longer in use. The report indicates that from 2005 to 2009, some 95 products containing 13 different carcinogens were utilized in hydraulic fracturing. Four compounds – 2-BE (a surfactant), naphthalene, benzene, and acrylamide (or polyacrylamide) – were singled out in this report for special emphasis. As context for the analysis of the impact of these compounds, it

[3] See Section 2 of the full report for the Waxman Report reference.

should be noted that all four are widely used in the manufacture and use of many commercial products and other applications.

2-BE (noted in the report for destruction of red blood cells and dangerous to the spleen, liver, and bone marrow) is widely used in many commercial products, such as solvents, paints, polishes, pesticides, household cleaners, and brake fluids. As a result of the production and use of 2-BE, it is now widely dispersed in a natural environment. In Canada alone, for example, 6100 tonnes of 2-BE were sold in 1996 as part of consumer products or for commercial uses. 2-BE is highly biodegradable, and in any case it is being replaced in hydraulic fracturing with a new product having low toxicity and with properties requiring use of a much lower volume of product.

Benzene (a known human carcinogen) and naphthalene (a probable human carcinogen) are also widely distributed in modern society. Naphthalene, for example, is a major component of mothballs and toilet bowl deodorizers. It is relatively biodegradable (half-life of a few weeks in sediment). Exposures to benzene take place through use of consumer products and in a number of workplace environments, as well as from fumes from gasoline, glues, solvents, and some paints. Cigarette smoking and secondhand smoke are significant sources of benzene exposure, accounting for about 50% of benzene exposure in the general population of the US.

PAM (polyacrylamide, which is confused with acrylamide in the Waxman report) is widely used as a consumer product – such as non-stick spray or frying pans, biomedical applications, cosmetics, and textiles – as well as other applications such as flocculants, thickening agents, and soil conditioners. Although some risk assessment research has been done for several environmental applications of PAM, it has generally been assumed that PAM is safe.

Although the release of more of these chemicals, which are used for many applications, into the environment by hydraulic fracturing is not necessarily totally acceptable, their use should be evaluated in the framework of other broad uses and environmental releases as well as the depth of release, which is typically several thousand feet below the surface.

Migration of Fracture Fluids to Aquifers

Closely related to the concerns about the chemicals in hydraulic fracturing fluid additives are allegations that the fluids are not contained in the shale being fractured but instead escape and cause groundwater contamination. The route of escape may be through propagation of induced fractures out of the target zone and into aquifers, intersection of induced fractures with natural fracture zones that lead to aquifers, through abandoned and improperly plugged oil and gas wells, or upward in the well bore through the annulus between the borehole and the casing.

However, there is at present little or no evidence of groundwater contamination from hydraulic fracturing of shales at normal depths[4]. No evidence of chemicals from hydraulic fracturing fluid has been found in aquifers as a result of fracturing operations. As noted in a subsequent section, it appears that the risk of such chemical additives is greater from surface spills of undiluted chemicals than from actual fracturing activities.

Although claims have been made that "out-of-zone" fracture propagation or intersection with natural fractures, could occur, this study found no instances where either of these has actually taken place. In the long term after fracturing is completed, the fluid flow is toward (not away from) the well as gas enters the well bore during production. Some allegations indicate a relatively small risk to water supplies from individual well fracturing operations, but that a large number of wells (in the Marcellus shale) has a higher likelihood of negative impacts. However, the evidence for this risk is not clearly defined.

Much of the concern is for migration of natural gas through unplugged abandoned oil and gas wells is for natural gas and the risk of house explosions and methane contamination of water wells, which are addressed in subsequent sections. The issue of well integrity and potential leakage upward around the well casing is connected to well blowouts and water well impacts by natural gas, which are also addressed below.

[4] Apparently in some cases, such as the Pavilion area, Wyoming, fracturing has been performed at depths shallower than normal for shale gas wells, which are typically more than 2,000 or 3,000 feet deep.

Impacts of Hydraulic Fracturing on Water Wells

Many allegations have been made by residents in shale gas areas of impacts on water wells by shale gas development activities. Claims of water well impacts have been among the most prominent of the shale controversies. The majority of the claims involve methane, chemical constituents (iron, manganese, etc.) and physical properties such as color, turbidity, and odor. These properties and constituents in many cases were present in water wells before shale gas development began, but often there is insufficient baseline (pre-drilling) sampling or monitoring to establish the impacts of drilling, fracturing, and other operations.

Iron and manganese are common naturally-occurring constituents in groundwater that are higher in concentration in some aquifers than others. Particularly in areas underlain by gas-producing shales, methane migrates out of the shales under natural conditions and moves upward through overlying formations, including water-bearing strata (aquifers). Such naturally-occurring methane in water wells has been a problem in shale gas areas for many years or decades before shale gas drilling began.

It appears that many of the water quality changes observed in water wells in a similar time frame as shale gas operations may be due to mobilization of constituents that were already present in the wells by energy (vibrations and pressure pulses) put into the ground during drilling and other operations rather than by hydraulic fracturing fluids or leakage from the well casing. As the vibrations and pressure changes disturb the wells, accumulated particles of iron and manganese oxides, as well as other materials on the casing wall and well bottom, may become agitated into suspension causing changes in color (red, orange or gold), increasing turbidity, and release of odors.

None of the water well claims involve hydraulic fracturing fluid additives, and none of these constituents has been found by chemical testing of water wells. The finding of acrylonitrile in a water well in West Virginia resulted in major concerns about its potential source in hydraulic fracturing fluid. However, no evidence has been found that this compound has ever been used in fracturing fluid additives.

The greatest potential for impacts from a shale gas well appears to be from failure of the well integrity, with leakage into an aquifer of fluids that flow upward in the annulus between the casing and the borehole. Well integrity issues resulting in leakage can be divided into two categories. In annular flow, fluids move up the well bore, traveling up the interface between the rock formation and cement or between the cement and the casing. Leak flow is flow in a radial direction out of the well and into the formation. In general, a loss of well integrity and associated leakage has been the greatest concern for natural gas – leading to home explosions as described in a subsequent section.

4.3 Flowback and Produced Water Management

After hydraulic fracturing has been accomplished in a shale gas well, the fluid pressure is relieved and a portion of the injected fluid returns to the well bore as "flowback" water, which is brought to the surface for treatment, recycling, and/or disposal. The fluid withdrawn from the well actually consists of a mixture of the flowback water and saline water from the shale formation, which is referred to as" produced" water. As withdrawal proceeds, the fluid becomes more saline as the relative contribution of produced water to the flow increases. The point in time when produced water dominates the flow has been a subject of controversy.

The amount of injected fluid returned as flowback ranges widely – from 20% to 80% – due to factors that are not well understood. The ratio of ultimate water production after fracturing to the volume of fracturing fluid injected varies widely in the different shale areas – Barnett (3.1), Haynesville (0.9), Fayetteville (0.25), and Marcellus (0.15). The return of hydraulic fracturing fluid is important because as recycling increases in the industry a higher rate of return reduces the water requirements of shale gas production. Greater emphasis is being placed on recycling and reuse not only to reduce water requirements but also to reduce the volume of flowback wastewater that must be managed.

Management of the combined flowback and produced water streams has become a major part of the shale gas controversy, both from the standpoint of uncontrolled releases and the treatment, recycling, and discharge of the fluid as a wastewater stream. Disposal of the flowback water has historically been primarily by permitted injection wells in the Barnett and Haynesville shale areas and by discharge to publicly-owned treatment works in the Marcellus shale area.

Flowback water contains some or all of the following: sand and silt particles (from the shale or returned proppants), clay particles that remain in suspension, oil and grease from drilling operations, organic compounds from the hydraulic fracturing fluids and the producing shale, and total dissolved solids (TDS) from the shale. This composition reflects the mixed origin of the fluids from hydraulic fracturing and produced shale water. The average TDS of flowback water has a considerable range for the different shale plays – 13,000 ppm for the Fayetteville, 80,000 ppm for the Barnett, and 120,000 ppm for the Marcellus. But there is also considerable variation in the TDS content in wells within each shale area. For example, one study of the Marcellus shale found a range of 1850 to 345,000 and mg/L.

Of the chemicals found in fluids related to shale gas development, the one that appears to be of greatest concern is arsenic. Although arsenic is not uncommon in domestic water wells where no hydraulic fracturing has taken place, it has become a source of strong allegations in Texas and Pennsylvania. Concerns over arsenic and other contaminants and flowback water have resulted in demands for increased regulation.

Although there has been considerable controversy over hydraulic fracturing fluid additives and their potential impact on water supplies, the potential risk of naturally-occurring contaminants like arsenic in flowback and produced water is also a major concern. Similar concern about risk may be associated with organic chemicals in flowback and produced water that may be present in injected hydraulic fracturing fluids or in the formation water of the shale.

4.4 Blowouts and House Explosions

Unplanned releases of natural gas in the subsurface during drilling may result in a blowout of the well or migration of gas below the surface to nearby houses, where the gas may accumulate in concentrations high enough to cause an explosion.

<u>Blowouts</u>

Blowouts are uncontrolled fluid releases that occur rarely during the drilling, completion, or production of oil and gas wells. They typically happen when unexpectedly high pressures are encountered in the subsurface or because of failure of valves or other mechanical devices. Blowouts may take place at the wellhead or elsewhere at the surface, or they may involve movement away from the well in the subsurface. High pressures may be encountered in natural gas in the subsurface or may be artificially induced in the well bore during hydraulic fracturing.

Many blowouts happen as a result of the failure of the integrity of the casing or the cementing of the casing such that high-pressure fluids escape up well bore and flow into subsurface formations. Blowout preventers (BOPs) are used to automatically shut down fluid flow in the well bores when high pressures ("kicks") are encountered, but like other mechanical devices, they been known to fail, although infrequently.

Blowouts are apparently the most common of all well control problems, and they appear to be under-reported. Data are not available on the frequency of blowouts for onshore oil and gas wells, but data from offshore wells indicate that the frequency is between 1 and 10 per 10,000 wells drilled for wells that have not yet had a BOP installed. The frequency depends on whether the well is being drilled or completed and whether the blowout is at the surface or in the subsurface.

Surface blowouts at the wellhead are primarily a safety hazard to workers and may also result in escape of drilling fluid or formation water to nearby surface water sources. Subsurface blowouts may pose both safety hazards and environmental risks. The potential environmental consequences of a blowout depend mostly on three factors: 1) the timing of the blowout relative to well activities (which determines the nature of the released fluid such as natural gas or pressurized fracturing fluid); 2) occurrence of the escape of containments through the surface casing or deep in a well; and 3) the risk receptors, such as freshwater aquifers or water wells, that are impacted. A major problem in these events is the limited ability to discern what is happening in the subsurface. For example, when a pressure kick causes a BOP to prevent flow from reaching the surface, the fluid may exploit weaknesses in the casing and cement below the BOP and escape into the surrounding formations (or aquifers).

Blowouts due to high gas pressure or mechanical failures happen in both conventional and shale gas development. Shale gas wells have the incremental risk of potential failures caused by the high pressures of fracturing fluid during hydraulic fracturing operations. Underground blowouts occur in both wells that had been or about to be hydraulically fractured. For example, in the Barnett shale, the Railroad Commission of Texas determined that two of 12 blowouts were underground, but publicly available information is insufficient to evaluate the causes or consequences of the blowouts.

An example of the environmental consequences of an underground blowout (related to conventional rather than shale gas drilling) has been reported in Louisiana, in which pressure changes in the Wilcox aquifer caused a number of water wells around the blowout will to start spouting water. And two craters also formed around two abandoned wells near the drill site.

In another incident in Ohio, again not involving shale gas drilling, high-pressure natural gas was encountered and moved up the well bore and invaded shallow rock formations. Within a few days gas bubbling was observed in water wells and surface water, and the floor of a basement in a house was uplifted several inches. Over 50 families were evacuated from the area. The well was brought under control and capped a week later.

Although the Louisiana and Ohio examples did not involve shale gas operations, they are illustrative of the types of blowout impacts that can occur when high pressure natural gas is encountered. In general, issues of blowouts – whether from high pressure natural gas or from high pressure hydraulic fracturing – may be addressed most effectively through proper well construction and ensuring well integrity.

House Explosions

Claims of impacts on water wells as a result of shale gas drilling have included methane as well as chemical contaminants as described in Section 4.2. Such observations are in most cases the result of naturally-occurring methane migration into aquifers and wells before shale gas development began. In addition to impacts on water quality in wells, claims have also been made of home and wellhouse explosions caused by migration of natural gas from shale gas wells. In one well-known case in Ohio, a house exploded soon after a nearby hydraulically fractured well was drilled. After much investigation by the regulatory agency and a private geological engineering consulting firm, followed by study of the case by a distinguished review committee, it was concluded that methane may have migrated to the house along shallow horizontal fractures or bedding planes. On the other hand, it was observed that the groundwater have very low levels of dissolved methane.

Other cases of methane explosions in homes and wellhouses have been investigated in Colorado, Pennsylvania, and Texas. In some of these cases, the explosions were found caused by gas migration from hydraulically fractured wells. In general, if natural gas migrates away from a shale gas or conventional gas well, it is because well integrity has been compromised such as through failure of the surface casing or cement job.

4.5 Water Requirements and Supply

Water consumption, particularly for hydraulic fracturing, is one of the most contentious issues for shale gas development. The drilling and fracturing of shale gas wells requires significant quantities of water for drilling mud, extraction and processing of proppant sands, testing natural gas transportation pipelines, gas processing plants, and other uses.

Although many of these requirements apply to conventional natural gas production as well as shale gas specifically, consumption is greater for hydraulic fracturing than for other uses. The water required to hydraulically fracture a single well has varied considerably as hydraulic fracturing of shale gas has become dominated by more complex, multi-staged horizontal wells. The average quantity of water used for a shale gas well varies somewhat by the shale gas area: Barnett (4.0 million gallons), Fayetteville (4.9 MG), Marcellus and Haynesville (5.6 MG), and Eagle Ford (6.1 MG).

Several metrics have been used in an attempt to quantify the significance of water used in shale production, but the most popular has been the energy water intensity (volume of water used per unit of energy produced). There appears to be a consensus among shale gas researchers that the water intensity of shale gas is relatively small compared to other types of fuels. The energy water intensity for the Barnett, Marcellus, and Haynesville shale plays has been estimated at 1.32, 0.95, and 0.84 gallons per million BTU, respectively.

The US EPA has estimated that if 35,000 wells are hydraulically fractured annually in the US, the amount of water consumed would be equivalent to that used by 5 million people. Pennsylvania's annual total water consumption is approximately 3.6 trillion gallons, of which the shale gas industry withdraws about 0.19% for hydraulic fracturing.

Water for shale gas wells may be obtained from surface water (rivers, lakes, ponds), groundwater aquifers, municipal supplies, reused wastewater from industry or water treatment plants, and recycling water from earlier fracturing operations. The primary concerns – and sources of controversy – are that the withdrawals will result in reduced stream flow or will deplete groundwater aquifers. Water impacts vary considerably by locations of withdrawals, and the seasonal timing of the withdrawal can be a critical difference between high impact and no impact on other users. The most reasonable approach to assessing water usage is to evaluate the impact it has on the local community and the local environment both in the short- and long-term. An important distinction among water sources is whether the water usage is sustainable (renewable). For example, surface-water usage is likely to be more sustainable than groundwater usage.

The sources for water used for hydraulic fracturing are not well documented in most states because the patchwork of agencies responsible for various water sources do not closely monitor withdrawals or consumption. Water sources and withdrawals differ significantly for the Barnett, Haynesville, Marcellus, Fayetteville, and Eagle Ford shale areas.

4.6 Spill Management and Surface Water Protection

Leaks and spills associated with shale gas development may occur at the drill pad or during transport of chemicals and waste materials. Sources at the wellsite include the drill rig and other operating equipment, storage tanks, impoundments or pits, and leaks or blowouts at the wellhead. Leaks or spills may also occur during transportation (by truck or pipeline) of materials and wastes to and from the well pad. The primary risk of uncontrolled releases is generally to surface water and groundwater resources.

On-site and off-site releases may occur because of accidents, inadequate facilities management or staff training, or illicit dumping. Released materials include fuels, drilling mud and cuttings, and chemicals (particularly for hydraulic fracturing). Hydraulic fracturing chemicals in concentrated form (before mixing) at the surface present a more significant risk above ground than as a result of injection in the deep subsurface.

Wastewater from flowback and produced water is typically temporarily stored in on-site impoundments before removal by trucks or pipeline for reuse, treatment, or disposal. These impoundments may be another source of leaks or spills. Lining of pits for flowback water depends on company policies and regulatory requirements, which vary from state to state. Because liners may leak, releases to the subsurface may still occur, resulting in calls to discontinue the use of pits in favor of closed-loop steel tanks and piping systems.

Three characteristics of a spill generally determine the severity of its consequences – volume, degree of containment, and toxicity of the fluid. Depending on toxicity, smaller releases generally have lower impact than larger spills. Effective containment is key to minimizing the impacts on human health and the environment when a spill occurs. The more toxic the release is, the higher the risk if containment is not effective to prevent migration into exposure pathways that are linked through surface water or groundwater to humans, animals, or other receptors.

An important aspect of spill management is to provide secondary containment for areas of fuel and fracturing fluid chemicals storage, loading and unloading areas, and other key operational areas. Such containment prevents a spill from reaching surface water or groundwater through the use of liners or other barriers.

Little information is available on the short- or long-term consequences of surface spills. Regulatory reports on spill investigations do not necessarily include information that would allow evaluation of environmental damage or the effectiveness of remedial responses. Data are also not readily available from regulatory agencies on the frequency of spills and other releases. One experiment in West Virginia involved an intentional release of about 300,000 gallons of flowback water in a mixed hardwood forest followed by observation of the effects on trees and other vegetation. Ground vegetation was found to suffer extensive damage very quickly followed by premature leaf drop from trees in about 10 days. Over two years the mortality rate for the trees was high – greater than 50% of one species. Available data indicate that the high salinity of the flowback water was responsible for the underbrush and tree mortality.

Advance planning to be prepared to respond to a spill is essential to minimize impacts. The most effective way to reduce risk of spills is to avoid the use of toxic chemicals through substitution of non-toxic substances were possible or by arranging for just-in-time delivery to reduce risks of on-site storage. Many states require Spill Prevention Control and Contingency (SPCC) plans at well pad sites, which specifies the best practices to be used in the event of a release. Spill management and remediation should be accomplished based on contingency plans that are prepared in advance and are developed jointly with regulatory agencies and emergency responders. Rapid communication of that nature, volume, and toxicity of a spill is essential to effective emergency response.

4.7 Atmospheric Emissions

Air emissions from shale gas operations occur at the drill site during drilling and fracturing and at ancillary off-site facilities such as pipelines, natural gas compressors. The onsite emissions include dust, diesel fumes, fine particulate matter (PM 2.5), and methane. Air emissions have become a major component of the shale gas controversies.

A principal concern is for shale gas emissions is related to the volatile organic carbon (VOC) compounds. Depending on the composition of the gas produced from the shale, VOCs are typically rich in the BTEX (benzene, toluene, ethylene, xylene) compounds. However, the role of VOCs as smog precursors – they combine with NOx in the presence of sunlight to form smog – is the main source of concern with these compounds. Ozone, a primary constituent of smog, and NOx are two of the five “criteria pollutants” of the Clean Air Act (CAA). The Fort Worth area in the Barnett shale play has been designated “non-attainment” for ozone under the CAA, which means that the established standard is not met for ozone concentration in the atmosphere. The role of VOCs in forming smog and their contribution to the elevated levels of ozone is the reason for the focus on VOC emissions from shale gas activities.

However, the contribution of shale gas activities to ozone levels is highly controversial. For example, investigations in the Fort Worth area have found that most VOCs are not associated with natural gas production or transport. Allegations that VOC and NOx emissions from natural gas production from Barnett shale activities play a significant role in ozone formation have been strongly contested. Records of the Texas Commission on Environmental Quality (TCEQ) monitoring program since 2000 actually show overall decreases in the annual average concentration of benzene, one of the VOCs, during the period of early shale gas development in the Fort Worth area.

Public concern over air quality and the need for more precise information led to more focused emissions studies sponsored by local governments or private foundations. The first – and most controversial – of these studies was at DISH, Texas, where elevated levels of benzene, xylene, and naphthalene were found from a set of 24 samples and four residences. Another study in a very active area of shale gas production located about seven or eight miles from DISH found that shale gas was responsible for less than half of the VOCs (43%) in the atmosphere, with motor vehicle emissions contributing most of the rest (45%). Modeling studies indicate that 70 to 80% of benzene is from fugitive emissions of natural gas, but that other VOC constituents are from motor vehicle emissions.

In portions of Western states such as Wyoming, air emissions from oil and gas activities are the largest source of VOCs and related high ozone levels. In Sublette County, Wyoming, for example, ozone levels in the winter routinely exceed the EPA 8-hour standard, resulting in air quality that is sometimes worse than in Los Angeles.

Allegations that the emission of VOC constituents such as benzene in “widespread” or “prevalent” amounts in shale gas operations appear not to be supported when comparisons are made with air quality standards or when the relative amounts are compared to other sources such as vehicle exhausts. The relative contribution of shale gas activities in relation to conventional oil and gas development and other sources such as vehicle exhaust emissions must be taken into account in reports such as those from Wyoming and Fort Worth.

Emissions of methane have caused public concerns over global climate change since methane is a strong greenhouse gas. Venting or flaring of natural gas may take place during the fracturing and flowback phase of shale gas well development. However, many operators use "green completions" to capture and sell rather than vent or flare methane produced with flowback water. Onsite fugitive emissions of methane may take place from other sources as well, such as pressure relief valves of separators, condensate tanks, and produced water tanks. Although natural gas is confined in pipelines from production wells to the point of sale, methane emissions may also occur from offsite gas processing equipment and compressors notwithstanding the economic motive to minimize loss of natural gas. It is not known in the public realm the extent to which Best Management Practices (e.g. low-emissions completions, low-bleed valves) result in reduced methane and fugitive losses of methane.

4.8 Health Effects

Potential health effects have emerged as a primary area of controversy for shale gas operations. Several chemicals associated with shale gas wells and natural gas infrastructure have the potential for negative impact on human health. Chief among these are benzene and other VOC compounds as well as endocrine disruptors. The main sources are air emissions (described in Section 4.7 above) and surface and underground releases of fluids such as hydraulic fracturing fluids and flowback and produced water. Claims of shale gas effects include leukemia and other forms of cancer, headaches, diarrhea, nosebleeds, dizziness, blackouts, and muscle spasms.

In order for health effects to be determined for shale gas activities (as for other industrial operations), not only must the types and toxicity of releases be known, but also the chain of events from the point of release. The transport, possible attenuation, and exposure of toxic substances to receptors must be established in order for health risk to be evaluated. Many of the health effects allegations have focused on the potential toxicity of shale gas chemicals, such as VOCs and hydraulic fracturing fluids, but they provide little or no data on releases, migration, or actual exposure.

A large number of the reports are anecdotal rather than the results of scientific investigation. In many situations, separating the health impacts of shale gas from other potential sources such as smoking, living conditions, and travel on busy streets and highways is a complex task. Our society faces a problem in that benzene (and other VOCs), polynuclear aromatic hydrocarbons (PAHs), hazardous air pollutants (HAPs), and a variety of endocrine disruptors are widespread pollutants in our environment. For most of the population individual exposure to benzene and other VOs compounds is dominated by exposure to tobacco smoke, highway driving, time spent in gas stations, and time spent in urban environments.

Very few rigorous risk assessments of health effects of shale gas for other "upstream" oil and gas activities have apparently been conducted. In the absence of information specifically for shale gas, reference is made to other similar operations, including refineries and chemical plants. Both workers and nearby populations have been the subjects of these studies. Releases of VOCs (especially benzene) and endocrine disruptors have been investigated in several studies.

A short-term study of VOC levels in a sample of the population of DISH, Texas has been the only health-related study that is focused specifically on the possible impact of shale gas extraction. Although the response to this study from hydraulic fracturing antagonists was strong, some argue that the results were interpreted in a somewhat misleading manner or were not accurately communicated.

In general, none of the studies reviewed for this initiative showed a clear link between shale gas activities and documented adverse health effects, It may also be worth noting that the gas industry has been using hydraulic fracturing for over 50 years, but the studies examined in this review did not find any direct evidence for health impacts on workers in the industry or the public living near oil and gas industry activity.

4.9 Regulation or Policy Topics: Environmental Impacts

- Surface disturbances during construction and operation of well pad sites and associated roads and facilities may result in soil erosion, and transport of sediment and other contaminants, particularly during storm events. Clean Water Act regulations call for preparation and implementation of Storm Water Management Plans (SWMPs) to mitigate impacts of well pad sites greater than one acre in size.

- On a large scale, construction of a number of well pads in shale gas areas may result in land clearing (estimated at 34,000 to 83,000 acres) with resulting loss of forest and fragmentation of habitats.
- Research is needed to assess impacts and inform regulations for individual well site construction and operations and for large-scale regional impacts of land clearing and loss of habitats.
- Continued progress in the detailed disclosure of chemicals present in hydraulic fracturing fluid additives will enable a more complete analysis to be made of their potential impact and will help address public concern over their risk to water resources.
- Publicly available information on the additives to date indicates that the chemicals receiving attention are widely used in commercial products and are already dispersed in the environment.
- Risks of additional utilization of commonly used chemicals for hydraulic fracturing are mitigated by the fact that the depth of injection (several thousand feet) and the generally high biodegradability of the chemicals.
- Claims of migration of fracturing fluids out of the target shale zone and into aquifers have not been confirmed with firm evidence.
- The possible routes of escape such as induced or natural fractures or improperly plugged abandoned oil and gas wells as conduits for fracture fluid flow have not been substantiated.
- Many claims of impacts on water wells by shale gas activities have been made, but none have shown evidence of chemicals found in hydraulic fluid additives.
- Most claims have involved naturally-occurring groundwater constituents, such as iron and manganese, which may form particles in water wells that are released (resulting in change in color and increased turbidity in the water) as a result of vibrations and pressure pulses associated with nearby shale gas drilling operations.
- Water wells in shale gas areas have historically shown high levels of naturally-occurring methane long before shale gas development began; methane observed in water wells with the onset of drilling may also be mobilized by vibrations and pressure pulses associated with the drilling.
- Management of flowback water, which includes saline formation water from the shale (“produced water”), as a wastewater stream requires careful advance planning to

maximize recycle and reuse and minimize the quantity of water required for fracturing and to be disposed after fracturing is completed.

- Gradually increasing contribution of produced water to flowback with time after fracturing results in increasing dissolved solids and associated challenges for reuse and disposal, particularly by land application or by discharge to surface water or to a publicly-owned treatment works (both requiring a permit).
- The potential risk from fracturing fluid additives in flowback water is smaller than that of naturally-occurring contaminants such as arsenic or high dissolved solids from produced water mixed with the flowback.
- Unplanned releases of natural gas in the subsurface during drilling may result in a blowout of the well or migration of gas below the surface to nearby houses, where the gas may accumulate in concentrations high enough to cause an explosion. Subsurface blowouts may pose both safety hazards and environmental risks. A major problem in these events is the limited ability to discern what is happening in the subsurface.
- Regulations for conventional oil and gas drilling address most issues of blowouts (such as through the use of blowout preventers) and other subsurface gas releases, primarily through provisions to ensure well integrity (especially for surface casing and cementing). But the added step in shale gas development of hydraulic fracturing through high downhole pressures may require upgrades of regulations in some states.
- Escape of methane from shale gas wells as a result of loss of well integrity (surface casing and cementing) may result in migration to water wells and homes along fractures or bedding planes. Methane accumulations in basements or wellhouses may result in explosions, but the rate of occurrence of such incidences is uncertain.
- Water requirements for hydraulic fracturing of shale gas wells are substantial (typically 4 to 6 million gallons per well), but the consumption may be relatively limited compared to other water users in the area. And for many shale areas, the withdrawalS may be sustainable for prolific aquifers – and particularly for surface-water supplies in high rainfall regions.
- Management of leaks and spills at the well pad site and at off-site facilities such gas pipelines and compressor stations for shale gas drilling is similar to conventional gas development. But shale gas wells also make use of hydraulic fracturing fluids and associated chemical additives, and they have impoundments for storage of flowback and produced water, both of which may increase risks of spills and other releases. Chemical additives may pose a higher risk in their concentrated form while being

transported or stored on-site than when they are injected into the subsurface for hydraulic fracturing.

- Emissions of volatile organic carbon compounds (VOCs) are the primary area of concern for air quality, particularly in ozone non-attainment areas like Fort Worth; however, the shale gas contribution to VOC emissions is quite limited in comparison to other sources such as vehicle exhaust.
- Methane releases during shale gas operations have caused concern over contribution to global climate change, since methane is a much stronger greenhouse gas than carbon dioxide. However, many operators already recover most methane during "green completions". Shale gas, like natural gas in general, may be subject to more stringent controls in the future if global climate change regulations are put in place.
- The primary concern for health effects of shale gas development are benzene and other VOC compounds, primarily as air emissions and from liquid sources such as flowback and produced water. Much research remains to be done on the toxicity, transport, exposure, and response of receptors to shale gas VOC emissions to verify claims of impacts on health, such as cancer, headaches, nosebleeds, and other symptoms.

5 Regulatory and Enforcement Framework

Effective regulation of shale gas development must not only provide adequate protection of human health and the environment, but also build upon what has been developed previously. Shale gas regulation is accomplished within a solid framework of laws and regulations that have been developed for conventional oil and gas over many decades. Although many of these regulations were put in place before the advent of major shale gas production, they are nevertheless applicable.

Shale gas development is regulated at almost all levels of government, but in general the principal regulatory authority lies with the states. Compliance with regulatory requirements for shale gas development is being accomplished in many states through additions to and modifications of existing regulations. The regulatory framework for shale gas is described below for federal laws and regulations and for state, regional, and local requirements. The description is then rounded out with an evaluation of regulatory enforcement by the states. Because the regulatory situation is similar for two similar resources – shale oil and tight gas – they are included in the description and analysis.

5.1 Federal Regulation

Shale gas development is subject to many federal regulations (as is the case for other oil and gas operations), but has also received exemptions from a number of regulations that normally would have been applicable. Federal regulation has also led to cooperative efforts between agencies and the private sector to optimize the effectiveness of applicable shale gas regulations.

5.1.1 Applicable Legislation and Regulations

A number of federal laws and associated regulations apply to various phases of shale gas development.

Clean Water Act (CWA). Stormwater controls aim to minimize erosion and sedimentation during construction (including construction of oil and gas sites), and the CWA prohibits the dumping of any pollutant into U.S. waters without a permit. The EPA intends to propose CWA standards for the treatment of wastewater from shale gas wells in 2014.

Clean Air Act (CAA). Under recently-proposed CAA regulations, shale gas operators will have to control volatile organic compound (VOC) emissions from flowback during the fracturing process by using a VOC capture techniques called “green completion.”

Endangered Species Act (ESA). Under the ESA, operators must consult with the Fish and Wildlife Service and potentially obtain an incidental “take” permit if endangered or threatened species will be affected by well development.

Migratory Bird Treaty Act (MBTA). Operators will be strictly liable for any harm to migratory birds under the MBTA and therefore must ensure that maintenance of surface pits or use of rigs does not attract and harm these birds.

Emergency Planning and Community Right-to-Know Act (EPCRA) and Occupational Safety and Health Act (OSHA). Under EPCRA and OSHA, operators must maintain material safety data sheets (MSDSs) for certain hazardous chemicals that are stored on site in threshold quantities.

Comprehensive Environmental Responsibility, Compensation, and Liability Act (CERCLA). Under CERCLA, operators must report releases of hazardous chemicals of threshold quantities and may potentially be liable for cleaning up spills.

5.1.2 Exemptions from Federal Regulations

In addition to having to comply with several federal requirements, shale gas developers, like other oil and gas operators, enjoy several federal exemptions.

Resource Conservation and Recovery Act (RCRA).

Most wastes (“exploration and production” or “E&P” wastes) from fracturing and drilling are exempt from the hazardous waste disposal restrictions in Subtitle C of the RCRA, meaning that states – not the federal government – have responsibility for disposal procedures for the waste. Although Subtitle C of RCRA originally covered oil and gas wastes – thus requiring that operators follow federally-established procedures for handling, transporting, and disposing of the wastes – in the 1980s Congress directed the EPA to prepare a report on oil and gas wastes and determine whether they should continue to be federally regulated. In its report, the EPA noted that some of the wastes were hazardous but ultimately determined that due to the economic importance of oil and gas development and state controls on the wastes, federal regulation under RCRA Subtitle C was unwarranted.

The EPA did note some state regulatory deficiencies in waste control, however, and relied on the development of a voluntary program to improve state regulations. This voluntary program has since emerged as the State Review of Oil and Natural Gas Environmental Regulations (STRONGER), a non-profit partnership between industry, nonprofit groups, and regulatory officials. STRONGER has developed guidelines for state regulation of oil and gas wastes, periodically reviews state regulations, and encourages states to improve certain regulations.

Despite the RCRA exemption, some states treat oil and gas wastes as unique wastes under their waste disposal acts. Pennsylvania, for example, treats certain oil and gas wastes (including flowback water from fracturing) as "residual" wastes under its state Solid Waste Management Act and has special handling and disposal requirements for these wastes. Furthermore, in all states, non-exempt oil and gas wastes still must be disposed of in accordance with federal RCRA requirements.

Comprehensive Environmental Responsibility, Compensation, and Liability Act (CERCLA).

CERCLA holds owners and operators of facilities, those who arrange for disposal of waste, and those who accept hazardous substances for disposal liable for the costs of hazardous substance clean-up, and the Act also requires reporting of certain hazardous waste spills. CERCLA exempts oil and natural gas from the hazardous substances that trigger these liability and reporting requirements, however. Oil and gas operators still must report spills of other hazardous wastes of a threshold quantity, however, and may ultimately be liable for clean-up of these wastes.

Clean Water Act (CWA).

Typically, industrial facilities that generate stormwater runoff (as "pollutant" under the Act) must obtain a stormwater permit under the Clean Water Act for this runoff; they are required to have a permit both for constructing the facility (at which point soil sediment may run off the site) and operating it (at which point polluted substances may continue to run off the site during precipitation events, for example). The Clean Water Act does not require oil and gas operators, however, to obtain a permit for uncontaminated "discharges of stormwater runoff from . . . oil and gas exploration, production, processing, or treatment operations."

In the Energy Policy Act of 2005 (EPAct 2005), Congress expanded the definition of oil and gas exploration and production under the Clean Water Act – a definitional change that potentially allowed for the exemption of more oil and gas activity from stormwater permitting requirements. The EPA subsequently revised its regulations to exempt oil and gas *construction* activities from the NPDES stormwater permitting requirements. The 2008 Ninth Circuit case *Natural Resources Defense Council v. EPA*, however, vacated these regulations, and the EPA has reinstated its prior requirements for stormwater permits along with "clarification" based on EPAct 2005.

In sum, oil and gas operators must obtain a stormwater permit under the Clean Water Act for the construction of a well pad and access road that is one acre or greater, but they need not obtain such a permit for any uncontaminated stormwater from the drilling and fracturing operation. Some states and regional entities such as New York and the Delaware River Basin Commission, however, have proposed to require stormwater permitting that addresses both the construction and operation of gas wells that are hydraulically fractured.

Safe Drinking Water Act (SDWA).

Fracturing operators also are exempt from the SDWA, which requires that entities that inject substances underground prevent underground water pollution. The SDWA applies only to waste from fracturing and drilling that is disposed of in underground injection control wells; operators need not obtain an SDWA underground injection control (UIC) permit for the fracturing operation itself. If operators use diesel fuel in fracturing, however, they are not exempt from SDWA. The EPA currently is developing UIC standards for fracturing with diesel fuel.

5.2 State, Regional, and Local Regulation

The primary regulatory responsibility for shale gas development is at the state level. State agencies both administer federal environmental regulations and write and enforce many state regulations covering nearly all phases of oil and gas operations. The degree of local regulation, such as by municipalities, is also subject to state control. Sixteen states that have produced – or soon will produce – shale gas are included in the scope of this investigation: Arkansas, Colorado, Kentucky, Louisiana, Maryland, Michigan, Montana, New Mexico, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, West Virginia, and Wyoming. In general, regulations applying to shale gas also apply to shale oil, so states producing shale oil are included in the above list. STRONGER, as noted above, is a partnership including regulatory officials and industry representatives that develops guidelines for state oil and gas regulations. STRONGER also periodically reviews the regulations of individual states.

An effective way of reviewing state, regional, and local regulations applying to shale gas is to consider the stages of the shale development process. The stages of the cycle are generally as follows:

- Shale Gas Exploration
- Well Pad Siting and Construction
- Equipment Transport
- Well Drilling and Casing
- Hydraulic Fracturing
- Water Supply and Consumption
- Air Emissions Controls
- Surface Water and Spill Management Controls
- Wastewater and Solid Waste Management
- Site Remediation
- Groundwater Contamination

State regulatory provisions, shown below, are organized according to these stages. The descriptions are derived from Section 5 of this report and are intended to be representative rather than comprehensive.

5.2.1 Shale Gas Exploration

The occurrence of shale gas in the US is well understood in a general way in the large sedimentary basins as described in Section 2. Additional, more detailed, delineation may be required when a specific development project is undertaken. The seismic method of exploration, a type of geophysical technology, may be used for locating suitable shale gas targets. In the seismic method, energy is introduced into the subsurface through explosions in shallow "shot holes", by striking the ground forcefully (with a truck-mounted "thumper"), or by vibration methods. A portion of this energy returns to the surface after being reflected (or refracted) from the subsurface strata. This energy is detected by surface instruments, called geophones, and the information carried by the energy is processed by computers to interpret subsurface conditions. The results are then used to guide shale gas drilling locations.

Exploration by seismic methods is subject to an array of safety, environmental, and related regulations. In many states, a permit must be obtained before seismic exploration can proceed. Some states have general environmental protection provisions, whereas others have more detailed stipulations, such as minimum distances from springs or water wells. General protection provisions often stipulate prevention of environmental damage, protection of natural resources such as surface water and groundwater, and restoration or prevention of impacts of large seismic equipment, such as shot hole rigs, thumpers, or vibration-inducing trucks. Minimum distances of seismic activities from roads, residences, schools, commercial buildings, and other cultural features may also be required. Safety regulations apply to the use of explosives in shot holes, such as a license for blasting. Plugging of shot holes is normally required after the survey to prevent the introduction of contaminants from the surface.

5.2.2 Well Pad Siting and Construction

Once the best location for a shale gas well (or wells) has been ascertained by exploration methods, a site for the well pad and associated facilities must be established. Besides the pad and access road, accommodation must be made for drilling mud and surface pits or containers, below-grade tanks, land application sites, trucks, and other well drilling materials. Regulations for drilling pad siting are designed to protect both natural resources and cultural features, such as residences, private water wells, public water supplies, parks, and commercial property. Natural features identified for protection include streams, floodplains, wetlands, watersheds, aquifers, and similar components of the environment. The principal method of assuring protection under the siting regulations is by designation of setbacks – minimum distances from the well pad and facilities to the feature being protected. In some cases, buffer zones are established within which the type of shale gas activity allowed is designated.

After a suitable location has been found (and a permit obtained, if required), the well pad, access road, and associated facilities are constructed and operated. Often, the well pad is used for drilling a number of individual wells that extend in different directions in the subsurface. The well pad typically requires about 3.5 acres and the access road 0.1 to 2.8 acres, depending on length.

One of the most important regulatory provisions, besides the setback as described above, is stormwater permitting as well as other Clean Water Act requirements. In general, Storm Water Management Plans (SWMPs) are required when a well pad site is greater than one acre in size. In many states, a "general industrial" stormwater protection permit is issued, which is based on "best management practices" (BMPs). The general industrial permit requires stormwater controls that are not individualized by site. The BMPs help control erosion and sedimentation during pad and access road construction and are generally consistent among the states.

Some states also have regulations for wildlife protection, which in many cases call for a BMP to minimize surface disturbances and prevent habitat fragmentation. And some states call for use of netting over pits to protect birds and may include a reminder of requirements of the Endangered Species Act where applicable. Certain regional jurisdictions, such as the Delaware River Basin Commission, have proposed to regulate many stages of shale gas development, including requirement for a Non-Point Source Pollution Control Plan.

5.2.3 Equipment Transport

During construction of the well pad, access road, and other drilling facilities, truck traffic is often substantially increased. Regulatory and other responses to increased traffic typically take place at the local rather than the state level. The increased traffic, along with the large size of the trucks and equipment that is being transported, gives rise not only to crowded roads (possibly necessitating road expansion), but also to greater stress on the roads and associated higher costs of road repair and maintenance. One estimate indicates a need for 100 to 150 truckloads of hydraulic fracturing equipment and another 100 to 1000 loads for the fracturing fluid (when trucks rather than pipelines are used) and sand for proppants. In some cases, operators are required to post bonds to help deal with rises in heavy traffic.

Some communities require operators to enter into a road repair or maintenance agreement with the city. Such agreements designate routes to be used in addition to bonding requirements, how operators must repair damage, and damage for which the city will not be liable. Some cities also require operators to pay road remediation assessments to cover the increased costs of repairs.

5.2.4 Well Drilling and Casing

Some of the most detailed state oil and gas regulations cover the well drilling and casing stages. There is considerable variation among states in the current regulatory provisions. In general, the primary emphasis is on surface casing integrity, cementing of the casing, and blowout prevention. Many of the existing regulations address well construction for conventional oil and gas operations, but some states are updating provisions specifically for shale gas drilling. The regulations address both short-term integrity during well drilling and formation fracturing and long-term operation of a producing well.

Protection of aquifers as sources of fresh water is the main objective of surface casing and cementing requirements. Such protection is provided from drilling fluids, methane leakage during drilling, and fracturing fluids during hydraulic fracturing. These provisions include depth of placement of surface casing, strength of the casing, and placement and strength of the cement that is injected around the surface casing. In addition to these requirements, a well log ("bond log") may be specified as a check that sufficient integrity is accomplished.

Regulations for blowout prevention cover both losses of control at the wellhead and in the subsurface and both the drilling and hydraulic fracturing phases. The depth that surface casing is required to be set may be specified in feet for all wells or on a well-by-well basis to account for site-specific aquifer conditions. Some states call for detailed pressure testing of the surface casing and cement jobs. Many oil and gas producing states have blowout prevention regulations in place for drilling into formations with unknown or abnormal pressures. Prevention of blowouts during the hydraulic fracturing phase is described in a previous section.

5.2.5 Hydraulic Fracturing.

Regulations for hydraulic fracturing have been put in place in many states for conventional oil and gas wells, but they also apply to hydraulic fracturing for shale gas. Such regulations emphasize the proper function of processes and equipment with little direct reference to groundwater or surface-water protection. A few states (e.g., Oklahoma, West Virginia) have water pollution prevention requirements for oil and gas wells in general, but they are not specific to hydraulic fracturing. These general provisions do not provide specific guidance for operators, but may be used in litigation if pollution occurs.

Some states require notification of the responsible agency when hydraulic fracturing is planned so that operations can be observed or supervised by the agency. STRONGER recommends that agencies require prior notification and follow up reporting of hydraulic fracturing operations.

One of the primary issues of aquifer protection is the existence of old, improperly plugged oil and gas wells that may provide conduits from the target fracture zone upward to aquifers. Another risk that must be managed is underground blowouts that may occur during the high-pressure phase of hydraulic fracturing, which is addressed in another section.

Most relevant regulations for hydraulic fracturing focus on the chemicals used, but the main focus is not so much on water quality protection as it is on human exposure and medical responses. Some of the regulations apply to chemical spills, with a focus on the transport of chemicals as addressed by the US Department of Transportation as well as state-level agencies. Regulations for chemical spills are covered in another section below.

Disclosure of chemicals used in hydraulic fracturing has become an issue in many states, but the focus of current regulations is on human exposure and meeting requirements of federal laws (EPCRA, OSHA). Many of the chemicals are required to have Material Safety Data Sheets (MSDSs) available at the point of storage and use.

5.2.6 Water Consumption and Supply

Shale gas development has a higher water requirement than most conventional oil and gas drilling because of the need for large quantities of water for hydraulic fracturing. A shale gas well may require as much as 300,000 gallons per day per well, and a total fracturing treatment may require up to seven million gallons (or more) of water. The amount of water used in relation to other consumptive uses in a shale gas area has become a major component of the shale gas controversy, particularly in areas of drought, such as Texas in recent years.

Water supplies for fracturing operations may come from surface water, groundwater, or a combination of both. Surface-water withdrawals are subject to the availability of water rights as determined by water law, a form of common law of the various states. Water rights are granted in the eastern states generally under riparian water law, whereas such rights are generally subject to prior appropriation rights in the western states. Water rights for shale gas are determined primarily by ownership of land adjacent to the surface water source under the riparian rights doctrine. Under the prior appropriation doctrine such rights depend on availability of water after the needs of earlier water rights holders have been met.

In many states, the straightforward concepts of the two common law doctrines have been supplemented by statutory law, which may have additional requirements such as permits for withdrawal or reporting of amounts withdrawn (or both). In some drainage basins, additional controls of water withdrawal and use are imposed by non-state Congressionally-mandated organizations, such as the Delaware River Basin Commission and Susquehanna River Basin Commission.

Regulation and control of groundwater withdrawals are also quite variable from state to state and must be ascertained by shale gas operators to be assured of water availability from these sources. In some states, for example, groundwater is owned by the surface owner and subject only to reasonable use requirements (if at all), whereas in other states groundwater is a public asset owned by the state and subject to permits from state agencies for withdrawal of water.

Some states have responded to the water needs of shale gas drilling with added or modified water use requirements. These changes focus on the processes of allocating water rights, granting permits for withdrawal, and reporting of amounts withdrawn. Some requirements address the water quality implications of large water withdrawals and regulate on the basis of need to maintain baseline water quality standards or to protect riparian ecosystems. In states where this connection is made, additional regulatory authorities, such as traditional state water quality agencies, many enter the picture for securing water for share gas drilling.

Some states are beginning to require increased reuse and recycling of flowback and produced water not only to reduce water consumption but also to moderate wastewater disposal impacts.

5.2.7 Air Emissions Controls

Shale gas development is subject to both federal and state air emissions regulations established by the Clean Air Act (CAA) and state-level legislation. Many of the CAA provisions are delegated from the US EPA to the various states' environmental agencies. The major air pollutant sources of shale gas drilling and fracturing are the drilling and associated equipment, tanks and pits for flowback water, flared gas, and methane sources at the wellhead and from pipelines and compressors.

Oil and gas operations, and shale gas in particular, are subject to regulations for "criteria pollutants" (sulfur dioxide, nitrogen oxides, ozone, particulate matter, carbon monoxide, and lead) and "hazardous air pollutants" (HAPs, including 187 compounds). However, these regulations focus on "major" sources, which generally do not include oil and gas operations for the sources listed above specifically. If regulated at all, oil and gas sources of criteria pollutants and HAPs fall under state minor source programs. The strictest criteria air pollutants regulations apply to areas not meeting established maximum ambient air standards, which are referred to as "non-attainment" areas.

Compressor stations are an example of an oil and gas emission source of criteria pollutants that are subject to technology-based emission controls referred to as new source performance standards (NSPS). Volatile organic carbon (VOC) compounds is another type of pollutant that is subject to regulation under the CAA. The US EPA has proposed VOC emission regulations that would apply to hydraulic fracturing. A number of states (e.g. Colorado, Wyoming, New York) have also adopted VOC regulations that include such requirements as emissions reductions, siting stipulations (distances from buildings), and VOC capture requirements.

Municipalities, including Fort Worth in the Barnett shale area, have implemented air emissions controls such as VOC capture requirements, reduced emissions stipulations, and exhaust mufflers. The primary sources of natural gas emissions from shale gas operations are wellhead releases and leaks from pipelines and compressors. Although much concern has been expressed about methane emissions as a strong greenhouse gas, regulations for its control have not been promulgated.

5.2.8 Surface Water Protection and Spill Management Controls

Shale gas development, like conventional oil and gas, is subject to many federal and state regulations to protect surface-water resources from intentional discharges and unintentional spills and other releases. The Clean Water Act (CWA) stipulates that a permit (National Pollutant Discharge Elimination System, NPDES permit) must be obtained for discharges to surface water, as described in below. Stormwater runoff must also be controlled and is subject to an NPDES discharge permit.

A source of primary concern for shale gas well production is the potential for spills or other releases at the well pad site or during transportation of chemicals, fuels and other materials. Other potential sources of release are diesel fuel for the drilling rig and on-site equipment, storage tanks and pits that may leak or overflow, drilling mud, flowback and produced water storage, and hydraulic fracturing fluid. The CWA, as amended by the Oil Pollution Act (OPA) addresses spills and other accidental releases, primarily through a requirement for a Spill Prevention Control and Countermeasures (SPCC) plan for adequate responses to releases. Most states require an SPCC plan or equivalent for oil and gas operations as well as a statewide plan for response to spills and other releases. SPCC plans include not only prevention and control, but also reporting and cleanup requirements.

When a release involves hazardous chemicals, regulations pursuant to The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) apply if the amount exceeds a threshold quantity.

In most states, the provisions of these federal laws have been delegated by the US EPA to state environmental regulatory agencies. These agencies are also responsible for state laws and regulations that have been prepared in addition to the federal requirements. Some states have recently updated their laws and regulations to address spills of chemicals and other materials specifically related to shale gas drilling and hydraulic fracturing, such as new or additional chemicals.

5.2.9 Wastewater and Solid Waste Management

Disposal of liquid and solid wastes from shale gas operations is subject to a host of federal and state regulations that apply to oil and gas operations in general as well as shale gas specifically. Disposal of drilling and fracturing wastes pose a number of potential environmental and health risks. Management of these wastes may be the greatest challenge of shale gas regulation by state agencies having the responsibility. Many of the wastes are the same as or similar to those of conventional oil and gas production, but some – notably flowback water and produced water – are somewhat unique to shale gas. Drilling fluids comprise most of the liquid wastes that are not specific to shale gas development. Drill cuttings are the primary solid wastes produced by both conventional and shale gas operations.

Regulations for waste storage primarily address temporary pits and tanks for drilling fluids and cuttings and for flowback and produced water. The regulations include requirements for pit liners, freeboard (excess volumetric capacity), and closure, all of which have the objective of preventing soil and water contamination. Some states are adopting provisions for "closed loop" drilling systems, which require that drilling and fracturing wastes must be stored in tanks rather than pits that are more likely to leak and enter the surrounding environment.

Although some states have only general requirements not to contaminate soils, surface water or groundwater, most have specific mandates for individual waste streams. Waste disposal requirements for drilling and hydraulic fracturing vary substantially from state to state and the type of waste being disposed of. Wastewater disposal is primarily by underground injection in western and southern shale gas producing states and by discharge to publicly owned treatment works (POTWs) in eastern states. Federal requirements for wastewater discharge to surface waters and POTWs under the CWA (in the form of an NPDES permit) have been delegated to state agencies for many shale gas producing states.

Wastewater discharge to a POTW – which is necessitated by less desirable subsurface conditions for underground injection wells in eastern states – has become controversial and has been prohibited by some of the shale gas producing states. Other states require pretreatment before discharge to a POTW. The US EPA has announced that wastewater treatment standards will be developed for shale gas wastewater by 2014.

In addition to administering federally delegated regulatory and permitting program, states have added their own restrictions on disposal. Some states, including Pennsylvania, prohibit discharge to POTWs, and other states are reevaluating the practice of onsite land disposal of wastes.

In general, increased emphasis is being placed on requirements for wastewater reduction through recycle and reuse of hydraulic fracturing fluids (which has the added benefit of produced water requirements) in a number of states.

In some shale gas areas, operators manage wastes at a centralized waste disposal facility that accepts RCRA-exempt waste from multiple well sites. These facilities may be subject to general state requirements such as best management practices to protect human health and the environment. They may also be subject to specific requirements, such as an operating plan (to address emergency response, site security, inspection and maintenance, safety requirements), water well monitoring, and surface water diversion for storm events.

Another important category of wastes for management is naturally occurring radioactive material (NORM), which is produced in both drill cuttings and in flowback and produced water. Federal regulations do not address NORM so its control takes place at the state agency level. In many cases NORM regulation is split among two or more state agencies, as in Texas.

5.2.10 Site Remediation

The requirements for plugging and abandoning shale gas wells at the end of their life cycle, as is the case for unconventional oil and gas wells, are specified by state agencies. States also have responsibility for specifying site (drill pad and surrounding area) restoration requirements. The objective is often to restore the site to its former use. Typically operators are required to remove the contents stored in pits, test for contamination and clean up as necessary, and revegetate the site within a reasonable time. For shale gas wells, restoration should consider testing and remediation of hazardous chemicals that may have been released as a result of hydraulic fracturing procedures.

5.2.11 Groundwater Contamination

Protection of shallow aquifers in conventional oil and gas operations through such measures as surface casing and cementing and drilling mud pit liners needs to be a primary focus for shale gas wells. For example, the use of additional chemicals and proppants for hydraulic fracturing and the potential for groundwater impacts by construction problems or failures in the upper part of the well bore require additional monitoring and protective measures. The focus of media attention specifically on the fracturing process has highlighted concern about potential groundwater impacts.

A few states, such as Pennsylvania, have supplemented oil and gas regulations with requirements directed specifically to shale gas wells in the Marcellus. Establishing pre-drilling groundwater quality through a baseline monitoring program, which has not been routinely performed as shale gas well locations in the past, will enable impacts to be detected and mitigative actions to be taken when required. Some states, for example Colorado and Pennsylvania, have implemented measures to protect water supplies during shale gas operations. These measures do not require systematic, well-designed monitor well programs, but instead provide for monitoring of existing water wells, replacement of water supplies if contamination occurs, and holding operators legally responsible for contamination.

5.3 State Enforcement of Regulations

Equally as important as having well-developed regulations on the books is adequate enforcement by staff both in the office and conducting field inspections. Regulatory enforcement can be measured in several ways, including number of staff assigned, inspections conducted, and violations recorded. The type and severity of violations demonstrate the type of adverse effects being addressed by the regulatory programs. Regulatory enforcement was analyzed for 15 of the 16 states whose regulations were assessed as described in the preceding section.

5.3.1 Enforcement Capacity

The capacity of an agency with regulatory responsibility was assessed by gathering information on the number of staff assigned to the inspections and the number of inspections actually accomplished for the years 2008 to 2011. The information included many of the 16 states including in the survey of regulations: Louisiana, Maryland, Michigan, Montana, New Mexico, North Dakota, Texas and Wyoming. The following parameters were included in the assessment:

- Number of active shale gas, tight sands, and/or shale oil wells, 2008
- Total number of field inspectors in agency, 2008
- Of total inspectors listed above, total number assigned to shale gas wells, 2008
- Number of field inspections, 2008
- Number of attorneys devoted enforcing activities that oil and gas wells, 2008

Texas had the highest number in all categories. A wide variation was found in the ratio of enforcement staff and field inspectors to the number of shale gas and similar wells in the state. Part of the variation is due to differences in methods of reporting among the states. Despite this variation, it was found that most states with current shale gas and related development have enforcement capacity necessary to address at least some complaints associated with oil and gas development and to conduct independent enforcement actions.

Some states have much higher enforcement capacity, and larger numbers of inspections, than others. This higher capacity more than likely influences the total number of violations noted and enforcement actions taken. A higher capacity may also result in more representative violations.

5.3.2 Development Activities and Environmental Effects

Shale gas development activities addressed by state violation and enforcement actions were also evaluated for Louisiana, Michigan, New Mexico and Texas for the following:

Construction of access road and well pad
- Erosion and sedimentation

Maintenance of site: vegetation, signs, fencing
- Fencing
- Signs and labeling
- Site maintenance (clearing weeds, for example)

Drilling (and potentially fracturing)
- Air quality
- Casing and cementing
- Commingling oil and gas
- Failure to prevent oil and gas waste
- Fire
- Gas or oil leak at wellhead/venting
- Noise
- Odors
- Surface spill condensate
- Surface spill contaminant not indicated
- Surface spill diesel
- Surface spill drilling mud
- Surface spill oil
- Surface spill produced water
- Wellhead and blowout equipment
- Well spacing

Fracturing-specific violations and complaints
- Fracturing
- Groundwater contamination (complaints only)
- Surface spill frac fluid

Storage of waste
- Pits and tanks: construction, operation, maintenance, closure
- Secondary containment

Disposing of waste
- Land application of waste
- Improper disposal

Plugging and site closure
- Plugging
- Removing equipment, filling ratholes
- Well not secured if shut in

Procedural violations: financial security, permits, tests and drills, reporting
- Financial issues (bonding, etc.)
- Permitting, plat filing, reporting
- Tests and drills

Other
- Water well construction

The percentages are violations each of the states and the categories were found as follows:

	LA	MI	NM	TX
Total violations (number)	158	497	77	72
Construction of access road and well pad	0%	1%	0%	0%
Maintenance of site: vegetation, signs, fencing	20%	55%	16%	6%
Drilling (and potentially fracturing)	10%	30%	58%	15%
Fracturing-specific violations and complaints	0%	0%	11%	0%
Storage of waste	41%	4%	1%	1%
Disposing of waste	0%	0%	2%	21%
Plugging and site closure	0%	10%	0%	1%
Procedural violations	20%	0%	7%	45%
Other	0%	0%	0%	0%

Except for Louisiana, few of the violations noted in the table resulted in formal enforcement actions. All of the violations were for Louisiana resulted in issuance of administrative orders.

5.3.3 Environmental Effects of Violations and Enforcement Actions

The types of environmental effects associated with state violation and enforcement actions were also evaluated. First, an interpretation of the effects of the actions was made in terms of "gravity of environmental effect" in five categories, and the percentages of total violations were computed, with the following result:

Gravity of Environmental Effect	Louisiana: Haynesville Shale wells 2009-2011	Michigan: Antrim Shale wells 1999-2011	New Mexico: tight sands & shales (non-exhaustive) 2000-2011	Texas: fractured shale wells, FY 2008-2011
	158 total violations	497 total violations	77 total violations	72 total violations
	Percent of total violations	Percent of total violations	Percent of total violations	Percent of total violations
Procedural	60	33	26	53
Minor—no effect	31	28	1	1
Minor effect	2	25	20	8
Substantial	7	15	42	29
Major	1	0	12	8

Generally, this information suggests that many of the violations are procedural and represent no environmental effects; are minor with no effect – meaning that an inspector noted a flaw in a pit or casing job, for example, but did not note any release of contaminant to the environment as a result of that flaw; or represent minor effects, such as small releases. The higher percentage of substantial and major effects noted for New Mexico could potentially result from several factors. New Mexico may focus more closely on environmental effects that are technical violations, such as a failure to post a sign. Alternatively, there could be more significant problems in New Mexico, or the smaller size of the data set could skew the percentages. Most of the major violations in New Mexico involved large spills of produced water.

In Pennsylvania, three activities at one site led to a consent order and agreements as well as a substantial penalty. The Pennsylvania agency also issued notices of violation for 80 additional activities ranging from improper casing and cementing to discharge of flowback water. Violations in New Mexico were for land application of produced water, a spill of hydraulic fracturing fluid, release of oil (with remediation required), failure to obtain well drilling permits, constructing surface pits, and disposing of produced water above the in a pit. Michigan actions included a compliance case for soil contamination at a wellhead and notices of non-compliance for failure to plug wells after production ended.

A limited number of the violations was noted in response to complaints. These included problems with seismic testing, compressor sounds and other noise, weed growth, brine spraying around a wellhead, venting gas from wellheads, an overflowing production pit, odors, equipment oil leaks, and improper reseeding of well sites. Overall, the data collected showed few complaints made to agencies. However this could be because of lack of records or no link being established between compliance and enforcement actions.

5.4 Regulation or Policy Topics: Regulatory and Enforcement Framework

The topics for regulation or policy consideration for shale gas regulation may be considered for Federal regulation; state, regional and local regulation; and state enforcement of regulations.

5.4.1 Federal Regulation

- In general, few Federal regulations are currently directed specifically to shale gas or to oil and gas generally; applicable regulations are pursuant to broader environmental laws for air, water, waste, and other areas.
- A number of exemptions from federal regulations have been granted for oil and gas activities and have been applied to shale gas development.
- In some states, similar requirements that are exempted from federal regulation are imposed at the state level.

5.4.2 State Regional and Local Regulation

- Primary regulatory authority for shale gas is at the state level; many federal requirements have also been delegated to the states.
- Most state oil and gas regulations were written before shale gas development became important; shale gas development is therefore subject to body of previously-developed oil and gas regulations in many of the states in the shale gas areas.

- Regulations for many shale gas activities and their consequences are applicable to oil and gas activities generally and not just to shale gas specifically, including exploration activities.
- Some states have revised regulations specifically for shale gas development; regulatory gaps remain in many states, including the areas of well casing and cementing, water withdrawal and usage, and waste storage and disposal.
- A number of organizations and activities are underway, including the Groundwater Protection Council (GWPC) and State Review of Oil and Natural Gas Regulations (STRONGER), to develop and improve state regulation of oil and gas operations, including shale gas development..
- Recent regulatory revisions focus on three prominent concerns: 1) proper casing of wells to prevent aquifer contamination; 2) disclosure of hydraulic fracturing chemicals; and 3) proper management of large quantities of wastewater.
- Any new regulations – and modification of existing provisions – should be developed with a strong foundation in science, with well-supported research into areas requiring better understanding to support regulations.
- Care must be taken to focus regulations on the most urgent issues (e.g. surface spill prevention) is well as areas of greatest public concern
- States not having regulations for blasting in environmentally sensitive areas or for shot hole plugging during the shale gas exploration phase may want to consider adding these requirements.
- Particularly in states not having previous extensive oil and gas development, new or additional site-specific regulations, such and stormwater requirements, may be needed to minimize surface disturbances and impacts on environmentally sensitive areas.
- For protection of sensitive areas and cultural features such as schools and public water supplies, state regulations may need to set minimum distances (setbacks) from drill pads and other facilities.
- States may need to specify more uniform requirements for truck traffic and other community impacts of shale gas activities – an area currently addressed primarily by municipalities and other local governments.

- More consistent requirements from state to state may be needed to ensure well integrity (surface casing and cementing) to prevent blowouts and leakage – but with provisions for flexibility to meet site-specific drilling and well completion conditions.
- Additional and consistent regulations for control of air emissions may be needed to address all phases and facilities of shale gas development, including conventional ("criteria") and hazardous air pollutants, fugitive emissions of natural gas from pipelines and other facilities, and gas releases during drilling, fracturing and well completion ("green completions").
- States may need to continue to modify common law rights systems (e.g., riparian, prior appropriation) with legislation to strengthen permitting and reporting of surface water withdrawals for shale gas development.
- States may also need to supplement current laws and practices for groundwater withdrawals and associated permitting for shale gas development.
- Disclosure of the chemical contents of additives to hydraulic fracturing fluids may be needed on a more uniform basis among state regulatory authorities.
- Additional requirements to ensure well integrity during hydraulic fracturing (e.g., strength testing of casing, bond logs) may be needed in some states.
- Updates may be needed for requirements of spill prevention and contingency plans in some states to take into account new chemicals, such as fracturing fluid additives, that are transported to and used at the drill site.
- Updates of state regulations may be needed to require adequate baseline (pre-drilling) groundwater sampling, analysis, and/or monitoring to improve the basis for determining if shale gas activities have an impact on water quality in nearby aquifers.
- Updates may also be required for establishing responsibility for groundwater impacts and for replacing water supplies when water wells are affected.
- With the additional wastewater streams of flowback and produced water from shale gas development, states may need to consistently update regulations for waste storage in pits to specify liners, minimum freeboard, closure methods, and other requirements.
- States may also need to more uniformly require a plan for disposal of wastes (including drilling fluids, drill cuttings, and flowback and produced water) and to ensure that the methods of disposal (e.g., centralized facility, surface discharge with

permit, discharge to POTW or injection well, land application) conforms with regulations and best practices

- States may need to update or put in place adequate regulations for disposal of wastes containing naturally-occurring radioactive material (NORM) – as for oil and gas operations in general.
- States may need to review requirements for site restoration after drilling and well completion to ensure that shale gas specific characteristics (e.g., fracturing fluid chemicals, flowback and produced water) are taken into account.

5.4.3 State Enforcement of Regulations

- Regulations that are effective for protecting human health and the environment depend not only on the content of the regulations but also on how well they are enforced by regulatory agencies.
- Evaluation of state enforcement is hindered by several factors, including differing methods of collecting, organizing, and recording violations and enforcement actions; variances in the completeness of records; and responsiveness of agencies to information requests.
- Enforcement capacity, as measured by staff levels, is highly variable among the states, particularly when measured by the ratio of staff to numbers of inspections accomplished.
- Preliminary findings from four states (Louisiana, Michigan, New Mexico, Texas) found over 800 violations involving most phases of shale gas operations – construction, site maintenance, drilling and fracturing, waste storage and disposal, site closure and well plugging, and operations procedures. But the comparison of these violations with those for conventional gas development is not known.
- When violations are classed into categories ranging from merely procedural to major environmental impact, 58% were found to be procedural or having little or no impact, and 42% indicated a major, substantial or minor effect.
- Surface spills, improper disposal of oil and gas wastes, and problems with leaking pits or tanks are relatively common violations, which can be prevented.
- Most violations were from operations in common with conventional gas drilling rather than shale gas specific; this comparison merits further research.

- Enforcement needs to be focused on shale gas effects with the highest risk (e.g., subsurface releases) rather than on minor or readily evident violations (e.g., inadequate fencing, misplaced signage).
- Regulations need to be set up to match as closely as possible the stiffness of penalties to the relative degree of environmental impact.
- Enforcement records indicate that surface incidents are important in relation to underground occurrences; this may in part be because they are easier to observe and report by inspectors; some states may need to turn inspection and enforcement efforts toward higher-risk incidents, both underground and at the surface.
- The tendency of the media to focus on the fracturing stage of shale gas development may not be justified based on the violations information found in the four states evaluated.
- Strong focus in the media on impacts on groundwater resources could pull attention away from potentially higher risks of surface incidents.

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