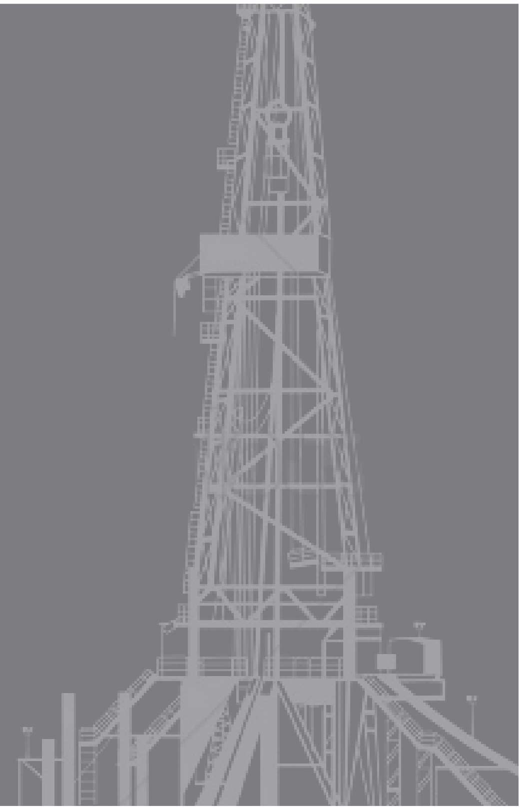

GRAHAM
SUSTAINABILITY INSTITUTE
UNIVERSITY OF MICHIGAN

Executive Summary

HYDRAULIC FRACTURING IN MICHIGAN INTEGRATED ASSESSMENT FINAL REPORT

SEPTEMBER 2015

About the Executive Summary

This executive summary is part of the Hydraulic Fracturing in Michigan Integrated Assessment (IA) which has been underway since 2012. The guiding question of the IA is: *"What are the best environmental, economic, social, and technological approaches for managing hydraulic fracturing in the State of Michigan?"*

The purpose of the IA is to present information that:

- expands and clarifies the scope of policy options, and
- allows a wide range of decision makers to make choices based on their preferences and values.

As a result, the IA does not advocate for recommended courses of action. Rather, it presents information about the likely strengths, weaknesses, and outcomes of various options to support informed decision making.

The project's first phase involved the preparation of technical reports on key topics related to hydraulic fracturing in Michigan which were released by the University of Michigan's Graham Sustainability Institute in September 2013. This document is the executive summary of the final report for the IA.

The IA report has been informed by the technical reports, input from an Advisory Committee with representatives from corporate, governmental, and non-governmental organizations, a peer review panel, and numerous public comments received throughout this process. However, the report does not necessarily reflect the views of the Advisory Committee or any other group which has provided input. As with preparation of the technical reports, all decisions regarding content of project analyses and reports have been determined by the IA Report and Integration Teams.

While the IA has attempted to provide a comprehensive review of the current status and trends of high volume hydraulic fracturing (HVHF), specifically, in Michigan (the technical reports) and an analysis of policy options (the IA report), there are certain limitations which must be recognized:

- The assessment does not and was not intended to provide a quantitative assessment (human health or environmental) of the potential risks associated with HVHF. Completing such assessments is currently a key point of national discussion related to HVHF despite the challenges of uncertainty and the lack of available data—particularly baseline data.
- The assessment does not provide an economic analysis or a cost-benefit analysis of the presented policy options. While economic strengths and/or weaknesses were identified for many of the options, these should not be viewed as full economic analyses. Additional study would be needed to fully assess the economic impact of various policy actions, including no change of current policy.

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Graham Sustainability Institute
Energy Institute
Erb Institute for Global Sustainable Enterprise
Risk Science Center

For more information on this project, please go to:
http://graham.umich.edu/knowledge/ia/hydraulic-fracturing

You may also contact John Callewaert, Graham Sustainability Institute Integrated Assessment Center Director,
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GRAPHIC DESIGN BY SUSAN E. THOMPSON DESIGN

Executive Summary

PURPOSE AND SCOPE OF THE ASSESSMENT

There is significant momentum behind natural gas extraction efforts in the United States, with many states viewing it as an opportunity to create jobs and foster economic growth. Natural gas extraction has also been championed as a way to move toward domestic energy security and a cleaner energy supply. First demonstrated in the 1940s, hydraulic fracturing—injecting fracturing fluids into the target formation at a force exceeding the parting pressure of the rock (shale) thus inducing a network of fractures through which oil or natural gas can flow to the wellbore—is now the predominant method used to extract natural gas in the United States.[1] As domestic natural gas production has accelerated in the past 10 years, however, the hydraulic fracturing process and associated shale gas development activities have come under increased public scrutiny particularly with respect to high volume hydraulic fracturing (HVHF). Key concerns include, for example, a perceived lack of information transparency, potential chemical contamination from fracturing fluids, water use, wastewater disposal, and possible impacts on ecosystems, human health, and surrounding communities. Consequently, numerous hydraulic fracturing studies are being undertaken by government agencies, industry, environmental and other non-governmental organizations, and academia, yet none have a particular focus on Michigan.

The idea for conducting an Integrated Assessment on HVHF in Michigan was developed by the Graham Sustainability Institute over a one-year time frame (June 2011-June 2012) and involved conversations with several other University of Michigan (U-M) institutes, the Graham Institute's External Advisory Board, U-M faculty, researchers at other institutions, regulatory entities, industry contacts, and a wide range of non-governmental organizations. Integrated Assessment (IA) is one of the ways the Graham Institute addresses real-world sustainability problems. This methodology begins with a structured dialogue among scientists and decision makers to establish a key question around which the assessment will be developed. Researchers then gather and assess natural and social science information to help inform decision makers. For more about the IA research framework, please visit: http://graham.umich.edu/knowledge/ia.

The assessment does not seek to predict a specific future for HVHF activity in Michigan. Rather, it posits that natural gas extraction pressures will likely increase in Michigan if the following trends persist: desire for job creation, economic strength, energy security, and decreased use of coal. Given that HVHF intersects many issues that are important to Michigan residents—drinking water, air quality, water supply, land use, energy security, economic growth, tourism, and natural resource protection—the assessment asks:

What are the best environmental, economic, social, and technological approaches for managing hydraulic fracturing in the State of Michigan?

This guiding question bounds the scope of the IA. The assessment focuses on Michigan, but it also incorporates the experience of other locations that are relevant to Michigan's geology, regulations, and practices. Additionally, the IA primarily concentrates on HVHF (defined by the State of Michigan regulations as well completion operations that intend to use a total volume of more than 100,000 gallons of primary carrier fluid),[2,3] but the analysis of options also considers implications for other practices and includes options for different subsets of wells.

The purpose of this IA is to present information that expands and clarifies the scope of policy options in a way that allows a wide range of decision makers to make choices based on their preferences and values. As a result, the assessment does not advocate for recommended courses of action. Rather, it presents information about the likely strengths, weaknesses, and outcomes of various options to support informed decision making.

OVERVIEW OF ACTIVITY IN MICHIGAN

Background

While recent interest from energy developers, lease sales, and permitting activities suggest the potential for increasing activity around HVHF in Michigan, consistently low gas prices for the past two years[10] has been identified as a key contributor to limited HVHF activity in Michigan at present.[11] Below are some key points regarding hydraulic fracturing in Michigan.

- According to the Michigan Department of Environmental Quality (DEQ), since 1952 more than 12,000 oil and gas wells have been fractured in the state, and regulators report no instances of adverse environmental impacts from the process.[12] The distribution of wells throughout Michigan's Lower Peninsula is illustrated by Figure 1. Most of these are relatively shallow (1,000 to 2,000 feet deep) Antrim Shale[13] vertical wells drilled and completed in the late 1980s and early 1990s in the northern part of Michigan's Lower Peninsula. Some new activity will continue to take place in the Antrim in the short term, and a very small number of the old wells may be hydraulically fractured in the future. This appears, however, to be a "mature" play and is unlikely to be repeated and will not involve HVHF.
- The hydrocarbon resources in the Utica and Collingwood Shales in Michigan (4,000 to 10,000 feet below ground) will likely require HVHF and below-surface horizontal drilling (a drilling procedure in which the wellbore is drilled vertically to a kickoff depth above the target formation and then angled through a wide 90 degree arc such that the producing portion of the well extends [generally] horizontally through the target formation) up to two miles.[14]
- A May 2010 Department of Natural Resources (DNR) auction of state mineral leases brought in a record $178 million—nearly as much as

Box 1: Key Terms

Terminology is important to any discussion of hydraulic fracturing. Below are key terms which will be used throughout the report. Additional terminology and definitions can be found in the glossary in Appendix A.

Conventional and Unconventional Natural Gas: Natural gas comes from both "conventional" (easier to produce) and "unconventional" (more difficult to produce) geological formations. The key difference between "conventional" and "unconventional" natural gas is the manner, ease, and cost associated with extracting the resource. Conventional gas is typically "free gas" trapped in multiple, relatively small, porous zones in various naturally occurring rock formations such as carbonates, sandstones, and siltstones.[4] However, most of the growth in supply from today's recoverable gas resources is found in unconventional formations. Unconventional gas reservoirs include tight gas, coal bed methane, gas hydrates, and shale gas. The technological breakthroughs in horizontal drilling and fracturing are making shale and other unconventional gas supplies commercially viable.[5]

Shale Gas: Natural gas produced from low permeability shale formations[6]

Hydraulic Fracturing: Injecting fracturing fluids into the target formation at a force exceeding the parting pressure of the rock thus inducing a network of fractures through which oil or natural gas can flow to the wellbore.

High Volume Hydraulic Fracturing: HVHF well completion is defined by State of Michigan regulations as a "well completion operation that is intended to use a total volume of more than 100,000 gallons of primary carrier fluid."[7,8]

Experts and the public often use terminology differently, and often interchangeably. In some instances, for example, the public tends to view hydraulic fracturing—including lower and high volume completions—as the entirety of the natural gas development process from leasing and permitting, to drilling and well completion, to transporting and storing wastewater and chemicals. Industry and regulatory agencies hold a much narrower definition that is limited to the process of injecting hydraulic fracturing fluids into a well.[9]

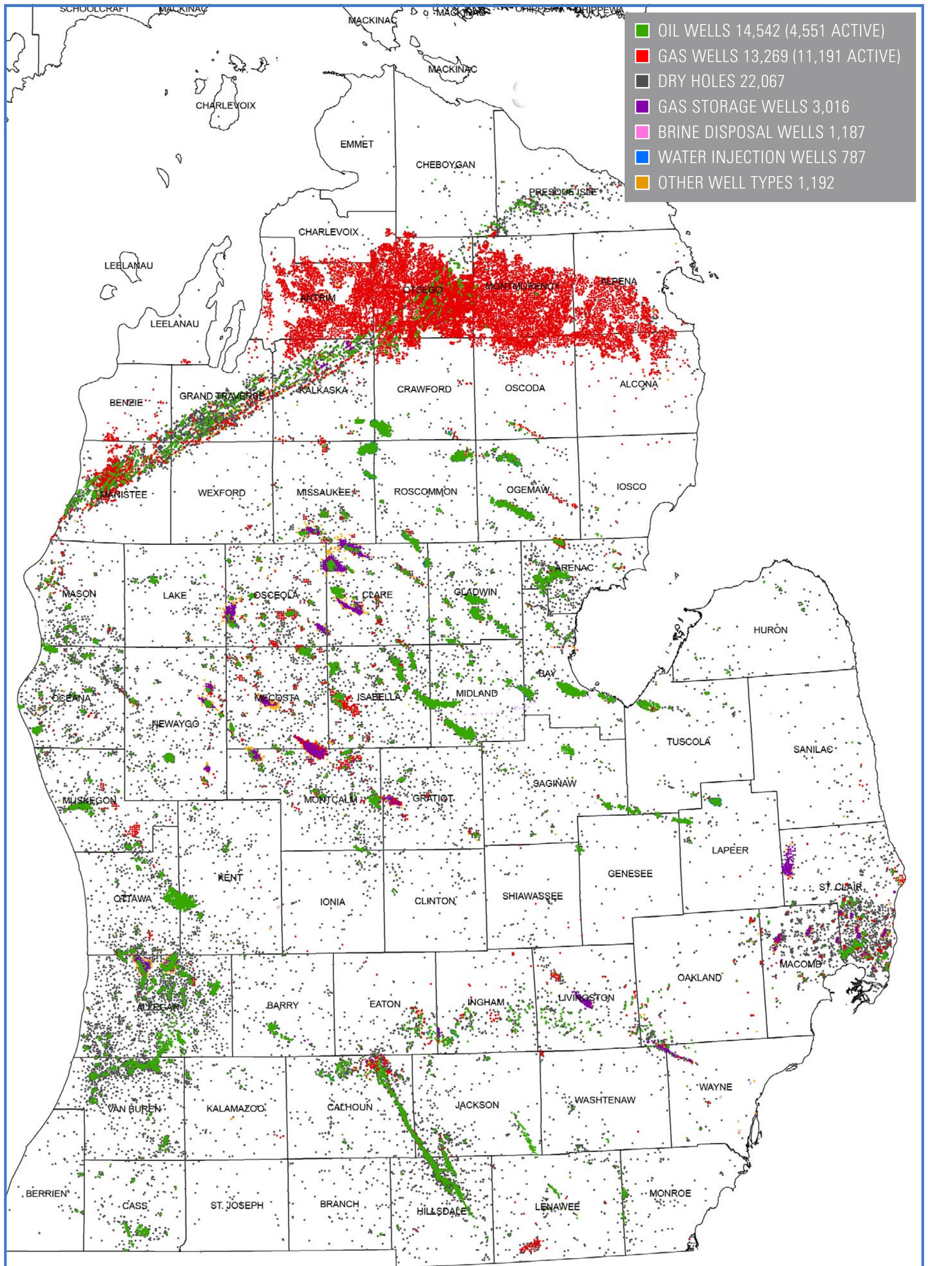

FIGURE 1a[i]: Activity in Michigan: oil and gas wells in 2005[22]

[i] Full size, zoomable map available at: http://www.michigan.gov/documents/deq/MICHIGAN_OIL_GAS_MAP_LP_411599_7.pdf

the state had earned in the previous 82 years of lease sales combined. Most of this money was spent for leases of state-owned mineral holdings with the Utica and Collingwood Shales as the probable primary targets.[15,16] However, there has been limited production activity thus far under these leases.

- As of May 28, 2015, there were 14 producing HVHF-completed oil and gas wells in Michigan, 2 active applications, 16 active permit holders, 6 locations with completed plugging, and 13 locations with completed drilling.[17] Figure 1 provides a map of these locations.
- Shale gas production in Michigan is much lower than production in other states (see U.S. Energy Information Administration shale gas production information in Figure 2).
- Given the limited activity to date, is it very difficult to predict the scale of future HVHF activity in Michigan, but there is agreement that further development of the Utica and Collingwood Shales is likely years away given that current low gas prices make development less feasible economically.[18]
- Over the past few years, several bills have been proposed in Michigan to further regulate or study hydraulic fracturing,[19] state officials implemented new rules for HVHF in March 2015,[20] and a ballot question committee has been working to prohibit the use of horizontal hydraulic fracturing in the state.[21]

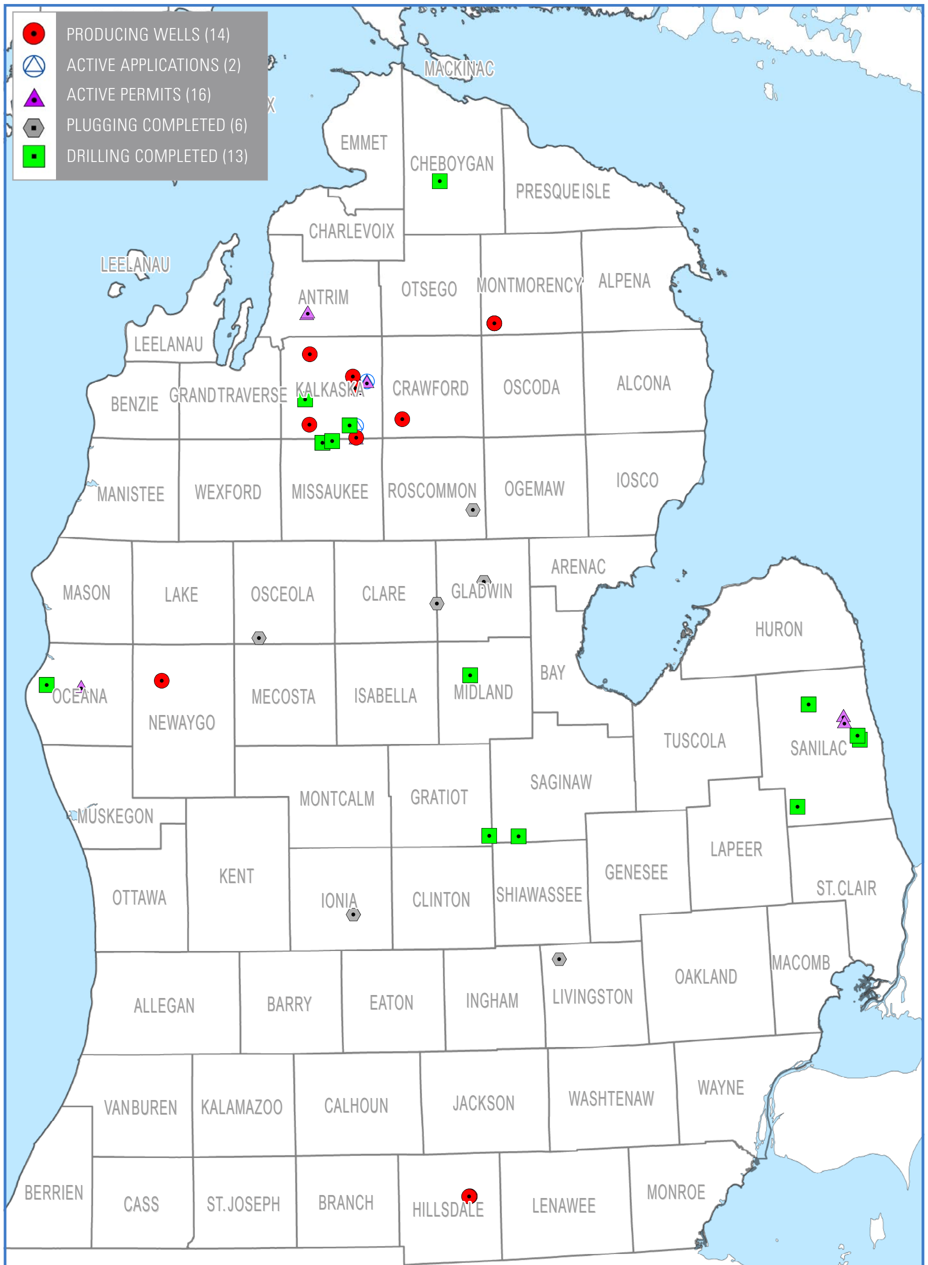

FIGURE 1b[i, ii]: Activity in Michigan: HVHF wells as of May 28, 2015.[23]

[i] Full size zoomable map available at: http://michigan.gov/documents/deq/hvhfwc_activity_map_new_symbols-jjv_483124_7.pdf

[ii] The source map contains the following disclaimer: "High volume hydraulically fractured well completions are defined in Supervisor of Well Instruction 1-2011 as a 'well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid.' We made all efforts to trace back the well completion records thru 2008 to compile [sic] this map and list. This information provided here in is accurate to the best of our knowledge and is subject to change on a regular basis, without notice. While the Department of Environmental Quality - Office of Oil, Gas, And Minerals (DEQ-OOGM) makes every effort to provide useful and accurate information, we do not warrant the information to be authoritative, complete, factual, or timely. It is suggested that this information be combined with secondary sources as a means of verification. Information is provided 'as is' and an 'as available' basis. The State of Michigan disclaims any liability, loss, injury, or damage incurred as a consequence, directly or indirectly, resulting from the use, interpretation, and application of any of this information."

Technical Reports

The first phase of the IA (2012-2013) involved preparation of seven technical reports on key topics related to hydraulic fracturing in Michigan (technology, geology/hydrogeology, environment/ecology, public health, policy/law, economics, and public perceptions). Each report includes an overview of the topic, a discussion of status and trends, a review of challenges and opportunities, and suggestions for additional analysis. The reports provide decision makers and stakeholders with a solid foundation of information on the topic based primarily on an analysis of existing data. Following a peer review process, the reports were made public in September 2013. Selected highlights from each report follow.[i]

Technology

Hydraulic fracturing originated in 1947–1949, initially in Kansas, Oklahoma, and Texas as a means of stimulating production from uneconomic gas and (mostly) oil wells, and was quickly successful at increasing production rates by 50% or more, typically using hydrocarbon fluids (not water) as the carrier. To date in the United States, an estimated more than 1.25 million vertical or directional oil/gas wells have been hydraulically fractured, with approximately 12,000 fractured wells located in Michigan.[26] Fracturing of deep and/or directional wells is most often done with several hundred thousand to several million gallons of high-pressure water that contains about 10-20% of sharp sand or an equivalent ceramic with controlled mesh size and about 0.5% of five to ten chemicals that are used to promote flow both into and subsequently out of the fractured formation. To facilitate fracturing, the steel casing that is inserted into the well is typically penetrated with pre-placed explosive charges. As illustrated by Figure 3, the fracturing mixture flows into the formation through the resulting holes, and these holes subsequently provide a route for product flow back into the production tubing.

Geology and Hydrogeology

One of the most widely cited issues regarding the environmental consequences of hydraulic fracturing operations is groundwater contamination, and water quality issues more broadly. One study, conducted by Osborn et al., concluded that water wells located near natural gas production sites in Pennsylvania had higher contribution of thermogenic methane than wells farther away from such operations, suggesting a possible (not definite) link between hydraulic fracturing and increased methane in drinking water.[27] Other studies, such as one by Molofsky et al., suggest that methane leakage occurs naturally, and may have more to do with land topography than hydraulic fracturing.[28] Another key concern about possible impacts from shale gas development includes the quantity of water used. Typically, HVHF will use over 100,000 gallons of fracturing fluid per well, the overwhelming majority of which is water, but some wells have used over 21 million gallons.[29] Of the total volume of hydraulic fracturing fluids injected into a well, amounts varying from 10 to 70% may return to the surface along with additional produced native formation brines. Disposal of flowback and produced brine fluids in Michigan occurs via deep well injection into brine disposal wells. This method for disposal of produced oilfield brines

[i] As it is not possible to include all of the information from the technical reports here, readers are encouraged to review the complete set of technical reports, available at: http://graham.umich.edu/knowledge/ia/hydraulic-fracturing.

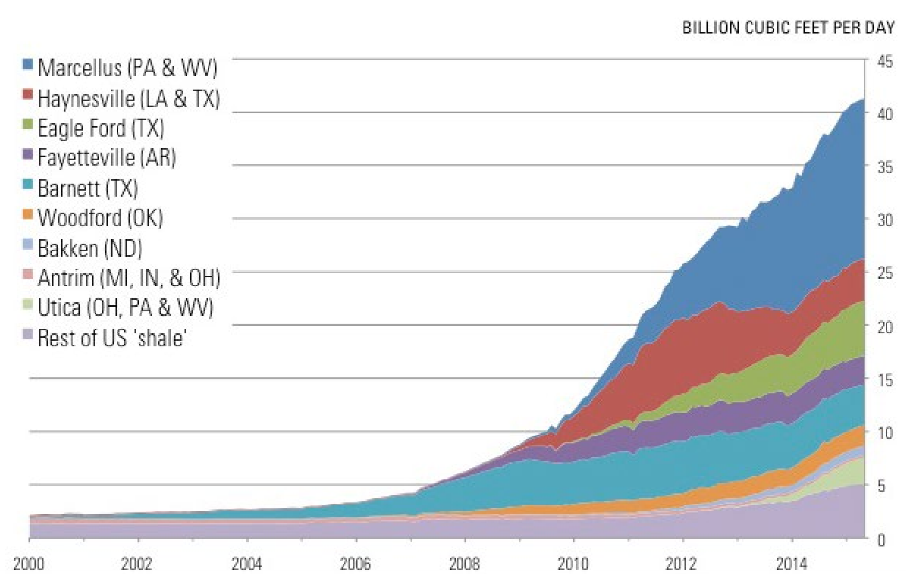

FIGURE 2: U.S. dry shale gas production[24]

is very common throughout the U.S.[30] HVHF flowback waters currently make up less than 1% of the annual brine disposal volumes in Michigan (compared to 2011 cumulative disposal volumes).

Environment and Ecology

There are numerous potential ecological consequences of all shale gas and oil development. Building the necessary roads, product transportation lines, power grid, and water extraction systems, together with the siting of drilling equipment and increased truck traffic, produces varying site-specific environmental impacts. Potential effects include: increased erosion and sedimentation, increased risk of aquatic contamination from chemical spills or equipment runoff, habitat fragmentation and resulting impacts on aquatic and terrestrial organisms, loss of stream riparian zones, altered biogeochemical cycling, and reduction of surface and hyporheic waters available to aquatic communities due to lowering groundwater levels.

Public Health

As with many of the areas that shale gas development could impact, possible impacts on public health have yet to undergo a rigorous assessment, owing primarily to substantial gaps in data availability, both in Michigan and beyond. It is important that public policy and regulations around shale gas development be grounded in strong, objective peer-reviewed science (as opposed to anecdotes). Nonetheless, the health related concerns expressed by community members, especially those that are scientifically plausible or those that are recurring, need to be seriously evaluated. While not all potential hazards have evidence to support their presence in or relevance for Michigan, certain ones, such as noise and odor, were identified as such. Noise pollution has been associated with negative health outcomes such as annoyance, stress, irritation, unease, fatigue, headaches, and adverse visual effects. Since some hydraulic fracturing operations occur around-the-clock (over roughly one to three weeks), the noise generated could also potentially interfere with the sleep quality of area residents. Silica exposure is another potential hazard identified, primarily impacting workers, who may be exposed to respirable crystalline silica. Silica sand is often used as a proppant during operations. Inhalation of silica can lead to the lung disease silicosis, which can include symptoms ranging from reduced lung function, shortness of breath, massive fibrosis, and respiratory failure.

Policy and Law

As HVHF and public concern have grown in the last few years, governments have begun to make policies specifically addressing hydraulic fracturing, and in some cases HVHF. The details of these policies may be presented in informal statements of policy or guidance, or may be made binding in law through legislative action or agency rulemaking. Courts have also been called upon to resolve disputes, creating an additional source of law. Michigan's DEQ is responsible for governing gas exploration, development, and production waste. With this authority, the DEQ issues specific rules and guidance, setting permitting conditions and enforcing requirements on the location, construction, completion, operation, plugging, and abandonment of wells. Michigan's DNR, which is the largest owner of mineral interests in the state, operates the program for leasing state owned mineral interests.

Economics

In Michigan, the shale gas industry generates employment and income for the state, but the employment effects are modest when compared with other industries. With regard to employment, there are two broad types of jobs to be found in the natural gas extraction industry: jobs directly involved in production and jobs that provide services to producers. While there tend to be fewer production jobs, they generally pay higher salaries and are less sensitive to well development than servicing jobs. It has been estimated that the number of production jobs in Michigan has ranged from 394 (in 2002) to 474 (in 2010), and the number of service industry jobs has ranged from 1,191 (in 2002) to 1,566 (in 2008).[31] Taxes paid to the State of Michigan from revenues earned by private landowners in 2010 were $32.6 million. These monies support the state general fund. In addition, the State of Michigan earns revenue from gas extracted from

Box 2: Hydraulic Fracturing and High Volume Hydraulic Fracturing

A vertical well that is hydraulically fractured in Michigan may use about 50,000 to 100,000 gallons of water while a high volume, horizontally drilled well may use 20,000,000 gallons of water or more.

While HVHF completions use significantly more water per completion than shallower, vertical completions, there is disagreement regarding the two completion techniques' relative overall use of water and efficiency of water use (the amount of water used standardized by the size of the reserves or amount of gas produced). Some argue that fewer large wells could produce more gas per volume of water used or size of production unit. Similar arguments are made regarding surface impact: that the development of multiple HVHF wells per site, rather than many individual wells and well pads, reduces the area of land disturbed.

However, HVHF activity is currently too limited in Michigan to draw any conclusions regarding these types of comparisons due to uncertainties such as, but not limited to, average production rates, decline curves, productive lifetimes, the extent of future development, and water use in the Utica and Collingwood. Additionally, some contend that comparisons between different shale resources are inherently problematic because different completion techniques and economic considerations are involved. Depending on the metric and assumptions used in these comparisons, one may reach different conclusions about the relative impacts.

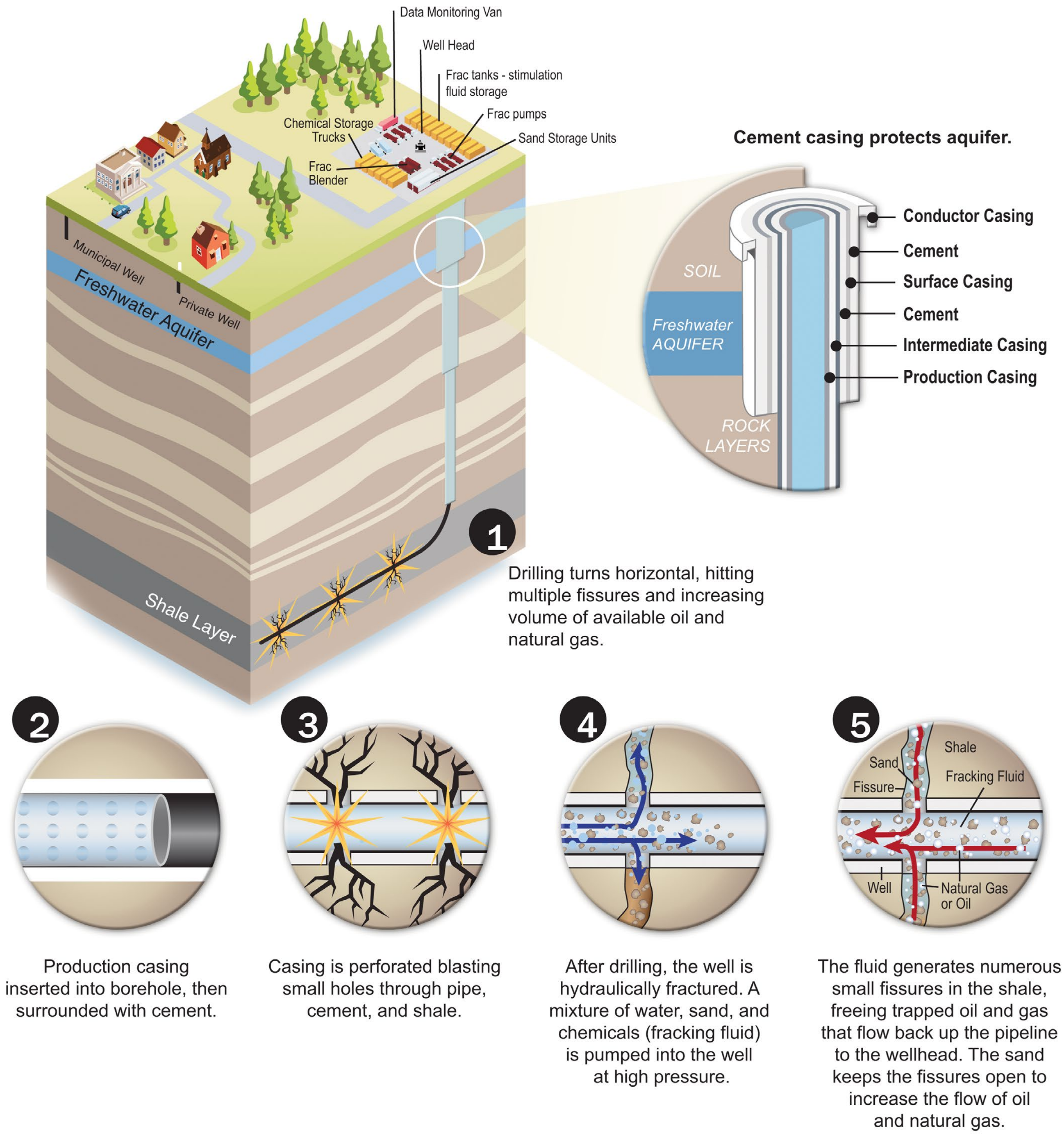

Illustration Not to Scale.
Top of the Mitt Watershed Council, 2013.
www.watershedcouncil.org

FIGURE 3: Hydraulic fracturing process[25]

OPTIONS ANALYSIS

The report focuses on an analysis of options for three issues relevant to the State of Michigan and specific to HVHF. Topics were identified as prioritized pathways in the technical report and in public comments.

- PUBLIC PARTICIPATION (Chapter 2)
- WATER RESOURCES (Chapter 3)
- CHEMICAL USE (Chapter 4)

STATE-SPECIFIC — **NATIONAL & GLOBAL**

HVHF — **UNCONVENTIONAL GAS DEVELOPMENT**

ADDITIONAL ISSUES

Other topics relevant to Michigan and HVHF, but not exclusive to HVHF, identified in the technical reports and public comments are included in Appendix C:

- Environmental impacts
- Air quality
- Landowner & community impacts
- Agency capacity & financing

BROADER CONTEXT

Issues related to unconventional shale gas more generally and relevant at scales larger than Michigan are included in Appendix B:

- Climate change & methane leakage
- Renewable energy
- Manufacturing renaissance
- Natural gas exports
- Understanding health risks

FIGURE 4: IA report organization

state property. In 2012, the DNR received $18.4 million in royalties, $7.7 million in bonuses and rent, and a $0.1 million in storage fees. Nearly all the revenue from gas extracted on state property is used to improve state land and game areas.[ii]

Public Perceptions

Among the general public, roughly 50-60% of Americans are at least somewhat aware of hydraulic fracturing, and awareness seems to be on the rise. In Michigan, a 2012 poll found that a majority (82%) of residents have heard at least "a little" about fracking and nearly half report that they follow debates about fracking in the state "somewhat" to "very closely." Consistent with other national and state-level polls, a slight majority of Michigan residents (52%) believes that the benefits of fracking outweigh the risks, but concerns remain about potential impacts on water quality and health. Fifty-two percent of respondents from the same poll agreed that the State of Michigan should impose a moratorium on hydraulic fracturing until its risks are better known. In Michigan and elsewhere, most people support tighter regulation of the oil and gas industry, including requiring disclosure of the chemicals used in hydraulic fracturing fluids.

[ii] In 2014, $40 million was collected for lease revenues (J. Goodheart, DEQ, personal communication, July 15, 2015)

STRUCTURE OF THE REPORT

Chapter 1 of this report provides an overview of the purpose, scope, and process used for this assessment including contributors, participants, previously released technical reports, and other stages of the project. Chapters 2, 3, and 4 represent the central part of the report and focus on an analysis of HVHF policy options specific for Michigan in the areas of public participation, water resources, and chemical use. Chapter 5 provides a framework for reviewing policy options presented in Chapter 2 (public participation), Chapter 3 (water resources) and Chapter 4 (chemical use) using adaptive and precautionary policy categories. Chapter 6 identifies the limits of this report and knowledge gaps. Several appendices are also included. Appendix A is a glossary of terminology used throughout the report and HVHF discussions. Appendix B provides an overview of broader issues related to expanded shale gas development that are not specific to Michigan. Appendix C offers a review of additional shale gas development issues that are relevant to Michigan but not specific to HVHF. Appendix D provides a description of the peer review process along with the review summary developed by the panel and a response document indicating how the panel's input was utilized. Appendix E provides a summary and response for public comments received following the release of the final draft IA report.

The key contribution of this report is the analysis of HVHF options specific for Michigan in the areas of public participation, water resources, and chemical use (Chapters 2–4). These topics were identified based on review of key issues presented in the technical reports from the first phase of the IA, numerous public comments, and the expert judgment of Report Team members based on a review of current policy in Michigan, other states, and best practices. Each chapter provides an overview of the topic, a description of current policy in Michigan (including new HVHF rules implemented by the state in March 2015), and a range of approaches, including approaches from other states and novel approaches. Each of these chapters also provides an analysis of the strengths and weaknesses of the policy options. There is some variation in approach for each chapter given the range of policies and conditions which are addressed. A complete list of all the policy options can be found at the end of this summary.

Figure 4 illustrates the organization of the report around its focus on HVHF in Michigan.

ANALYSIS OF POLICY OPTIONS

Public Participation

Governing HVHF and related activities in a manner that is socially acceptable can be challenging, especially given the different and often conflicting viewpoints held by different stakeholder groups. Similar dilemmas have been provoked by technologies such as nuclear power plants and hazardous waste facilities. In these settings, a large body of research has argued that to arrive at sound public policies that reflect democratic decision making and address stakeholder concerns, the public must have a significant participatory role.[32–36]

There are numerous ways in which the public could inform deep shale gas development. These might include, for example, sharing knowledge about local conditions, identifying key concerns and risks, and helping decision makers prioritize needed regulations. How the public weighs in on these issues can take many forms. In the context of public policy, public participation is often construed as public comment periods and hearings, where the public might be described as having a consultative role.[37,38] Other forms of public participation such as moderated workshops and deliberative polling may allow for more interactive discussions that encourage collaborative decision making.

Scholars and industry alike are beginning to reconsider how the public might be more involved in shaping HVHF-related policies, in particular, and oil and gas policy, in general. For example, the National Research Council, which serves as the working arm of the National Academy of Sciences, hosted two workshops in 2013 to examine risk management and governance issues in shale gas development.[39] One of the papers to emerge from this workshop argues that public participation efforts must go beyond simply informing the public about HVHF or allowing them to submit comments on proposed activities; instead, stakeholders should be engaged in analytic-deliberative processes where they have the opportunity to "observe, learn, and comment in an iterative process of analysis and deliberation on policy alternatives."[40]

Only a few states have made efforts to engage the public in more deliberative discussions about unconventional shale gas development. Instead, most states have relied on existing oil and gas regulations to govern their public participation practices. In some states this means the public may be notified of proposed oil and gas wells and possibly given an opportunity to submit comments. In other states, only surface owners are given such an opportunity, even though the impacts of HVHF well development may extend beyond the well site.

Chapter 2 examines options for improving how public values and concerns are incorporated into HVHF-related policy. The first section explores this question broadly by looking at how public values inform unconventional shale gas policies, in general, and by examining what opportunities exist for improvement. The remaining two sections explore how public interests are represented in state mineral rights leasing decisions and well permitting as these two activities both affect a question of primary importance to the public: where will HVHF occur.

Options for public involvement in HVHF-related policies

To date, Michigan has largely treated HVHF as an extension of other types of oil and gas activities. As a result, the public has had few opportunities to weigh in on whether and where HVHF occurs. Beyond changing regulations specific to state mineral rights leasing and well permitting practices, the state could consider implementing a number of other options to address the needs and concerns of residents. These include:

- Revising the content and usability of the DEQ website
- Requiring risk communication training for DEQ and DNR staff
- Participating in interactive listening sessions moderated by a skilled facilitator, where the public can engage in genuine dialogue about their concerns related to deep shale gas development.
- Increasing stakeholder representation on the Oil and Gas Advisory Committee
- Appointing a multi-stakeholder advisory commission to further study the potential impacts of HVHF in Michigan
- Imposing a moratorium or ban on HVHF permitting

Options for public involvement in state mineral rights leasing

Michigan's existing policy of requiring public notice and comment before auctioning state mineral rights has been reasonably responsive to public concerns. Additional options for public involvement include:

- Increasing public notice to targeted stakeholders (e.g., nearby landowners and users of state lands)
- Providing moderated workshops where the public can engage in dialogue with the state about proposed leases
- Requiring public notice and comment when well operators request modifications of existing state mineral rights leases
- Requiring responsiveness summaries of public input received

Options for public involvement in well permitting

Michigan's existing policy for involving the public in well permitting decisions is more inclusive than many states but less inclusive than others. By only notifying surface owners and local units of government, the current policy hinders transparency about HVHF operations in the state and reduces the ability of affected community members to voice concerns. Options that can help address these concerns include:

- Increasing public notice
- Requiring a public comment period
- Explicitly allowing adversely affected parties to petition for a public hearing

Water Resources

HVHF as commonly practiced requires water as a primary component in its operation. This crucial need for large volumes of water makes the regulation of water withdrawal and wastewater disposal strong tools for regulating HVHF activities themselves. The State of Michigan has a well-developed system for the management of water withdrawals, the Water Withdrawal Assessment Program (WWAP), which was developed as part of the Great Lakes Compact and instituted in 2009.[41] By managing water resources of the state, the WWAP offers a mechanism for managing HVHF operations. Currently, the state regulates HVHF water withdrawals along a parallel regulatory pathway. While HVHF water withdrawals are not governed by the WWAP, such water withdrawals are required to be assessed using the same online assessment tool—Water Withdrawal Assessment Tool (WWAT)—used for the WWAP. In addition to the required use of the WWAT, HVHF water withdrawals must identify existing nearby water withdrawal wells, install their own groundwater monitoring wells, and report all water withdrawal activities to the Supervisor of Wells.

If concerns over water withdrawal are held at the start of the HVHF process, at the other end of the process are concerns over the wastewater accumulated during the HVHF process. Indeed, concerns over impacts to water quality have also arisen in the popular media, scientific literature, and governmental reports. HVHF utilizes a suite of chemicals, which effectively contaminates the water used in the HVHF process, some of which returns back to the surface.

Chapter 3 is organized into two major sections. The first explores various methods in which improvements to the Supervisor of Wells regulations and the WWAP may provide mechanisms to govern water withdrawals associated with HVHF. Many of these improvements have been raised in public comment as well as in public meetings of the state-appointed Water Use Advisory Council.[42] The second section explores regulatory rules changes concerning management of wastewater from HVHF operations. Both sections use regulatory examples from other Great Lakes states, the Susquehanna River Basin Commission (SRBC), and the Delaware River Basin Commission (DRBC). All of these regions share a basis of water law (i.e., regulated riparianism[43]), which places them in a similar framework regarding their approach to governing water withdrawals.

Options for HVHF water withdrawal regulation

The parallel structure of governing water withdrawals in Michigan (through the Supervisor of Wells in the case of HVHF water withdrawals and through the WWAP for almost all other large scale water withdrawals) rests upon the common use of the WWAT for initial assessment of the withdrawal. However, since the water itself doesn't recognize regulatory boundaries, it is necessary to assess different aspects of water withdrawals in response to the additional physical and public perception challenges that HVHF brings to the table.

One of the major policy options presented in Chapter 3 is to update the WWAT. Updates to the WWAT would allow for greater precision and accuracy in assessing the impacts of large-volume water withdrawals from HVHF as well as other large water withdrawals across the state. Options include:

- Updating the scientific components of WWAT
- Implementing a mechanism for updating the models underlying WWAT

Other HVHF water withdrawal regulation options include altering the thresholds for enacting regulation. Enacting parallel measures within the WWAP and the Supervisor of Wells regulations could likely have negative consequences on certain types of water users but would also increase the strength and quality of water conservation throughout the state. Options include:

- Lowering water withdrawal thresholds for regulation
- Metering HVHF water withdrawal wells
- Setting total volumetric water withdrawal limits for certain types of withdrawals

Another major policy option revolves around water withdrawal permitting, the fees for such permitting, and the question of whether such permits might be transferrable. This last change could provide local water users greater ability to make their own decisions about water use. However, such changes would significantly alter the fundamental basis of water governance in the state, moving it more deeply into a regulated riparian system. Options such as fee schedules, like those used by the SRBC and DRBC, could be implemented to fund and improve water governance mechanisms and structures within the state. Water withdrawal permitting options include:

- Including HVHF water withdrawals within the current fee schedule
- Modifying water withdrawal fee schedules
- Prohibiting HVHF operations from obtaining a water withdrawal permit
- Providing a mechanism to transfer, sell, lease registered/permitted water withdrawals

In much of the area of the state where HVHF will take place, public concern over potential impacts stems from concern that watersheds may be over-allocated due to errors in the predictions of water available made by WWAT. At present Michigan has the site-specific review (SSR) mechanism to deal with potential overallocation of, and related impacts to, water resources. Additional monitoring and public engagement options include:

- Requiring SSRs for all HVHF water withdrawal proposals
- Providing a mechanism to use private monitoring
- Including HVHF operators in water users committees
- Incentivizing the organization of water resources assessment and education committees

Options for wastewater management and water quality

Presently, the wastewater management and water quality policies of the State of Michigan have been adequate in dealing with most of the issues surrounding the historic generation of wastewaters associated with hydraulic fracturing. However, with the intensity of wastewater generation associated with HVHF, it is not clear whether the laws and regulations written at a time of small-scale, shallow hydraulic fracturing options will be adequate. Where there once were thousands of gallons of wastewater being created by a single hydraulic fracturing well, a future with HVHF will be one where each well potentially creates hundreds-of-thousands of gallons of wastewater—several hundred times more than a historic hydraulic fracturing well.

The current process for managing hydraulic fracturing wastewater fluids in the State of Michigan is deep well injection. The *Underground Injection Control Program*, which is the national governing framework for deep well injection, is managed by the U.S. Environmental Protection Agency (EPA), and, together with Michigan law, it requires the disposal of hydraulic fracturing fluids into Class II wells.[44] Although Class II disposal wells are designed to keep underground drinking water supplies safe from contamination, there have been well casing failures in production wells in other states due to high pressure that have caused groundwater contamination. In addition, the public often perceives groundwater resources as vulnerable to hydraulic fracturing operations in general. Given these concerns, additional options for managing and monitoring wastewater disposals are presented. These include:

- Increasing monitoring and reporting requirements
- Obtaining primary authority over Class II well oversight by the state
- Requiring use of Class I hazardous industrial waste disposal wells

In addition to deep well injection, another way to manage wastewater and water quality is to promote alternative sources of hydraulic fracturing fluids, including recycled wastewater and treated municipal water. Currently, the State of Michigan provides only a single defined regulatory option for recycling hydraulic fracturing wastewater (i.e., ice and dust control, but only if the wastewater meets specific quality conditions), even though recycling technologies are actively being developed. Recycling wastewater and using alternative water resources both hold potential benefits of improved water quality through diminished demands for groundwater resources, even though both carry associated environmental risks. Additional options here include:

- Providing options for greater wastewater recycling
- Using alternative water sources for HVHF

Chemical Use

The chemical substances associated with HVHF activities are numerous and may be found at every point in the process. For example, between January 2011 and February 2013, the EPA identified approximately 700 different chemicals that were used in fracturing fluids.[45] The fracturing fluid for each well contained a median of 14 chemical additive ingredients, with a range of 4 to 28 ingredients.[1] A number of these chemicals may interact with receptors (e.g., humans, animals and/or plants) at the HVHF worksite, and in the ecological and community environments situated near these worksites via air, water, and/or soil. The presence and use of these chemicals in HVHF has engendered much debate and concern among stakeholders in the U.S. generally,[46–49] as well as in other jurisdictions currently engaging in HVHF.[50,51] Nearly all chemical substances are characterized by one or more ecological and/or human health hazards (i.e., the potential to do harm). However, it is the conditions surrounding the presence of that chemical that determine the ecological and/or health risks (i.e., the probability of causing harm).

When faced with scientific uncertainty about the risks of an activity to human health and the environment, policymakers can take three general approaches. The first is to adopt a precautionary approach. Particularly when there are threats of irreversible damage or catastrophic consequences, policymakers may decide to regulate the activity to prevent harm.[52] In its strongest form, the precautionary approach would counsel banning an activity that could potentially result in severe harm.[53] The second is to adopt an adaptive approach. Policymakers may choose to take some regulatory action at the outset, then refine the policy as more information becomes available.[54] The third is to adopt a remedial—or post-hoc—approach. Policymakers may decide to allow the activity and rely on containment measures and private and public liability actions to address any harm.[55]

Chapter 4 examines three types of policy tools that states have used to address chemical use in HVHF activities: information policy, prescriptive policy, and response policy. Information policies gather data about HVHF for decision makers and the general public; prescriptive policies mandate a specific action to reduce risk or set a performance standard; and response policies manage any contamination through emergency planning, cleanup, and liability requirements. The chapter focuses on the policies of eight states: Arkansas, Colorado, Illinois, New York, North Dakota, Ohio, Pennsylvania, and Texas. The states were chosen to reflect a range in the characteristics of production, demography, and policy.[56] For each type of policy tool, and building on the approaches to uncertainty, the chapter presents the range of state policies and describes Michigan's current policies. The chapter then offers three combinations of policy options the state could adopt, including returning to its previous policies.

Options for information policy

U.S. states have focused much of their policy attention on gathering information about chemical use in hydraulic fracturing through reporting and monitoring requirements. These policies build on existing laws that require well operators to submit reports on the methods used for completing a well. Mechanisms for regulating the provision of information by HVHF operators vary. Moreover, such mechanisms may or may not be specific to HVHF activities, but rather capture HVHF activities by their scope. Variation is evident in terms of their objective/s, obligations, penalties, and audience. Yet despite the differences in design, the overarching goal of such mechanisms is to increase transparency of otherwise private information. While the focus may be on increasing transparency between the operator and the state, information policies may also increase transparency between all relevant stakeholders, including the public at large. In doing so, they may enhance public participation in the decision-making process. As this section illustrates, the mechanisms and/or tools adopted by the state will therefore depend on their overall policy objective around access to, use of, and availability of information.

State information policies primarily focus on three types of technical information:

1. information on the chemical additives in the hydraulic fracturing fluid;
2. information on the integrity of the well, the barrier between the chemicals and the environment; and
3. information on movement of chemicals in water resources around the well.

Michigan's existing information policies primarily adopt a remedial approach to uncertainty, the most common approach of the other states surveyed. Michigan gathers information about well integrity through pressure monitoring during HVHF and information about water quality through a baseline test; both are remedial policies that use the information to address contamination and liability. The exception is the state's chemical disclosure policy, which takes a precautionary approach. By requiring operators to provide information on chemical constituents prior to HVHF, the state can take preventative actions in permitting. These actions are limited, however, by the incomplete nature of the chemical information: operators may withhold the identities of chemical constituents considered to be a trade secret, and may use other chemicals in HVHF that are not disclosed in the permit application.

Options presented for information policy include:

- Chemical Use: Plain-language description of all chemicals; careful scrutiny of trade secret claims; full disclosure to the state of all constituents prior to HVHF activity
- Well Integrity: Monitoring during HVHF activity with problems reported immediately to state and nearby landowners; periodic tests through life of operating well not just when a problem is indicated
- Water Quality: Long-term monitoring, including baseline tests, of water resources including surface water based on characteristics of the aquifer/watershed; reporting results within 10 days to the state, owner, and public

Options for prescriptive policy

Prescriptive policy responds to scientific uncertainty about risk by requiring private actors to take an action, such as install a specified technology, or to attain a specified level of performance. Under a precautionary approach, prescriptive policies use preventative mandates that restrict the activity causing the threat of harm or ban the activity altogether. Under an adaptive approach, prescriptive policies use initial mandates that can be altered over time as more is learned about risk. Under a remedial approach, prescriptive policies use corrective mandates that minimize the harm from any incident and assist in identifying the source of harm.

State prescriptive policies primarily focus on four areas:

1. restrictions on the chemicals used in HVHF;
2. limitations on siting an HVHF well;
3. controls focused on minimizing risks to groundwater; and
4. controls focused on minimizing risks to surface waters.

As in the majority of states surveyed, Michigan has adopted a combination of approaches. Michigan takes a precautionary approach to well siting through setback requirements, though the policy is limited to groundwater drinking sources. The state's policies controlling groundwater risks are primarily adaptive: well construction requirements are made flexible by the discretion given to permitting staff to set conditions. Yet the state also employs a precautionary approach by requiring operators to address potential conduits. Lastly, Michigan's policies controlling surface risks are both precautionary (requiring flowback to be stored in tanks) and remedial (mandating secondary containment measures for storage tank areas, though not for chemical staging areas).

Options presented for prescriptive policy include:

- Chemical Use: Developing a list of prohibited chemicals which could be amended over time; approving chemicals only if applicant demonstrates low toxicity
- Limitations on Siting: Modifying siting distances for wells and surface facilities over time based on new findings; no siting in protected areas
- Controls on Groundwater Risks: Modifying construction requirements over time based on groundwater monitoring data/best practices; relocation of well unless no risk from conduits
- Controls on Surface Risks: Storing flowback in pits or tanks, and modifying practices over time based on leakage data/best practices; requiring closed loop systems for chemical additives and flowback; imposing restrictions on additive handling

Options for response policy

Response policy responds to scientific uncertainty about risk by requiring private actors to prepare for possible incidents, clean up contamination, and take responsibility for environmental and human health harm. Under a precautionary approach, response policies focus on incidents, but their underlying purpose is to deter actors from engaging in activities that could cause significant harm. Under an adaptive approach, response policies seek to protect the most sensitive areas from harm while using information on incidents to adjust requirements over time. Under a remedial approach, response policies acknowledge that incidents can happen and seek to minimize harm and hold actors responsible.

State spill response policies primarily focus on four areas:

1. planning for emergencies;
2. reporting and cleanup;
3. financial responsibility; and
4. liability to private parties.

As in the majority of the states examined, Michigan's approach is remedial. In the event of a spill, the state requires quick reporting and cleanup. The state's financial responsibility policies encourage operators to take responsibility for a spill and remediate the site, but the state could do more to encourage prevention by also requiring liability insurance.

Options presented for response policy include:

- Emergency Planning: Requiring emergency response plans for HVHF wells in sensitive

areas and modifying the policy over time based on data; requiring emergency response plans for all HVHF wells
- Reporting and Cleanup: Cleanup criteria modified over time based on long-term monitoring data; immediate reporting of all spills to state, surface owners, and public
- Financial Responsibility: No blanket bonds; modifying individual bond amount over time based on restoration costs, requiring individual well bonds of $250,000 and liability insurance
- Liability to Private Parties: Liability if no environmental monitoring around well; strict liability unless operator can demonstrate caused by other sources; requiring the restoration of environment for all spills

OTHER MATERIAL

Broader Context

In response to public comments received during the IA process and broader context topics identified in the technical reports, Appendix B provides an overview of the literature on several key issues related to expanded shale gas production, including: climate change and methane leakage, natural gas as a bridge fuel to a cleaner energy future, the potential for a U.S. manufacturing renaissance based on expanded natural gas production, the potential economic impacts should the U.S. expand natural gas exports, and methodological approaches to understanding and managing human health risks. While not exhaustive, these issues are central to the national debate and discourse regarding the challenges and opportunities of expanded shale gas production. For many of the topics, the results presented in the literature are mixed or uncertain due to the application of different methodological approaches, datasets, scenario assumptions, and other factors. In other areas, there are clearer indications of outcomes such as existing opportunities to reduce GHG emissions through existing technology and best practices, the influence of federal renewable mandates for transitioning to low- or zero-carbon technologies, economic benefits for gas-intensive industries from lower gas prices, and the price effects of expanding natural gas exports.

These discussions should not be read as definitive conclusions but a snapshot of current understandings of these topics. The body of peer-reviewed literature on the impacts of shale gas development is relatively new; one comprehensive review of the available scientific peer-reviewed literature estimated that 73% of the literature has been published since January 1, 2013.[57] As has been noted above, much still needs to be examined regarding expanded shale gas development, and there is significant work currently taking place that hopefully will better inform decision making moving forward.

Additional Issues

Drawing again from the range of public comments received during this project, as well as the IA technical reports, media releases, and scientific literature, Appendix C provides a scan of topics relevant to natural gas development in Michigan but not necessarily specific to HVHF. These include a range of potential environmental impacts, air quality concerns, landowner and local community impacts, as well as agency capacity and financing issues. For each of these issues, an overview of the potential impacts and concerns is provided along with a brief description of regulations or practices in Michigan related to the topic and a list of different approaches intended to address aspects of these concerns or examples from other states.

ENDNOTES

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List of Policy Options

CHAPTER 2: POLICY OPTIONS FOR PUBLIC ARTICIPATION	
2.2 INCORPORATING PUBLIC VALUES IN HVHF-RELATED POLICIES AND DECISION MAKING	
2.2.3.1	Keep existing Michigan policy • No mandatory public notice and comment on well applications; public comments on proposed rules and testimony at rule promulgation public hearings; DEQ informs residents about HVHF through website and participates in public meetings/events
2.2.3.2	Revise the DEQ website to improve transparency and usability
2.2.3.3	Require risk communication training for DEQ and DNR employees
2.2.3.4	Conduct public workshops to engage Michigan residents in state and local-level HVHF decision making
2.2.3.5	Impose a state-wide moratorium on HVHF
2.2.3.6	Ban HVHF
2.2.3.7	Appoint a multi-stakeholder advisory commission to study HVHF impacts and identify best practices for mitigating them
2.2.3.8	Increase stakeholder representation on Oil and Gas Advisory Committee

2.3 PUBLIC INPUT IN STATE MINERAL RIGHTS LEASING	
2.3.3.1	Keep Michigan's existing state mineral rights leasing policy • NRC and DNR manage state-owned lands and mineral resources; DNR runs leasing program for state-owned mineral rights and is responsible for collection royalties from production; oil and gas rights leased for qualified lands via public auction; auction lists made publically available; public comment is allowed and, in practice, DNR prepares response although not required to do so; notification of public auctions via newspapers in leasing regions, on DNR website, and to DNR mailing list
2.3.3.2	Increase public notice • Expand notification to all landowners adjacent to parcel; notification at parcel itself if it is used as a public recreational area
2.3.3.3	Require DNR to prepare a responsiveness summary
2.3.3.4	Require public workshops prior to state mineral rights auctions
2.3.3.5	Increase public notice and comment when lessees submit an application to revise or reclassify a lease
2.4 PUBLIC PARTICIPATION AND WELL PERMITTING	
2.4.3.1	Keep existing Michigan well permitting policy • DEQ is required to give notice of permit applications to surface owner, county, and city/village/township if the population >70,000, but, in practice, provides notice regardless of population size; is required to consider written comments from any city, village, township, or county with a proposed well; informally accepts any public comments on permit applications; voluntarily posts map of HVHF activity and notices of weekly permit activity on website
2.4.3.2	Increase notification of permit applications • Remove population threshold; public notice in local newspapers and nearby property—potentially done by permit applicant
2.4.3.3	Require a public comment period with mandatory DEQ response
2.4.3.4	Explicitly allow adversely affected parties to request a public hearing before a HVHF well permit is approved

3.2 REGULATING HVHF THROUGH WATER WITHDRAWAL REGULATION

3.2.1 REQUIREMENTS FOR WATER WITHDRAWAL APPROVAL

3.2.1.2.1	Keep existing Michigan policy for water withdrawal approval • No cumulative water withdrawals in subwatershed units may cause an adverse resource impact (ARI). HVHF water withdrawals must be submitted to Supervisor of Wells and run through WWAT; may not create Zone C (Zone B in a cold-transitional systems); and require identification of all nearby groundwater wells and installation of groundwater monitoring wells.
3.2.1.2.2	Revert to previous Michigan policy • Supervisor of Wells Instruction 1-2011 required of use of WWAT for HVHF and stated withdrawals causing an ARI would not be allowed.
3.2.1.2.3	Disallow any HVHF operation within a cold-transitional system
3.2.1.2.4	Make conservative estimates of HVHF water withdrawals

3.2.2 WATER WITHDRAWAL REGULATION THRESHOLDS

3.2.2.2.1	Keep existing Michigan policy for water withdrawal regulation • Registration required for all water withdrawals >70 gpm for any 30-day period; permit required for withdrawals > 1,388 gpm (with some exceptions)
3.2.2.2.2	Lower thresholds for regulation
3.2.2.2.3	Meter HVHF withdrawal wells
3.2.2.2.4	Set total volumetric water withdrawal limits

3.2.3 IMPROVEMENTS TO THE WWAT

3.2.3.1	Keep existing Michigan WWAT • The current WWAT reflects water quantity measures, regulatory subwatersheds, and Policy Zone determinations from 2008.
3.2.3.2	Update the scientific components of WWAT • Update scientific dataset; use numerical models; include lakes and wetlands
3.2.3.3	Implement a mechanism for updating the models underlying WWAT

3.2.4 WATER WITHDRAWAL FEE SCHEDULES

3.2.4.2.1	Keep existing Michigan water withdrawal fees • HVHF operators are exempt from the WWAP and pay no water withdrawal fees for registration.
3.2.4.2.2	Include HVHF water withdrawals within the current fee schedule
3.2.4.2.3	Modify water withdrawal fee schedules • Fee schedule could take into account site- and project-specific factors; project planning fees could be levied against projects in vulnerable areas; large-scale projects could be subject to a withdrawal fee based on the total project cost

3.2.5 MODIFY WATER WITHDRAWAL PERMITTING

3.2.5.2.1	Keep existing Michigan policy for water withdrawal permitting • Permits only available for withdrawals >1,388 gpm (694 gpm in a Policy Zone C area; 70 gpm for intrabasin water transfers)
3.2.5.2.2	Prohibit HVHF operations from obtaining a water withdrawal permit • HVHF operations would need to keep water withdrawal rates below 1,388 gpm and register the rate through the Supervisor of Wells

3.2.6 TRANSFER/SALE/LEASE OF WATER WITHDRAWALS

3.2.6.2.1	Keep existing Michigan policy for transfer/sale/lease of water withdrawals • Responsibilities and liabilities associated with water withdrawals devolve to the property owner under statutes associated with WWAP; Supervisor of Wells HVHF regulations imply permittees much register or obtain permits for withdrawals
3.2.6.2.2	Provide a mechanism to transfer, sell, lease registered/permitted water withdrawals
3.2.6.2.3	Prohibit transfer or use of registered water withdrawals to HVHF operations

3.2.7 ADDITIONAL MONITORING

3.2.7.1.1	Keep existing Michigan policy for monitoring • Site-specific review may be conducted when ARI is suspected in a Policy Zone C subwatershed unit or when a proposed withdrawal would cause a Policy Zone C or D
3.2.7.1.2	Require site-specific reviews for all HVHF water withdrawal proposals
3.2.7.1.3	Provide a mechanism to use private monitoring

3.2.8 PUBLIC ENGAGEMENT ON NEW WATER WITHDRAWALS	
3.2.8.2.1	Keep existing Michigan policy for public engagement on new water withdrawals • Notification for withdrawal permits but not registrations
3.2.8.2.2	Include HVHF operators in water users committees
3.2.8.2.3	Incentivize the organization of water resources assessment and education committees
3.2.8.2.4	Require notifying the public about new high-capacity wells

3.3 WASTEWATER MANAGEMENT AND WATER QUALITY	
3.3.5 DEEP WELL INJECTION	
3.3.5.2.1	Keep existing Michigan policy for deep well injection • DEQ and USEPA manage Class II disposal wells for the disposal of flowback fluids
3.3.5.2.2	Increase monitoring and reporting requirements
3.3.5.2.3	Obtain primary authority over Class II well oversight by the state
3.3.5.2.4	Require use of Class I hazardous industrial waste disposal wells
3.3.6 WASTEWATER RECYCLING	
3.3.6.3.1	Keep existing Michigan policy for wastewater recycling • Deep-well injection of all flowback fluids is the sole defined regulatory option for wastewater management
3.3.6.3.2	Provide options for wastewater recycling
3.3.6.3.3	Use alternative water sources for HVHF

CHAPTER 4: POLICY OPTIONS FOR CHEMICAL USE

4.2 INFORMATION POLICY

4.2.2 CURRENT INFORMATION POLICY	
CHEMICAL USE	**Subject of disclosure:** hazardous constituents
	Means of disclosure: permit application; information posted on FracFocus
	Timing of disclosure: before HVHF and within 30 days of well completion
	Trade secret claim review: statement of claim; must use family name or other description
WELL INTEGRITY	**Pressure monitoring:** monitored during HVHF and reported immediately to state if problem; HVHF ceases until plan of action implemented; report all data within 60 days of completing operations
	Mechanical integrity test: when monitoring during HVHF indicates problem
WATER QUALITY	**Water source:** groundwater
	Area around well: ¼-mile radius around well
	Number of sources tested: up to 10
	Frequency of testing: baseline test, >7 days but <6 months prior to drilling of new well or HVHF of existing well
	Test results: within 45 days to state and owner; immediate report of BTEX to state

4.2.4.1 OPTION A: INFORMATION POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH	
CHEMICAL USE	**Subject of disclosure:** hazardous constituents
	Means of disclosure: MSDS on state website
	Timing of disclosure: within 60 days
	Trade secret claim review: none
WELL INTEGRITY	**Pressure monitoring:** monitored and reported within 60 days
	Mechanical integrity test: none
WATER QUALITY	**Water source:** none
	Area around well: none
	Number of sources tested: none
	Frequency of testing: none
	Test results: none

4.2 INFORMATION POLICY *continued*

4.2.4.2 OPTION B: INFORMATION POLICY EMPLOYING AN ADAPTIVE APPROACH

CHEMICAL USE	**Subject of disclosure:** all constituents; plain-language description
	Means of disclosure: master list; state website; FracFocus
	Timing of disclosure: no change
	Trade secret claim review: careful scrutiny of claims
WELL INTEGRITY	**Pressure monitoring:** monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; HVHF ceases until plan of action implemented
	Mechanical integrity test: periodic tests through life of operating well
WATER QUALITY	**Water source:** groundwater and surface water
	Area around well: based on characteristics of aquifer/watershed
	Number of sources tested: part of larger monitoring system in area
	Frequency of testing: baseline test; long-term regular monitoring
	Test results: within 10 days to state, owner and public; immediate report of contaminants of concern

4.2.4.3 OPTION C: INFORMATION POLICY EMPLOYING A PRECAUTIONARY APPROACH

CHEMICAL USE	**Subject of disclosure:** all constituents; plain-language description of risks and alternatives; studies
	Means of disclosure: permit application; state website
	Timing of disclosure: before HVHF
	Trade secret claim review: full information provided to state
WELL INTEGRITY	**Pressure monitoring:** monitored during HVHF and reported immediately to state and nearby landowners if problem; status placed on website; operator must demonstrate integrity before continuing
	Mechanical integrity test: prior to approval of HVHF; when monitoring indicates a problem
WATER QUALITY	**Water source:** groundwater and surface water
	Area around well: based on characteristics of aquifer/watershed
	Number of sources tested: based on importance of sources to be protected
	Frequency of testing: baseline test; long-term continuous monitoring of critical sources
	Test results: prior to approval of well and within 10 days to state, owner, and public; immediate report of all contaminants

4.3 PRESCRIPTIVE POLICY

4.3.2 CURRENT PRESCRIPTIVE POLICY

RESTRICTIONS ON CHEMICAL USE	**Restrictions:** none
LIMITATIONS ON SITING	**Object of siting:** oil or gas well; surface facility
	Distance: 300 feet; 800-2,000 feet
	Resource protected: freshwater wells; public water supply wells
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** casing and cementing requirements
	Area of review analysis: within 1,320 feet; relocation, demonstration of no movement, or other preventative actions
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** flowback stored in tanks or approved containers; secondary containment for production wellheads and surface facilities, including flowback storage tanks; tanks monitored for leaks

4.3.4.1 OPTION A: PRESCRIPTIVE POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH

RESTRICTIONS ON CHEMICAL USE	**Restrictions:** none
LIMITATIONS ON SITING	**Object of siting:** no change
	Resource protected: no change
	Distance: no change
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** no change
	Area of review analysis: no change
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** no substantive change

4.3.4.2 OPTION B: PRESCRIPTIVE POLICY EMPLOYING AN ADAPTIVE APPROACH

RESTRICTIONS ON CHEMICAL USE	**Restrictions:** list of prohibited chemicals, amended over time
LIMITATIONS ON SITING	**Object of siting:** oil or gas well site and storage areas, modified over time based on risks of activity
	Resource protected: particularly sensitive features, modified over time based on new findings/best practices
	Distance: change over time based on new findings/best practices
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** current requirements, modified over time based on groundwater monitoring data/best practices
	Area of review analysis: within area affected by HVHF; corrective action modified over time based on groundwater monitoring data/best practices
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** flowback stored in pits or tanks; modified over time based on leakage data/ best practices

4.3.4.3 OPTION C: PRESCRIPTIVE POLICY EMPLOYING A PRECAUTIONARY APPROACH	
RESTRICTIONS ON CHEMICAL USE	**Restrictions:** approval of chemicals only if applicants demonstrate low toxicity
LIMITATIONS ON SITING	**Object of siting:** oil or gas well; storage and handling areas
	Resource protected: all potentially affected natural resources
	Distance: varies by feature with additional cushion; no siting in protected areas
CONTROLS ON GROUNDWATER RISK	**Well construction requirements:** additional requirements that create as many layers of safety as feasible
	Area of review analysis: within drilling unit or larger area; relocation of well unless no risk from conduits
CONTROLS ON SURFACE RISK	**Handling of flowback and chemical additives:** closed loop system for chemical additives, flowback; additive handling restrictions

4.4 RESPONSE POLICY

4.4.2 CURRENT RESPONSE POLICY	
EMERGENCY PLANNING	**Emergency response plan:** hydrogen sulfide wells; to state
REPORTING AND CLEANUP	**Notification:** all spills of chemical additives and fracturing fluid; larger spills of flowback reported within 8 hours; exception for small spills of flowback that can be quickly contained; to state and surface owners
	Remediation standard: general cleanup criteria
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** $30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** State common law
	Presumption: none
	Remedy: State common law

4.4.4.1 OPTION A: RESPONSE POLICY EMPLOYING MICHIGAN'S PREVIOUS APPROACH	
EMERGENCY PLANNING	**Emergency response plan:** no change
REPORTING AND CLEANUP	**Notification:** no change
	Remediation standard: no change
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** no change
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** no change
	Presumption: no change
	Remedy: no change

4.4.4.2 OPTION B: RESPONSE POLICY EMPLOYING AN ADAPTIVE APPROACH	
EMERGENCY PLANNING	**Emergency response plan:** HVHF wells in sensitive areas; policy modified over time based on spill data; to state, surface owners, nearby residents
REPORTING AND CLEANUP	**Notification:** all spills; larger spills reported immediately; threshold modified over time based on spill data; to state, surface owners, nearby residents
	Remediation standard: general cleanup criteria; criteria modified over time based on long-term monitoring data
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** no blanket bonds; modify individual bond amount over time based on restoration costs
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** all spills into groundwater
	Presumption: for liability if do not monitor environment around well
	Remedy: remediation; modified over time based on long-term monitoring

4.4.4.3 OPTION C: RESPONSE POLICY EMPLOYING A PRECAUTIONARY APPROACH	
EMERGENCY PLANNING	**Emergency response plan:** all HVHF wells; includes preventative considerations; to state, surface owners, and public
REPORTING AND CLEANUP	**Notification:** immediate reporting of all spills; to state, surface owners, and public
	Remediation standard: restoration of environment
FINANCIAL RESPONSIBILITY	**Bonds and insurance:** individual well bond to $250,000; liability insurance
LIABILITY TO PRIVATE PARTIES	**Type of contamination:** all spills
	Presumption: strict liability unless operator can demonstrate caused by other sources
	Remedy: restoration of environment