HYDRAULIC FRACTURING IN MICHIGAN

INTEGRATED ASSESSMENT

DRAFT FINAL REPORT

FEBRUARY 2015

UNIVERSITY OF MICHIGAN

Participating University of Michigan Units

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

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

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ABOUT THIS DRAFT REPORT

This draft report 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 to address that question in a way that 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 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 (Graham Institute) in September 2013. This document is a draft version of the final report for the IA and is a work in progress. Because it is a work in progress, it is incomplete and subject to revision. The content does not reflect a consensus position and is not intended to limit on-going discussions, revisions, or preclude new options from being considered. This is not an official document and as such, this document is not to be quoted, cited in any reference, or used by anyone for any purpose other than as a draft document.

Topics covered in this report have been informed by the technical reports, input from an advisory committee with representatives from corporate, governmental, and non-governmental organizations, and a review of numerous public comments received throughout this process. However, the draft report does not necessarily reflect the views of the advisory committee or of all public comments received to date. In addition, this draft document does not yet reflect detailed input from a peer review panel, the advisory committee, or the general public. Those reviews and public comment processes are currently underway and will be fully considered as the Graham Institute prepares the final version of the report. As with preparation of the technical reports, all decisions regarding content of project analyses and reports will be 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) in Michigan (the technical reports) and an analysis of policy options (this report) there are certain limitations which must be recognized. First, 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 limited available data–particularly baseline data. Second, the assessment does not provide 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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EXECUTIVE SUMMARY

OVERVIEW

There is significant momentum behind natural gas extraction efforts in the United States, with many individual states embracing it as an opportunity to create jobs and foster economic strength. Natural gas extraction has also been championed as a way to move toward domestic energy independence 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 recent years, however, the hydraulic fracturing process and associated shale gas activities have come under increased public scrutiny – particularly with respect to high volume hydraulic fracturing (HVHF), which uses substantially more water and materials to complete the process. Concerns include perceived lack of transparency, chemical contamination from fracturing fluids, water availability, wastewater disposal, and 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 University of Michigan (U-M) Graham Sustainability Institute over a one year time frame (June 2011-June 2012) and involved conversations with several other 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 dialog 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 better prepare decision makers in addressing the question. 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 Integrated 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.

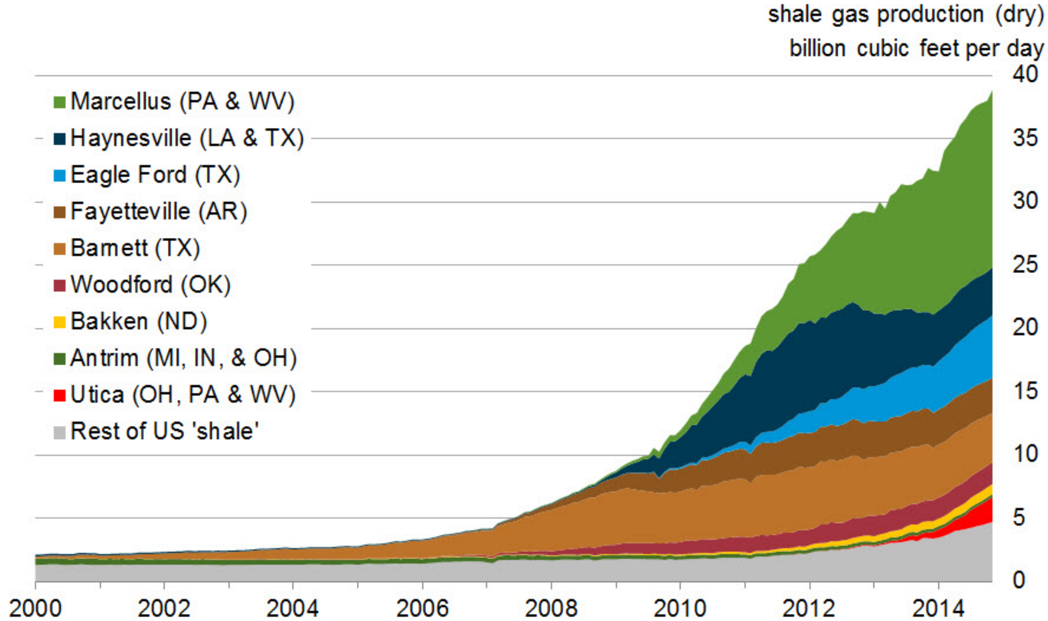
High volume hydraulic fracturing intersects many issues that are important to Michigan residents—drinking water, air quality, water supply, local land use, energy security, economic growth, tourism, and natural resource protection, including the Great Lakes. The project does not seek to predict a specific future for HVHF in Michigan, but it posits that natural gas extraction pressures will likely increase in Michigan if the following trends persist: desire for job creation, economic strength, energy independence, and decreased use of coal.

The guiding question—*What are the best environmental, economic, social, and technological approaches for managing hydraulic fracturing in the State of Michigan?*—bounds the scope of the IA. While the IA focuses on Michigan 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 Michigan Department of Environmental Quality guidelines as well completions that intend to use a total of more than 100,000 gallons of hydraulic fracturing fluid), but the analysis of options may also consider implications for other practices or include options for different subsets of wells.

Recent interest from energy developers, lease sales, and permitting activities suggest increasing activity around deep shale gas extraction in Michigan. Below are some key points regarding hydraulic fracturing in Michigan.

- According to the Michigan Department of Environmental Quality (DEQ), over the past several decades more than 12,000 oil and gas wells have been fractured in the state and regulators report no instances of adverse environmental impacts.[2] Most of these are Antrim Shale vertical wells drilled and completed in the late 1980s and early 1990s. Some new activity will still take place, and a very small number of the old wells may be hydraulically fractured in the future, but this is a "mature" play and is unlikely to be repeated.
- The hydrocarbon resources in the Utica and Collingwood Shales in Michigan will likely require high volume hydraulic fracturing and 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 horizontally through the target formation).
- A vertical well that is hydraulically fractured in Michigan may typically use about 50,000 to 100,000 gallons of water while a high volume, horizontally drilled well may use up to 20,000,000 gallons of water or more.[3]
- A May 2010 auction of state mineral leases brought in a record $178 million—nearly as much as 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.[4,5] However, there has been limited production activity in response to these leases.
- As of December 22, 2014, there were 13 producing HVHF completed wells in Michigan, 2 active applications, 28 active permit holders, 5 locations with complete plugging, and 11 locations with completed drilling.[6]
- 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 1.1).
- Several bills have been proposed in Michigan to further regulate or study hydraulic fracturing,[7] state officials are proceeding with promulgation of additional rules on high volume hydraulic fracturing,[8] and a ballot question committee has been working to prohibit the use of horizontal hydraulic fracturing in the state.[9]

Figure 1.1: U.S. dry shale gas production[10]



Terminology is important to any discussion of shale gas and 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 of the full report.

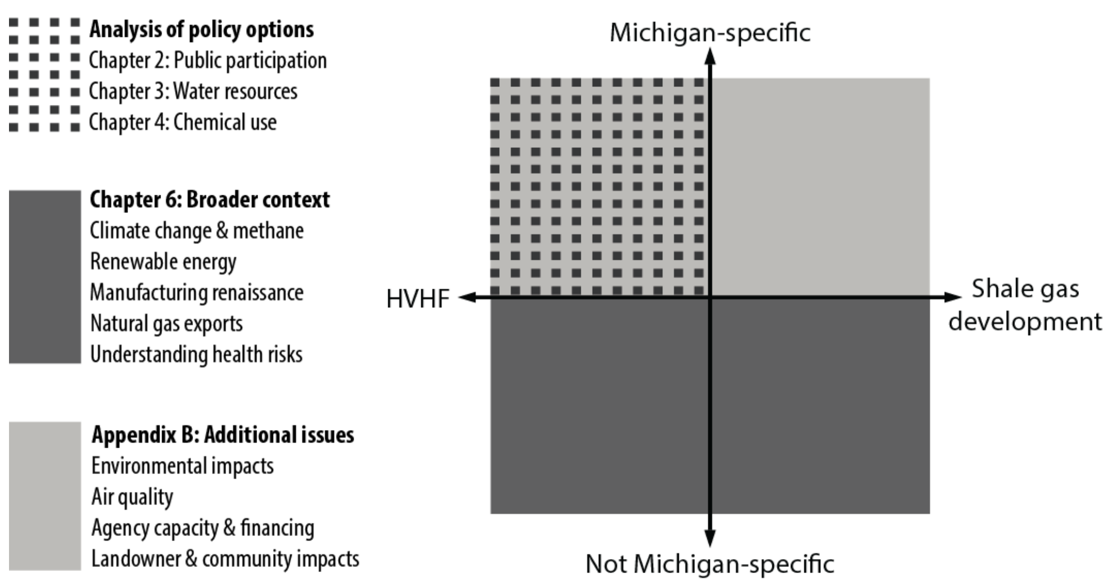
- **Conventional and Unconventional Natural Gas:** Natural gas comes from both "conventional" (easier to produce) and "unconventional" (more difficult to produce) geological formations. The key difference between "conventional" and "unconventional" natural gas is the manner, ease, and cost associated 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.[11] 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.[12]
- **Shale Gas:** Natural gas produced from low permeability shale formations.[13]
- **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:** High volume hydraulic fracturing well completion is defined by State of Michigan regulations as a "well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid."[14,15]

Chapter 1 of the full 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 primarily HVHF policy options specific for Michigan in the areas of public participation, water resources, and chemical use. Chapter 5 provides a frame for analyzing all the new policy options presented in Chapter 2 (public participation), Chapter 3 (water resources) and Chapter 4 (chemical use). Using adaptive and precautionary policy frames, this chapter categorizes policy options by their approach to uncertainty in order to help identify options appropriate for several plausible futures or conditions with respect to high volume hydraulic fracturing in Michigan. Chapter 6 provides an overview of key points of discussion within the broader context of shale gas development that are not specific to Michigan. Chapter 7 identifies the limits of this report and knowledge gaps. Appendix B offers a review of additional shale gas development issues that are relevant to Michigan but not specific to HVHF.

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.

The technical reports and public comments also include other issues related, but not specific, to HVHF activity in Michigan. While these issues are beyond the focus of this IA, they are important at geographic scales beyond Michigan and for unconventional shale gas development more generally. Therefore, a concise summary of key topics in the broader context and national discourse related to expanded natural gas production and use is provided in Chapter 6, and information about additional issues related to shale gas development but not HVHF-specifically is included in Appendix B. Figure 1.2 illustrates the organization of the full report around its focus on HVHF in Michigan.

Figure 1.2: Report organization



ANALYSIS OF POLICY OPTIONS

Chapters 2 through 4 present an analysis of HVHF options specific for Michigan in the areas of public participation, water resources, and chemical use. Within each chapter an overview of the topic is provided along with a description of current policy in Michigan, new HVHF rules proposed by the state, and a range of 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 related conditions which are addressed.

Public Participation

"Public participation" has been interpreted in many ways. In the context of public policy, it often takes the form of public comment periods and hearings, where the public might be described as having a consultative role. Other forms of public participation such as moderated workshops and deliberative polling may allow for more interactive discussions that encourage collaborative decision making. Although no unified theory of public participation exists, scholars generally agree that good public participation should:

(1) Lead to higher-quality decisions by appropriately incorporating stakeholder information and values,
(2) Be legitimate and perceived as fair,
(3) Reduce conflict and build trust in institutions,
(4) Lead to a shared understanding of the issues, and
(5) Improve the capacity of all parties to engage in the policy-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. By contrast, 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.

The public participation chapter examines options for improving how public values and concerns are incorporated into HVHF-related policy. The first subsection explores this question broadly by looking at how public values inform unconventional shale gas policies, in general, and what opportunities exist for improvement. The remaining two subsections examine how public interests are represented in state land leasing decisions and well permitting as both affect a question of primary importance to the public: where will HVHF occur?

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 land leasing and well permitting practices (which will be discussed in the next two sections), the state could consider implementing a number of options to better represent public values in unconventional shale gas policies. As a first step toward building the public's trust and signaling that public concerns have been heard, the state could revise the content and usability of the DEQ website as well as require risk communication training for DEQ and DNR staff. DEQ could augment these efforts by providing 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. Information generated during these discussions may help ease some of the public's concerns as well as inform state decision making.

To help ensure that potential impacts to human health, the environment, and local communities are adequately considered in HVHF policies, the state could increase stakeholder representation on the Oil and Gas Advisory Committee as well as appoint a multi-stakeholder advisory commission to further study the potential impacts of HVHF in Michigan. Finally, to ease tensions around HVHF and provide an opportunity to engage the public in more analytic-deliberative discussions about unconventional shale gas development, the state could impose a moratorium or ban on HVHF permitting.

Michigan's existing policy of requiring public notice and comment before auctioning state mineral rights has been reasonably responsive to public concerns. The existing policy could be strengthened, however, by 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, and/or requiring public notice and comment when well operators request modifications of existing state land leases. Each of these steps could enhance transparency about state land leasing as well as increase the likelihood that the DNR's decisions will be informed by relevant environmental, health, and community considerations.

Michigan's existing policy for involving the public in well permitting decisions is more inclusive that 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 that should be legitimately considered in DEQ's decision making. Increasing public notice, requiring a public comment period, and allowing adversely affected parties to petition for a public hearing are all options that can help address these concerns. To be most effective, these options should be implemented together.

The policy options addressed in Chapter 2 – Public Participation are listed in Table 1.1. The descriptions are not complete; refer to the chapter section for additional detail.

Table 1.1: Policy options for public participation and incorporating public values into shale gas development policy

Incorporating public values in unconventional shale gas development policy	
2.2.3.1	Keep existing Michigan policy for public engagement
	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 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
Public input in state land leasing	
2.3.3.1	Keep Michigan's existing state land leasing policy
	NRC and DNR manage state-owned lands and mineral resources; 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 or within ¼ mile of parcel; notification at parcel itself if near a recreational area
2.3.3.3	Require DNR to prepare a responsiveness summary
2.3.3.4	Require public workshops prior to state land auctions
2.3.3.5	Increase public notice and comment when lessees submit an application to revise or reclassify a lease
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	Allow adversely affected parties to request a public hearing before a HVHF well permit is approved

Water Resources

High volume hydraulic fracturing requires large quantities of water for its operation and these numbers are often a source of concern for many citizens when it comes to thinking about the potential impacts caused by HFHV. The State of Michigan has a well-developed system for the management of water withdrawals, the (Water Withdrawal Assessment Process) WWAP, which was developed as part of the Great Lakes Compact, and instituted in 2009. The WWAP offers a unified mechanism of managing HVHF operations, by managing the water resources of the State. The management of water resources as a central means of managing HVHF operations is currently utilized by both the DRBC and the SRBC. In the same vein, the WWAP provides a singular mechanism for managing HVHF operations by recognizing that their water needs can also fall under the purview of the WWAP, just like all other large-scale water uses in the state.

The water resources chapter is organized into two major sections. The first explores the various methods in which improvements to 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 Water Use Advisory Council. The second section explores regulatory rules changes concerning waste management of water used in HVHF.

As sophisticated as the WWAP is in governing water withdrawals, it was not designed to address the specific issues of water withdrawals associated with HVHF, which means that—in order to effectively use the state's core mechanism for water conservation—the various parts of the WWAP need to be updated and modified in order to address the unique technical, physical, and social challenges presented by HVHF. The different parts of WWAP address different issues associated with water quantity governance, and this section presented different policy options to deal with each of them. Two general means of addressing water quantity governance were provided: enacting changes to the WWAP that would specifically include HVHF and treat it no differently from other water withdrawals or putting policies in place that specifically address only HVHF water withdrawals, specifically to assuage public concerns over the water volumes associated with HVHF operations. The thresholds for regulation could be altered to ensure the inclusion of HVHF water withdrawal operations. These changes could have negative consequences on certain types of water users, but they will also have the benefits of increasing the strength and quality of water conservation throughout the state. The scientific models underlying the central piece of the WWAP—the water withdrawal assessment tool—can be improved in various ways in order to broaden the types of water withdrawals for which it can predict associated impacts as well as to expand its capacity to model impacts to inland lakes, ponds, and wetlands (hydric systems that are not currently included the models). While these improvements will require additional public investments, the long-term benefits of these investments will be a far more predictive, automated, and equitable water governance structure. Furthermore, improvements to the existing public engagement structures outlined in the

WWAP—specifically WUCs and Water Resources Education Advisory Committees—can help develop local water use governance, especially in cases where water resources approach an adverse resource impact (ARI) designation.

In addition to modifying and updating the existing WWAP structure, a number of additions to the WWAP are presented in this section. Options such as fee schedules, like those used by the Susquehanna and Delaware River Basin Commissions could be implemented to fund and improve water governance mechanisms and structures within the state. In addition, providing opportunities for the public to provide monitoring information to the DEQ allows for civic engagement at little additional governmental cost. Finally, discussion of implementation of a water-use market is presented, which could provide options for minimizing additional water withdrawals by HVHF operations through financial agreements with existing water-withdrawal registrants over the use of a portion of their registered water withdrawals.

The future of water uses in the State of Michigan will undoubtedly become more complex, and the process of governing the state's water resources to ensure they align with the requirements of the Great Lakes Compact will simultaneously require modification. The WWAP provides a unique mechanism for addressing most water conservation decisions through an automated, scientifically based, free online tool as well as a system of human-based reviews for areas with heightened scrutiny in addition to a system of local decision making over water uses. It is necessary to recognize that the current WWAP was meant as only an initial version of an increasingly sophisticated water governance framework. High-volume hydraulic fracturing presents a challenge for the current version of the WWAP, but it is one that can – with sufficient applications of policy options – be addressed effectively without the need of building a completely new water conservation structure.

Presently, the wastewater management and water quality policies of the State of Michigan have been mostly 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 high volume hydraulic fracturing, 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 per well to handle from historic small-scale fracturing operations, a future with high-volume hydraulic fracturing will create hundreds-of-thousands (and possibly millions) of gallons of wastewater; one hundred to one thousand times more than historic wells.

A future with high volume hydraulic fracturing in the State of Michigan should be met with the understanding of the vastly different implications associated with high volume hydraulic fracturing. Providing additional safeguards will provide better protection of public drinking water supplies and the sources of water for many of the state's prime fishing rivers. Furthermore, providing additional options for managing wastewater use and alternative sources for water acquisition will provide well operators with a means of minimizing the local negative impacts of water withdrawals as well as providing potential economic savings in the operations of the 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 State Law, it requires the disposal of hydraulic fracturing fluids into Class II 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 provide 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. The State of Michigan also does not allow for the use of treated municipal wastewater as the water source for hydraulic fracturing operations, even though this can be used an alternative water source. Providing opportunities for recycling wastewater and using alternative water resources both hold potential benefits of improved water quality, through diminished demands for groundwater resources. However, neither of these are a total panacea, as they both carry associated environmental risks and costs.

The policy options addressed in Chapter 3 – Water Resources are listed in Table 1.2. Refer to the chapter section for a complete description of each policy option.

Table 1.2: Policy options for water resources

<u>Regulating HVHF by modifying the WWAP</u>	
Requirements for water withdrawal approval	
3.2.1.3.1	Keep existing Michigan policy for water withdrawal approval
	No cumulative water withdrawals in subwatershed units may cause an adverse resource impact (ARI)
3.2.1.3.2	Remove the HVHF exemption from the WWAP
3.2.1.3.3	Disallow HVHF operation approaching an ARI (Michigan proposed rule)
3.2.1.3.4	Adopt additional rules for proposed water withdrawals (Michigan proposed rule)
	Requires provision of well logs of recorded and reasonably identifiable fresh water wells within a certain distance; permit applicants required to show the locations of proposed withdrawal wells along with recorded wells, reasonably identifiable wells, and proposed fresh water pit impoundment and containment facilities; must also provide a contingency plan if deemed necessary
3.2.1.3.5	Disallow any HVHF operations within a cold-transitional system
3.2.1.3.6	Overestimate proposed HVHF water withdrawals
Water withdrawal regulation thresholds	
3.2.2.3.1	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)

3.2.2.3.2	Lower thresholds for regulation	
3.2.2.3.3	Increase water use reporting frequency	
		Require reporting and $200 reporting fee every 30 days for HVHF withdrawals (currently required annually)
3.2.2.3.4	Set a total volumetric water withdrawal limit	
Improvements to the WWAT		
3.2.3.1.1	Keep existing Michigan WWAT	
		The current WWAT reflects water quantity measures, regulatory subwatersheds, and Policy Zone determinations from 2008
3.2.3.1.2	Update the scientific models of WWAT	
		Increase data collection; use mechanistic models; include lakes and wetlands
3.2.3.1.3	Implement a mechanism for updating the models underlying WWAT	
Water withdrawal fee schedules		
3.2.4.3.1	Keep existing Michigan water withdrawal fees	
		HVHF operators are exempted from the WWAP and pay no water withdrawl fees
3.2.4.3.2	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
Water withdrawal permitting		
3.2.5.3.1	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)
3.2.5.3.2	Open option to obtain a large-scale water withdrawal permit	
3.2.5.4.1	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 WWAT
Transfer/sale/lease of water withdrawals		
3.2.6.3.1	Keep existing Michigan policy for transfer/sale/lease of water withdrawals	
		Ambiguity regarding whether registered or permitted water withdrawals can be used by someone other than the registrant
3.2.6.3.2	Provide a mechanism to transfer, sell, lease registered/permitted water withdrawals	
3.2.6.4.1	Prohibit transfer or use of registered water withdrawals to HVHF operations	
Additional monitoring		
3.2.7.2.1	Keep existing Michigan policy for monitoring	
		Site-specific review may be conducted when adverse resource impact is suspected, in a Policy Zone C subwatershed unit, or proposed withdrawal would cause a Policy Zone C or D
3.2.7.2.2	Install additional monitoring wells in the presence of other water withdrawal wells (Michigan proposed rule)	
		If one or more fresh water wells are within 1,320 feet of a proposed large

	volume water withdrawal, permittee must install a monitoring well and record the water level daily during withdrawal and weekly afterwards until the water level stabilizes
3.2.7.2.3	Collect baseline groundwater data (Michigan proposed rule)
	HVHF permittees and applicants required to collect baseline samples from all available water sources (up to 10), within a ¼-mile radius
3.2.7.2.4	Require site specific reviews for all HVHF water withdrawal proposals
3.2.7.2.5	Provide a mechanism to use private monitoring
Public engagement on new water withdrawals	
3.2.8.3.1	Keep existing Michigan policy for public engagement on new water withdrawals
	Notification for withdrawal permits but not registrations
3.2.8.3.2	Organize water users committees
3.2.8.3.3	Organize water resources assessment and education committees
3.2.8.3.4	Require public notice on new high-capacity wells
3.2.8.4.1	Report to the Supervisor of Wells (Michigan proposed rule)
	Requires approval from Supervisor of Wells before withdrawing a large volume of water for HVHF
Wastewater management and water quality	
Deep well injection	
3.3.5.2.1	Keep existing Michigan policy for deep well injection
	DEQ and USEPA responsible for management of 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	Require use of Class I hazardous industrial waste disposal wells
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

Chemical Use

The chemical substances associated with HVHF activities are numerous and may be found at every point in the process. For example, between 2005 and 2011, the EPA identified over 1,000 different chemicals that were either used in fracturing fluids or found in associated wastewaters. 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, as well as in other jurisdictions currently engaging in HVHF.

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. In its strongest form, the precautionary approach would counsel banning an activity that could result in severe harm. The second is to adopt an adaptive approach. Based on the principles of adaptive management, policymakers may choose to take some regulatory action at the outset, and continually refine the response as further information becomes available. 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.

The chemical use chapter 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 or set a performance standard; and response policies manage any contamination through emergency planning, cleanup, and liability requirements. For each type of tool, Michigan's existing policies are described and a range of policies adopted by other states are presented. Building on the three approaches to uncertainty, combinations of policy options are offered and compared to the proposed rules.

U.S. states have focused much of their policy attention on gathering information about chemical use in hydraulic fracturing through reporting and monitoring requirements. While the focus may be on increasing transparency between the operator and the state (through such mechanisms as chemical disclosure websites and/or Material Safety Data Sheets (MSDS)), 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.

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.

Information policy responds to scientific uncertainty about risk by gathering information on chemical hazards and the potential for human and ecological exposure. State objectives for collecting information depend on the policy approach. Under a precautionary approach, states collect information on threats prior to HVHF to set preventative limits on the location, construction, and operation of the HVHF well or to decide whether to allow HVHF at all. Under an adaptive approach, states continually collect information so that over time they can better understand risk and refine their HVHF policies. Under a remedial approach, states collect information after HVHF to respond to contamination and to ensure HVHF well operators are held liable for any damage.

Information policy also may respond to public uncertainty about risk by helping members of the public both participate in the democratic process and make individual decisions about property and health. Under a precautionary approach, members of the public use information to participate in setting preventative limits and also to take actions prior to HVHF to reduce the potential for individual exposure. Under an adaptive approach, members of the public use information to participate in the refinement of policies and also to change their behavior over time, such as determining whether to continue to drink water from wells. Under a remedial approach, members of the public use information to take actions to minimize their exposure to contamination and also to decide whether to seek compensation from a well operator.

Michigan's current information policy, as in several other states, responds to uncertainty through a remedial approach. Information on hazardous chemicals, when combined with well pressure records, are primarily useful in helping the state to identify the source of any contamination. Broad trade secret protection and lack of monitoring data on water quality make it difficult for the state to use the information in an adaptive way to refine policies. Members of the public are also unlikely to use the information to change their behavior. While the MSDSs provide more information on the hazards of chemicals than does a list of chemical constituents of additives, the sheets are written for trained employees and focus on the risks to workers.

The state has traditionally used prescriptive approaches-or 'command and control' regulation-as a mechanism to influence and shape behavior. Unlike information policy, states have not been uniform in their attention to prescriptive requirements that restrict or control aspects of hydraulic fracturing. As the chapter on chemical use illustrates, legislation and regulation can lag behind technological advances. As such, the opportunity to craft a suite of prescriptive regulatory requirements tailored specifically for various activities associated with HVHF currently exist in Michigan, as well as a number of other states.

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.

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 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 flexible 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.

Like most states, Michigan has adopted all three approaches in its prescriptive policies. Michigan's well integrity requirements and surface controls are primarily adaptive, made more flexible by the discretion given to permitting staff to set conditions for well construction and surface pad construction under state rules. Yet Michigan also uses both a precautionary approach in its area-of-review analysis and in requiring tanks for flowback, and a remedial approach in mandating secondary containment measures for storage tank areas. Finally, Michigan has adopted precautionary setback requirements for groundwater drinking sources.

Spills, or accidental release, of chemicals used in HVHF activities, and the implications of exposure to these chemicals on humans and the environment, have engendered significant debate and concern among stakeholders and the public generally. Such concern has been, arguably, fueled by a lack of comprehensive policies addressing emergency planning for dealing with chemical discharge, liability for contamination, and public transparency. As with all other facets of HVHF activities, the state has the ability to introduce policies specifically tailored to address emergency planning, and operator response, in the event that spills and/or release occur.

State spill response policies primarily focus on three areas:

(1) Planning for emergencies;
(2) Cleanup of spills and releases; and
(3) Imposing liability for contamination.

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 happen, and seek to minimize harm and hold actors responsible.

Most states, including Michigan, have adopted a remedial approach. The primary response policy is to require oil or gas well operators to promptly report and clean up after incidents. Bonds ensure that the state can recover at least some costs if an operator refuses or is not able to pay for remediation. And in some of the states, operators are also liable to private surface owners for damage to the surface environment, including damage from spills and releases. While Michigan does not have a statute on surface damages, operators are liable under common law.

Table 1.3 presents a list of the policy options addressed in Chapter 4 – Chemical Use. Note that the policy options considered in this chapter contain a combination of multiple policy elements. Refer to the chapter section for a more detailed description.

Table 1.3: Policy options for chemical use

Information policy		
4.2.2 Existing Michigan policy		
	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 construction	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
4.2.4.1 Option A: Michigan's proposed rules		
	Chemical use	Subject of disclosure: all constituents
		Means of disclosure: permit application; FracFocus
		Timing of disclosure: before HVHF and within 30 days after HVHF
		Trade secret claim review: statement of claim; must use family name or other description
	Well construction	Pressure monitoring: monitored and reported immediately to state if problem; HVHF ceases until plan of action implemented
		Mechanical integrity test: when monitoring 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: once, >7 days but <6 months prior to drilling of new well or HVHF of existing well
		Test results: within 45 days; immediate notification of contaminants of concern; to state and owner
4.2.4.2 Option B: Adaptive approach		
	Chemical use	Subject of disclosure: all constituents; plain-language description
		Means of disclosure: master list; state website; FracFocus
		Timing of disclosure: before and within 30 days after HVHF
		Trade secret claim review: narrow exception for trade secrets
	Well construction	Pressure monitoring: monitored and reported immediately to state and nearby landowners if problem; status on website; HVHF ceases until plan of action implemented
		Mechanical integrity test: 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: part of larger monitoring system in area

	Water quality	Frequency of testing: baseline test; long-term regular monitoring
		Test results: within 10 days; immediate notification of contaminants of concern; to state, owner, and public (through website)
4.2.4.3	Option C: 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 construction	Pressure monitoring: monitored and reported immediately to state and nearby landowners if problem; status on website; HVHF ceases until operator demonstrates integrity
		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: variable, based on importance of sources
		Frequency of testing: baseline test; long-term regular monitoring
		Test results: prior to approval of well and within 10 days; immediate notification of contaminants of concern; to state and owner
Prescriptive policy		
4.3.2	Existing Michigan policy	
	Restrictions on chemical use	None
	Limitations on siting	Siting: oil or gas well; storage tanks at surface facility
		Feature: freshwater wells; public water supply wells
		Distance: 300 feet; 800-2000 feet
	Controls on groundwater risk	Construction requirements: casing and cementing requirements
		Area of review analysis: wells within 1,320 feet; must relocated well, demonstrate no contamination, or take other actions
	Controls on surface risk	Flowback and chemical additives: “brine” (including flowback) stored in tanks
		Secondary containment: storage tanks at surface facility
4.3.4.1	Option A: Michigan's proposed rules	
	Restrictions on chemical use	None
	Limitations on siting	Siting: no change
		Feature: no change
		Distance: no change
	Controls on groundwater risk	Construction requirements: no change
		Area of review analysis: no change

	Controls on surface risk	Flowback and chemical additives: clarification that flowback stored in tanks
		Secondary containment: no change
4.3.4.2	Option B: Adaptive approach	
	Restrictions on chemical use	List of prohibited chemicals, amended over time
	Limitations on siting	Siting: oil or gas well site; storage tanks
		Feature: particularly sensitive features
		Distance: change over time based on new findings/best practices
	Controls on groundwater risk	Construction requirements: change over time based on new findings/best practices
		Area of review analysis: within area affected by HVHF; corrective action or monitoring of conduits
	Controls on surface risk	Flowback and chemical additives: flowback stored in tanks; monitor well site for leaks and spills
		Secondary containment: storage tanks at well site and surface facility
4.3.4.3	Option C: Precautionary approach	
	Restrictions on chemical use	Approval of chemicals only if reduced toxicity
	Limitations on siting	Siting: all related facilities
		Feature: all potentially affected water resources
		Distance: larger setback; protected areas
	Controls on groundwater risk	Construction requirements: strict requirements for several levels of safety
		Area of review analysis: within area affected by HVHF; relocate well unless no risk from conduits
	Controls on surface risk	Flowback and chemical additives: closed loop system for chemical additives, flowback; additive handling requirements
		Secondary containment: entire well site and surface facility
Planning, response, and liability policy		
4.4.2	Existing Michigan policy	
	Emergency Planning	Emergency response plan: hydrogen sulfide wells
	Cleanup	Notification: all losses or spills of chemical additives and “brine,” which includes flowback; larger spills reported within 8 hours; to state
		Standard: not specified; other cleanup standards could apply
		Bonds and insurance: $30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance
	Liability	Type of contamination: losses and spills of brine, which includes flowback
		Presumption: none
		Remedy: clean up

4.4.4.1 Option A: Michigan's proposed rules		
	Emergency Planning	Emergency response plan: no change
	Cleanup	Notification: no change
		Standard: no change
		Bonds and insurance: no change
	Liability	Type of contamination: no change
		Presumption: no change
		Remedy: no change
4.4.4.2 Option B: Adaptive approach		
	Emergency Planning	Emergency response plan: HVHF wells in sensitive areas; adapt plans over time
	Cleanup	Notification: all losses or spills; larger spills reported immediately; to state and public
		Standard: remediation and long-term monitoring
		Bonds and insurance: eliminate blanket bonds
	Liability	Type of contamination: spills of chemical additives and flowback into groundwater
		Presumption: for liability if do not monitor environment around well
		Remedy: remediation and long-term monitoring
4.4.4.3 Option C: Precautionary approach		
	Emergency Planning	Emergency response plan: all HVHF wells
	Cleanup	Notification: immediate reporting of all losses or spills to state and public
		Standard: restoration of environment
		Bonds and insurance: increase individual well bond to $250,000; liability insurance
	Liability	Type of contamination: all spills of chemical additives and flowback
		Presumption: strict, joint and several liability
		Remedy: restoration of environment

Policy Framing Analysis

As noted in the section on chemical use, when there is scientific uncertainty about the risks of an activity, two common responses are to adopt an adaptive approach whereby some regulatory action is taken at the outset which can be refined as more information becomes available or a precautionary approach which seeks to control or prohibit activity which may cause harm. Using that adaptive/precautionary frame, policy options from the public participation, water resources, and chemical use sections are organized into four adaptive policy categories: no regrets, automatic adjustment, complex systems principles, and formal review. This should not be perceived as an absolute categorization but is meant to provide a useful approach for identifying and integrating policy options which might best fit different conditions or scenarios.

Adaptive Policy Options

- No Regrets*:* With respect to HVHF in Michigan, this includes policy options which deserve consideration regardless of the level of future conditions such as the price of natural gas, the level of activity in Michigan, new technological innovations, or new understandings of risks. A no regret policy does not imply no cost or administrative burden. No regrets options were identified across all three of the main policy areas – public participation, water resources, and chemical use.
- Automatic Adjustment: In reviewing the policy options regarding public participation, water resources, and chemical use, potential automatic adjustment policy options can be identified for all three major categories – public participation, water resources, and chemical use. These are options which are already developed but are not activated until a particular threshold is reached or activity takes place. Examples of relevant HVHF policy options include allowing permits to be challenged when there is evidence of adverse impacts, additional regulations based on levels of water withdrawals, the formation of a user committee once a particular water withdraw zone status is established, responding to monitoring results, and adjustments to siting based on proximity to sensitive features.
- Complex Systems Principles: A third category of adaptive policy are those policies which involve complex systems principles – or conditions which require examining multiple factors. For the options presented in this report there are only a few within the Water Resources chapter which can be categorized as adaptive policies employing complex systems principles such as developing a system for the transfer, sale or lease of water withdrawals by water users and novel approaches for wastewater recycling – both of which would require substantial review given the potential to increase surface contamination risks, water quality impacts, and additional truck traffic.
- Formal Review: A fourth category of adaptive policy is formal review. It is similar to automatic adjustment, in that it acknowledges that monitoring and remedial measures are integral to complex adaptive systems and that it is necessary to constantly refine interventions through a continual process of variation and selection. However, it is different from automatic adjustment in that automatic adjustment can anticipate what signposts to use and what actions might need to be triggered to keep the policy effective. Formal review is a mechanism for identifying and dealing with unanticipated circumstances and emerging issues. Policies which can be categorized as formal review options include updating the models which are used for the Water Withdrawal Assessment Tool (WWAT) and establishing a mechanism for scheduling updates as well as reviewing and amending any list of prohibited chemicals and well integrity monitoring systems to ensure the application of best practices.

Precautionary Policy Options

A second overall approach is precautionary policy which can be employed to prevent harm when there are threats of irreversible damage or catastrophic consequences. In this situation, policymakers may decide to regulate the activity to prevent harm. Precautionary policy options exist across all three major categories – public participation, water resources, and chemical use. They range from a complete ban and moratorium on high volume hydraulic fracturing in Michigan to prohibitions, restrictions, or requirements on a range of activities. The objectives of these policies are to avoid harm, ensure additional safety precautions or monitoring, or provide full information on activities in advance. The recent decisions to ban HVHF in New York and Quebec based in part on potential health and environmental impacts can be viewed as a precautionary approach.

BROADER CONTEXT

In response to numerous public comments received over the course of the project, the report includes an overview of the broader context and national discourse of issues (not specific to Michigan) related to expanded natural gas production and use: 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 impacts in the event U.S. policy is changed to expand exports, and methodological approaches to understanding and managing human health risks.

LIMITATIONS AND KNOWLEDGE GAPS

While the integrated assessment has attempted to provide a comprehensive review of the current status and trends of HVHF in Michigan (the technical reports) and an analysis of policy options (this report) there are certain limitations which must be recognized. First, the assessment does not provide a quantitative assessment (human health or environmental) of the risks associated with HVHF. This was not the intent of the assessment but it is a question we have often received regarding the scope of the project. Second, the assessment does not provide economic analysis or a cost-benefit analysis of the policy options presented in the preceding chapters. 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. Additional areas of investigation and knowledge gaps were identified through the technical reports. Those items are listed in the last chapter of the report along with other emerging research questions.

CHAPTER 1: INTRODUCTION

1.1 OVERVIEW

There is significant momentum behind natural gas extraction efforts in the United States, with many individual states embracing it as an opportunity to create jobs and foster economic strength. Natural gas extraction has also been championed as a way to move toward domestic energy independence and a cleaner energy supply. First demonstrated in the 1940's, 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.[16] As domestic natural gas production has accelerated in recent years, however, the hydraulic fracturing process and associated shale gas activities have come under increased public scrutiny – particularly with respect to high volume hydraulic fracturing (HVHF), which uses substantially more water and materials to complete the process. Concerns include perceived lack of transparency, chemical contamination from fracturing fluids, water availability, wastewater disposal, and 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.

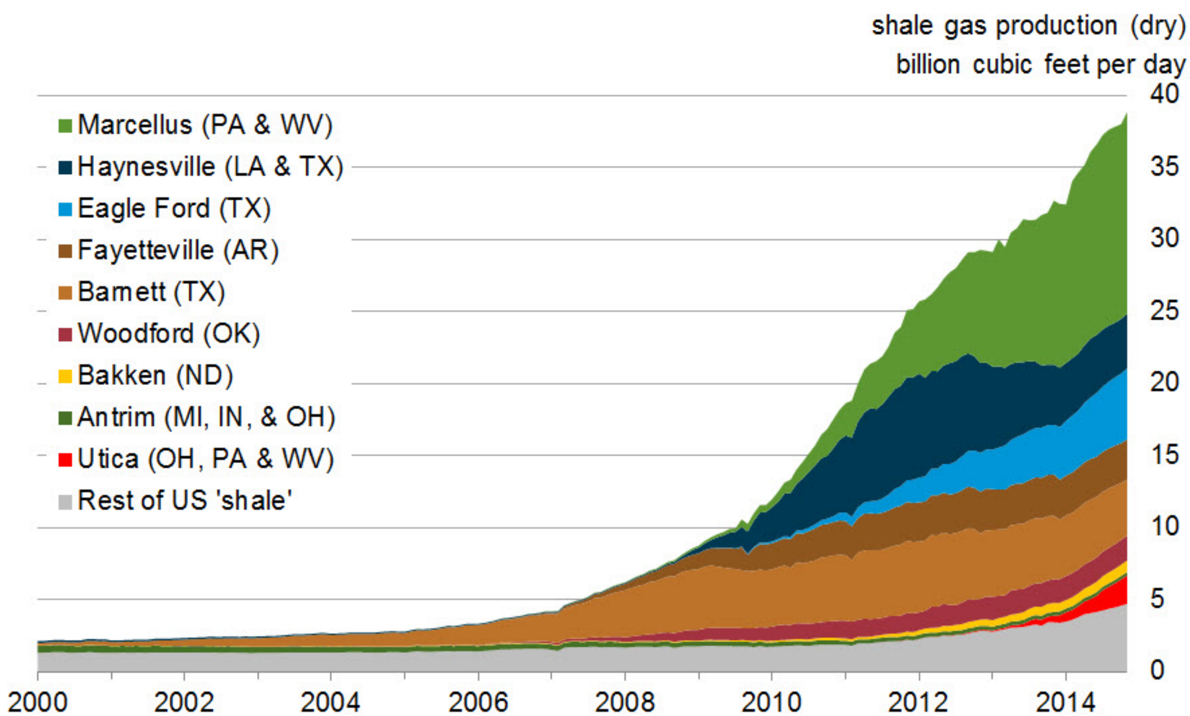
Recent interest from energy developers, lease sales, and permitting activities suggest increasing activity around deep shale gas extraction in Michigan. Below are some key points regarding hydraulic fracturing in Michigan.

- According to the Michigan Department of Environmental Quality (DEQ), over the past several decades more than 12,000 oil and gas wells have been fractured in the state and regulators report no instances of adverse environmental impacts.[17] Most of these are Antrim Shale vertical wells drilled and completed in the late 1980s and early 1990s. Some new activity will still take place, and a very small number of the old wells may be hydraulically fractured in the future, but this is a "mature" play and is unlikely to be repeated.
- The hydrocarbon resources in the Utica and Collingwood Shales in Michigan will likely require high volume hydraulic fracturing and 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 horizontally through the target formation).
- A vertical well that is hydraulically fractured in Michigan may typically use about 50,000 to 100,000 gallons of water while a high volume, horizontally drilled well may use up to 20,000,000 gallons of water or more.[18]
- A May 2010 auction of state mineral leases brought in a record $178 million—nearly as much as 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.[19,20] However, there has been limited production activity in response to these leases.

- As of December 22, 2014, there were 13 producing HVHF completed wells in Michigan, 2 active application, 28 active permit holders, 5 locations with complete plugging, and 11 locations with completed drilling.[21]
- 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 1.1 below).
- Several bills have been proposed in Michigan to further regulate or study hydraulic fracturing,[22] state officials are proceeding with promulgation of additional rules on high volume hydraulic fracturing,[23] and a ballot question committee has been working to prohibit the use of horizontal hydraulic fracturing in the state.[24]

Figure 1.1: U.S. dry shale gas production[25]



Terminology is important to any discussion of shale gas and 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.[26] 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.[27]

- **Shale Gas:** Natural gas produced from low permeability shale formations.[28]
- **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:** High volume hydraulic fracturing well completion is defined by State of Michigan regulations as a "well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid."[29,30]

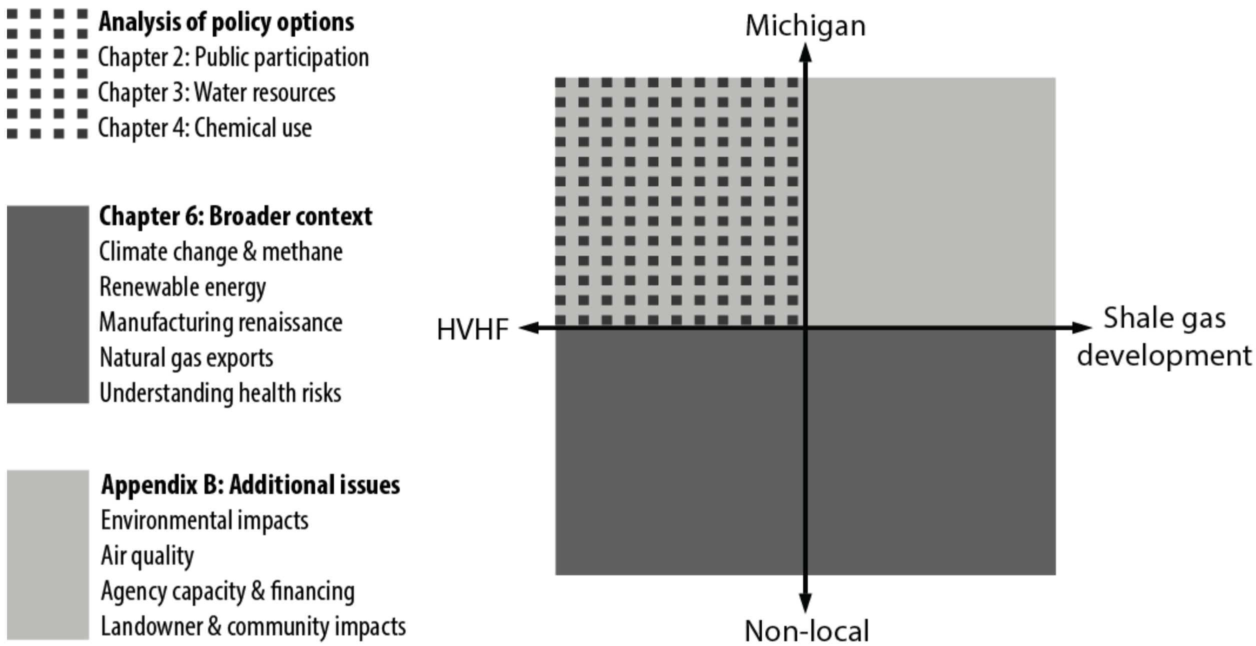
1.2 STRUCTURE OF THE REPORT

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 primarily HVHF policy options specific for Michigan in the areas of public participation, water resources, and chemical use. Chapter 5 provides a frame for analyzing all the new policy options presented in Chapter 2 (public participation), Chapter 3 (water resources) and Chapter 4 (chemical use). Using adaptive and precautionary policy frames, this chapter categorizes policy options by their approach to uncertainty in order to help identify options appropriate for several plausible futures or conditions with respect to HVHF in Michigan. Chapter 6 provides an overview of key points of discussion within the broader context of shale gas development that are not specific to Michigan. Chapter 7 identifies the limits of this report and knowledge gaps. Appendix B offers a review of additional shale gas development issues that are relevant to Michigan but not specific to HVHF.

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. Within each chapter an overview of the topic is provided along with a description of current policy in Michigan, the additional rules proposed by the state, and a range of 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 related conditions which are addressed.

The technical reports and public comments also include other issues related, but not specific, to HVHF activity in Michigan. While these issues are beyond the focus of this IA, they are important at geographic scales beyond Michigan and for unconventional shale gas development more generally. Therefore, a concise summary of key topics in the broader context and national discourse related to expanded natural gas production and use is provided in Chapter 6, and information about additional issues related to shale gas development but not HVHF-specifically is included in Appendix B. Figure 1.2 illustrates the organization of the report around its focus on HVHF in Michigan.

Figure 1.2: Report organization



1.3 PURPOSE

High volume hydraulic fracturing intersects many issues that are important to Michigan residents—drinking water, air quality, water supply, local land use, energy security, economic growth, tourism, and natural resource protection, including the Great Lakes. The project does not seek to predict a specific future for HVHF in Michigan, but it posits that natural gas extraction pressures will likely increase in Michigan if the following trends persist: desire for job creation, economic strength, energy independence, and decreased use of coal.

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 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 dialog 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 better prepare decision makers in addressing the question. For more about the IA research framework, please visit: http://graham.umich.edu/knowledge/ia.

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 Integrated 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.

1.4 INTEGRATED ASSESSMENT SCOPE

The guiding question—*What are the best environmental, economic, social, and technological approaches for managing hydraulic fracturing in the State of Michigan?*—bounds the scope of the IA. While the IA focuses on Michigan 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 Michigan DEQ guidelines as well completions that intend to use a total of more than 100,000 gallons of hydraulic fracturing fluid), but the analysis of options may also consider implications for other practices or include options for different subsets of wells.

1.5 PROCESS

1.5.1 Technical reports summaries

The project's first phase involved preparation of technical reports on key topics related to hydraulic fracturing in Michigan. These seven technical reports were peer-reviewed and made public in September 2013 (available at: http://graham.umich.edu/knowledge/ia/hydraulic-fracturing). Upon completion of the peer review process, final decisions regarding report content were made by the technical report authors in consultation with the Graham Institute. These reports provide decision makers and stakeholders with a solid foundation of information on the topic based primarily on analysis of existing data. The reports also identify additional information needed to fill knowledge gaps. The technical reports were informed by (but do not necessarily reflect the views of) an Advisory Committee, expert peer reviewers, and numerous public comments. The reports were downloaded more than 1,500 times in the year following their release. Below is a list of lead authors for the technical reports and summaries for each report.

- Technology: John Wilson, Energy Institute; Johannes Schwank, Chemical Engineering

- Geology/Hydrogeology: Brian Ellis, Civil and Environmental Engineering
- Environment/Ecology: Allen Burton, School of Natural Resources & Environment; Knute Nadelhoffer, Department of Ecology and Evolutionary Biology
- Public Health: Nil Basu, School of Public Health (now at McGill University)
- Policy/Law: Sara Gosman, Law School (now at University of Arkansas)
- Economics: Roland Zullo, Institute for Research on Labor, Employment, & the Economy
- Public Perceptions: Kim Wolske and Andrew Hoffman, Erb Institute for Global Sustainable Enterprise

1.5.1.1 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.[31]

Most hydraulic fracturing begins with the construction of a drilling pad that may be 1-4 acres in area. The pad is now often covered with a thick polyethylene sheet and a thin layer of absorbent material (often just sand or soil) to minimize the impact of spills. The location of the pad site and the position of the drilling rig are primarily determined from a variety of information on the geological substructure and the estimated probability of striking oil and/or gas, but a wide range of environmental factors are also considered. A drilling rig is brought in and situated over the intended well site. Vertical drilling is then begun. In the case of formations like Michigan's Antrim shale, the hole is drilled down into the production zone, the rig is removed and preparations are made to fracture the well. A drilling rig requires a lot of energy to turn the rotary drill bit and is usually powered by high-torque diesel-electric motors but, in response to environmental concerns, more and more rigs are using engines powered by compressed or even liquefied natural gas.

In some cases, lateral wells in shale may also be drilled using directional drilling. The lateral penetrates the hydrocarbon-bearing formation and provides more routes for product to enter the well. In the case of dry gas wells with no production of water or gas liquids, the lateral may be close to horizontal. In cases where liquids drainage must be managed or if the formation itself is not horizontal (common in basin structures), the lateral may be inclined to the horizontal. Laterals are typically 10-20,000 ft. in length but a few have been as long as 40,000 ft. Once the well is drilled (or more usually concurrently with drilling) all of the well is cased throughout in one or more layers of high-strength steel tubing that are sealed to one another and to the well wall with cements developed for the purpose. This is especially true if the well passes through an aquifer, as most do, or through a part of the formation that may have low strength and therefore might collapse. All wells are cased through and below the fresh water zone with surface casing after the well has been drilled through the fresh water zone and before drilling can continue to deeper depths. All wells then have at least one deeper string of casing (and typically two or more) to or through the target zone. The purpose of the casing is to contain fluids within the appropriate zone and prevent uncontrolled flows into fresh water zones or other zones that must be protected.

Because the tubing must withstand fracturing pressures (especially the longitudinal stresses set up in the vertical bore), it is also normally constructed of high-strength steel and joints between tubing segments are strengthened and may even be welded, although that is rare. Nevertheless, one of the most common reasons for well failures, usually during fracturing when the internal pressure is high, is tube joint failure or even tubing failure. In severe cases this can result in the ejection of a section of tubing from the well along with the "Christmas Tree", the complex arrangement of tubing at the top of the well that is designed to handle the produced gas or oil and that usually includes the blowout preventer(s). Very little fluid leaks under these circumstances because the fracturing pumps immediately detect the pressure drop and shut down.

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. The list of chemicals includes hydrochloric acid to dissolve minerals and initiate cracks in the formation. Biocides such as glutaraldehyde or quaternary ammonium chloride may be added to eliminate bacteria that produce corrosive byproducts. Choline chloride, tetramethyl ammonium chloride, or sodium chloride may be added as clay stabilizers. Corrosion inhibitors such as isopropanol, methanol, formic acid, or acetaldehyde may be dissolved in the water, along with friction reducing compounds, for example polyacrylamide. In some cases, scale inhibitors are mixed in, for example acrylamide/sodium acrylate copolymer, sodium polycarboxylate (commonly used in dishwasher detergents), or phosphoric acid salt. Surfactants such as lauryl sulfate are added to prevent emulsion formation, and in some cases, the surfactant is dispersed in a carrier fluid such as isopropyl alcohol. To adjust the pH, sodium or potassium hydroxide or carbonate is used. The sand or ceramic acts as a so-called "proppant" and helps to prop the cracks open. Sometimes, more complex proppants are used—rigid fibers, for example, or ceramic particles of controlled size and geometry. Calcined bauxite is common since it has very high crushing strength.

To facilitate fracturing, the steel casing that is inserted into the well is typically penetrated with pre-placed explosive charges (shaped charges are common). 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. In deep wells with long laterals, the fracturing may be done in stages, beginning at the far end of the well bore, with the later stages separated by a temporary plug to isolate the section being fracture. Once each section is fractured, the plug is removed and the same fracturing solution may be used for the next segment.

Once the well is fractured, the fracturing water that can be recovered (usually between 25 and 75% of the total used) is pumped out of the well or (if gas flows from the well under sufficient pressure) flows out of the well along with the produced gas. Wells in oil-bearing formations, especially those involving shale, are much more likely to require pumping. The ‘lost water’ disappears into areas around the fractured formation or enters saline deep aquifers in which it is diluted and eventually lost.[32]

Despite still producing significant levels of gas, yields from the main producing fields in the state—such as the Antrim shale and Utica Collingwood shale—have been in decline. For the Utica Collingwood shale however, this could be due to the greater depths of the shale gas, as well as the greater uncertainty surrounding quantities present. Natural gas production in Michigan peaked in 1997, at 280 billion cubic feet per year (bcf/y), and by 2010 had fallen to 141 bcf/y.[33]

1.5.1.2 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 levels of *thermogenic* methane than wells farther away from such operations, indicating that there is a possible (not definite) link between hydraulic fracturing and increased methane in drinking water.[34] Other studies, such as one by Molofsky et al., suggest that methane leakage might occur naturally, and may have more to do with land topography than hydraulic fracturing.[35]

Indeed, evidence of vertical leakage of deeper brines into shallower formation waters in Michigan[36] suggests that this sort of vertical migration is possible. Central to this topic is the possibility that the fractures induced in the target shale formations could extend beyond the target and into higher-up formations, potentially creating pathways for fracturing fluids to migrate beyond the targeted shale. A study by Fisher and Warpinski looked at hydraulically fractured wells in states outside of Michigan over the course of nine years (ending in 2010), and found no evidence of induced fractures extending into overlying fresh water aquifers.[37] However, it is important to note that this study did not collect any data on how fractures propagate in formations in the Michigan Basin.

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. For perspective, an Olympic size swimming pool holds roughly 660,000 gallons of water. While many other industries and consumers of water may use more water, its use in shale gas development generally occurs over a very short timeframe, which could potentially lead to local impacts for communities, industries, and ecosystems.

After injecting the fracturing fluid, fluid will return to the surface over the course of days or weeks. Depending on a variety of factors, this fluid may contain some or all of the original fracturing fluid (known now as *flowback water*), as well as minerals, water, or other compounds that were originally in the shale formation. All of the fluids that return to the surface are collectively known as *produced water*. In Michigan, the DEQ requires that all flowback and produced fluids be contained in aboveground steel containers. This contaminated water is injected underground into special *Class II disposal wells*. One growing concern, in states such as Oklahoma and Ohio, is the risk of induced seismicity—where the injected wastewater could lubricate a nearby fault and cause an earthquake. In Michigan, however, the Basin has been tectonically stable since the Jurassic Period, and there have been no reports of induced seismicity in the state, despite many years of ongoing underground injection for a variety of waste fluids.

Finally, likely the greatest risk to water quality comes from surface contamination. One analysis in particular, by Rozell and Reaven, identified the risk of drinking water contamination from wastewater disposal, specifically around the Marcellus Shale region, to be several orders of magnitude higher than contamination from other sources, such as contaminant migration through underground fracture networks.[38] The handling of waste and production fluids from hydraulically fractured wells in Pennsylvania has been a continuing challenge, since there are only five disposal wells in the state, three of which are privately owned and operated. However, since all produced water is disposed of via deep-well injection in Michigan, and may not sit in open pits, as will sometimes happen in Pennsylvania, the risk of this type of contamination will be lower than some other states.

1.5.1.3 Environment and Ecology

There are numerous potential ecological consequences of shale gas development. First, operators may construct access roads in order to transport equipment and materials to and from sites. These roads are frequently unpaved, and without sufficient erosion controls, sediment and harmful pollutants could erode and be carried into nearby rivers, lakes, and streams. These sediments can decrease photosynthetic activity, destroy organisms and their habitats, and contaminate water and plant or animal life. Further, the truck traffic from these and other connected access roads can be substantial. This increased level of traffic can lead to air quality risks from engine exhaust.

Aquatic ecosystems can be impacted from shale gas development as well. One evaluation, performed by Entrekin, of fracturing operations in Arkansas, found that surface water quality violations were most commonly due to erosion, illegal discharges, and spills.[39] Importantly, wells are often located near rivers and streams, so in areas with many wells or more extensive operations, the cumulative impacts on the watershed could be compounded.

More generally, wildlife and their habitats could also be affected, though the specific impacts may vary among different types and species. Exposure to light and noise is a concern, as they can cause localized disturbances, disrupting feeding, breeding, and rest patterns in animals and plants of all sizes. Depending on their magnitude and scope, these impacts could become more systemic in nature, potentially impacting entire ecosystems.

1.5.1.4 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.

Focusing on three main contexts—the workplace, the surrounding environment, and the nearby community—enables a detailed description of the public health risks and benefits to be created. In the workplace, possible hazards include accidents and injuries, exposure to silica and industrial chemicals, and shift or night work. In the surrounding environment, possible hazards include impaired local/regional air quality, water pollution, and the degradation of ecosystem services. In nearby communities, hazards include increased traffic and motor vehicle accidents, increased stress levels, and effects associated with boomtowns, such as strained healthcare systems and road degradation.

While not all of these 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, the noise generated could also potentially interfere with the sleep quality of area residents. Additionally, while there are Michigan regulations controlling 'nuisance odors' in general, the primary source of odor related to hydraulic fracturing comes from hydrogen sulfide (H2S). In low concentrations, it has a rotten egg smell, and there are anecdotes of the odor sickening residents exposed to it from various sources.

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. Proppants are pumped deep underground, where they are responsible for keeping fractures open and allowing natural gas to flow out of the well. 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.

Exposure to chemicals used intentionally, as well as those generated as by-products represent additional risks with relevance to Michigan, where workers may be exposed to a wide variety of such chemicals. Two recent studies, one conducted by Colborn et al, and the other prepared for U.S. Representative Henry Waxman, found a total of 632 chemicals in 944 products.[40,41] Of these, only around half (56%, or 353 chemicals) could be connected with a Chemical Abstacts Service (CAS) number (needed to assure the correct identification of a specific chemical). Analysis of these 353 chemicals revealed that approximately 75% of them could adversely impact human health in ways ranging from respiratory to neurological to cardiovascular impacts, with 25% identified as known, probable, or possible carcinogens.

By-product chemicals are those that may be released unintentionally. Chemicals falling into this category could include those found in diesel exhaust, hydrocarbons in the natural gas itself, hydrogen sulfide, naturally occurring minerals (which could contribute to high salinity of produced water), and naturally occurring radioactive substances.

1.5.1.5 Policy and Law

There are a wide variety of laws and regulations on every level from federal to state to local that govern shale gas development and its associated activities. Traditionally in Michigan, a landowner (either a private or public entity) owns *both* the 'surface' of the land as well as the 'mineral interest' in the oil/gas beneath it. However, it is also possible for the mineral rights to be separated from the surface, resulting in what is known as a *split estate*. When the rights are separated like this, with two different owners, the owner of the mineral interest is considered the dominant interest, and has the right to reasonably use the surface to extract the gas underneath. It is noteworthy that while the mineral interest owner has a reasonable opportunity to extract the gas, they do not actually have a right to the specific gas underneath that property.

In general, the owner of gas rights will lease those rights to an exploration and production company that has the expertise and capability to drill wells and manage production. Michigan's Department of Natural Resources (DNR), which is the largest owner of mineral interests in the state, has its own program for leasing state owned mineral interests. They face a balancing act, wherein they try to maximize revenue and ensure that the oil and gas is not being drained by wells on adjacent properties, while at the same time protecting the environmental, archaeological, and historical features on the surface.

Another state agency, the 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. After obtaining rights from the mineral interest owners, gas companies must obtain a DEQ permit before drilling any wells. This permitting process includes a number of different components, including fees, bonds, reports, a public comment period, information regarding the technical details of the proposed well, and factors related to whether the applicant's plan would be in compliance with standard environmental conservation measures.

Traditionally, federal and state environmental agencies (such as the DEQ in Michigan) regulate the impacts of an activity on natural resources, while local governments regulate the location of land uses through zoning and planning. With regards to gas wells, the state regulates both the well location *and* the impacts of well sites, constraining the authority of localities. Michigan's DEQ has numerous requirements for well location, including a 300 foot setback from freshwater wells used for human consumption, and a 2,000 foot setback from larger public water supply wells. Furthermore, in the application process for a DEQ permit, the applicant must submit an environmental impact assessment identifying nearby natural resources and describing impacts of access roads, the well site, surface facilities, and flow lines.

With regard to the regulation of chemicals used in hydraulic fracturing operations in Michigan, this responsibility falls primarily on the DEQ. Once chemicals are on-site, there are no federal or state restrictions on which substances may be used in fracturing fluid. Currently, the operator must provide the DEQ with copies of Material Safety Data Sheets (MSDS's) for each additive within 60 days of well completion, along with the volume of each additive used.

1.5.1.6 Economics

In Michigan, the shale gas industry does create employment and generate income for the state, but the employment effects are modest when compared with other industries, and are not large enough to 'make or break' the state's economy.

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).[42]

The State of Michigan receives taxes from revenue earned by private landowners ($32.6 million in 2010), as well as revenue from gas extracted from state property. Although low in comparison to previous periods in the past decade, in 2012, the Department of Natural Resources received $18.4 million in royalties, $7.7 million in bonuses and rent, and $0.1 million in storage fees. Revenue received from private taxes goes to the state's general fund, and almost all the revenue received from gas extraction on state property goes to improving state land and game areas.

1.5.1.7 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, where high volume hydraulic fracturing is still in a relatively early stage of development, the issue is still relevant to residents, with 40% reporting they have heard "a lot" about hydraulic fracturing, and 48% saying they follow the issue "somewhat" to "very closely."

When asked to weigh the benefits of hydraulic fracturing against its risks, people tend to view it positively, with one survey with multiple samples finding that 53-62% of people believe that its benefits "somewhat" to "far" outweigh its risks. In Michigan specifically, a poll found that 52% of people believe that "drilling for natural gas" in the state had resulted in more benefits so far, 24% who thought it had led to more problems, and 8% who thought the benefits and problems were about equal.

In Michigan, residents identified economic benefits, energy independence, reduced carbon emissions, and reduced energy costs as some of the greatest possible benefits. Conversely, residents identified water contamination, health issues, pollution, and general environmental damage as the greatest possible risks from hydraulic fracturing.

Several surveys have found a fairly evenly divided nation on the issue of whether citizens favor or oppose “fracking.” In Michigan, a majority of respondents (54%) either “somewhat supports” or “strongly supports” the extraction of natural gas from shale deposits in the state, while 35% somewhat to strongly oppose it. In Pennsylvania, where there is extensive hydraulic fracturing activity, support for shale gas development is weaker – 49% somewhat or strongly support shale gas extraction, while 40% somewhat to strongly oppose it. A majority of respondents in both Michigan and Pennsylvania agree that their states should impose a moratorium on hydraulic fracturing until more is known about its potential risks.[43]

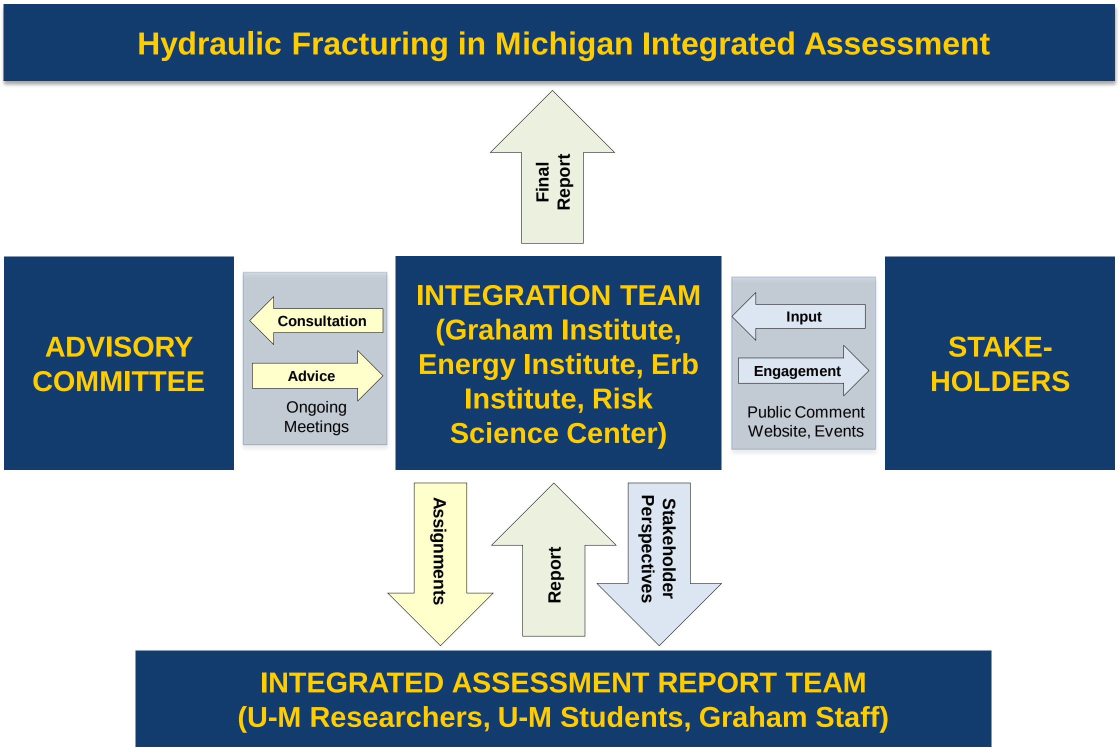
Different stakeholders in Michigan have different perspectives on shale gas development. Industry organizations emphasize the potential economic benefits of deep shale extraction and address potential risks by highlighting the strength of state regulations and otherwise, the negligibility of risks. Nonprofit and grassroots organizations can be divided into two broad categories – those that seek greater regulation of hydraulic fracturing, and those seeking a permanent ban on it. Regardless of their desired outcomes, these organizations tend to emphasize risks and uncertainties rather than potential benefits in their communications, framing high volume hydraulic fracturing as a new and unprecedented process. Finally, state agencies such as the DNR and DEQ are visible on the issue, as a result of their mandates and regulatory authority. The main divergence between public concerns and the DEQ’s messaging can be found in the DEQ maintaining that the latest developments in high volume fracturing are the continuation of a long history of regulations, and thus should not require significant changes to the system. The DEQ tries to assuage public concerns regarding potential environmental or health risks by arguing that no conclusive evidence links hydraulic fracturing to such issues.

Ultimately, these differences highlight a few key points. The first is that different stakeholders define key terminology differently. The lack of a common language can sometimes lead to miscommunications and increased mistrust. Different conceptions of risk by different stakeholder groups (for instance, whether or not ‘risk’ includes psychological or social considerations) also can lead to miscommunications and to government or industry assuming that the public simply needs more technical information, when in actuality, greater involvement in collaborative decision making processes might be a more effective solution.

1.5.2 Contributors and participants

The preparation of the final IA, or second phase, has involved an iterative process among various groups and individuals as framed in Figure 1.2.

Figure 1.2: Integrated Assessment Process



1.5.2.1 Integration Team

The Integration Team has been led by the U-M's Graham Institute and includes the U-M's Energy Institute, Risk Science Center, and Erb Institute. This team was charged with:

- Identifying U-M researchers to serve on the Report Team,
- Identifying experts to serve as peer review panelists,
- Coordinating Advisory Committee input and broader stakeholder engagement,
- Working with the Report Team to ensure the final IA products meet established guidelines and address significant comments received from the review panel, and
- Making final editorial decisions regarding IA content.

The Integration Team members are:

- Maggie Allan, Integrated Assessment Program Specialist, U-M Graham Sustainability Institute
- Mark Barteau, Director, U-M Energy Institute
- John Callewaert, Integrated Assessment Center Director, U-M Graham Sustainability Institute
- Andy Hoffman, Director, U-M Erb Institute for Global Sustainable Enterprise
- Drew Horning, Deputy Director, U-M Graham Sustainability Institute
- Andrew Maynard, Director, U-M Risk Science Center
- Don Scavia, Director, U-M Graham Sustainability Institute

- Tracy Swinburn, Managing Director, U-M Risk Science Center

1.5.2.2 Report Team

The Report Team consists of the following U-M researchers:

Fully Engaged Members		
Researcher	**Expertise**	**U-M Unit**
Diana Bowman	Risk science & health policy	School of Public Health; Risk Science Center and Department of Health Management and Policy
Sara Gosman	Law	Law School (now at the University of Arkansas)
Shaw Lacy	Environment/water	Graham Sustainability Institute (now at the Pontificia Universidad Católica de Chile)
Ryan Lewis	Environmental health	School of Public Health; Department of Environmental Health Sciences
Kim Wolske	Risk communication & engagement	School of Natural Resources and Environment and the Ross School of Business; Erb Institute
Consulting Members		
Researcher	**Expertise**	**U-M Unit**
Brian Ellis	Geology	College of Engineering; Department of Civil and Environmental Engineering
Ryan Kellogg	Economics	College of Literature, Science, and the Arts; Department of Economics
Eric Kort	Atmospheric science	College of Engineering; Department of Atmospheric, Oceanic and Space Sciences
John Meeker	Environmental health	School of Public Health; Department of Environmental Health Sciences
Johannes Schwank	Chemical engineering	College of Engineering: Department of Chemical Engineering

Fully engaged members are responsible for preparing major sections of the IA report and consulting members have contributed by reviewing and providing comments on report materials.

This team has:

- Received funding from the Graham Institute commensurate with their level of engagement to carry out the analysis.
- Collaborated with other Report Team members to identify common themes, strategies, and policies.

- Sought consensus on the report and followed a process whereby if consensus cannot be reached on any issue, it will be brought to the Integration Team who may seek additional outside expertise. If the Integration Team cannot reach consensus, then the Graham Institute will make final editorial decisions.

The Report Team has been supported by numerous students and Graham Institute staff members throughout the entire process. Below is a list of students and staff who contributed to the project:

- Mark Bradley
- Kevin Chung
- Meredith Cote
- Michelle Getchell
- Manja Holland
- Boyu Jang
- Casey McFeely
- Daniel Mitler
- Marie Perkins
- Kathleen Presley
- Scott Robinson
- Susie Shutts
- Joshua Sims
- Lukas Strickland
- Alison Toivola
- Sarah Wightman
- William Zang
- Tianshu Zhang

1.5.2.3 Advisory Committee

The following committee was assembled to advise project efforts:

- Valerie Brader, Senior Strategy Officer, Office of Strategic Policy, State of Michigan
- James Clift, Policy Director, Michigan Environmental Council
- John DeVries, Attorney, Mika Meyers Beckett & Jones; Michigan Oil and Gas Association
- Hal Fitch, Director of Oil, Gas, and Minerals, Michigan Department of Environmental Quality
- Gregory Fogle, Owner, Old Mission Energy; Michigan Oil and Gas Association
- James Goodheart, Senior Policy Advisor, Michigan Department of Environmental Quality
- Tammy Newcomb**,** Senior Water Policy Advisor, Michigan Department of Natural Resources
- Grenetta Thomassey, Program Director, Tip of the Mitt Watershed Council
- John Wilson, President, TMGEnergy

The committee's role has been to provide input and advice reflecting the views of key stakeholder groups and to ensure the IA scope is relevant to decision makers. Committee members have also provided data and input to the Report and Integration Teams throughout the process, including feedback on the policy topics, analytical approach, and format of the IA and draft reports. As with preparation of the technical reports, all decisions regarding content of project analyses and reports are determined by the IA Report and Integration Teams.

1.5.2.4 Stakeholders

Stakeholder input is an important part of any IA and has been a key component of this assessment. Key points of stakeholder engagement have included the following:

- An online comments/ideas submission webpage (http://graham.umich.edu/knowledge/ia/hydraulic-fracturing/comment) was established at the start of the project to direct public input to the teams working on the IA, and it will remain open until the IA has concluded. Nearly 1,000 individuals are currently included in a contacts database for this project.
- During the preparation of the technical reports, the Graham Institute convened a meeting in Lansing, Michigan on March 5, 2013, to present research plans to nearly 100 decision makers and stakeholders.
- A public webinar was held on September 6, 2013 following the release of the technical reports. Summaries and recordings of these two public events can be found at: http://graham.umich.edu/knowledge/ia/hydraulic-fracturing.
- More than 200 comments were received following the release of the technical reports. They were carefully reviewed, organized, and shared with the technical report authors, Integration Team, Report Team, and Advisory Committee to aid in developing the IA plan.
- Similar to what was done upon releasing the technical reports, another public webinar will be scheduled to coincide with the release of the draft IA report. Comments on the draft IA report will be sought through a publicly available web-based form and through direct solicitation of experts who represent a balanced mix of sectors with significant expertise and interest on the topic (e.g., industry affiliates, environmental organizations, academics, policymakers).

1.5.2.5 Review Panel

To ensure a rigorous, scientific analysis of the topic, the Integration Team has identified subject area experts representing multiple disciplines to serve on a peer review panel. As technical experts on the subject, reviewers will evaluate the scientific credibility, rigor, and integrity of the assessment. Panelists will receive the draft IA report and a summary of the public and directly-solicited comments. After preparing individual reviews, panelists will meet in person to discuss their reviews and the draft IA report. The panel will then provide a single, final written review of the draft IA. Reviewers will be reimbursed for travel expenses by the Graham Institute and receive a modest honorarium for their time. Based on the review panel input and public comments, the Report Team will prepare the final IA report. Responses will be prepared to address the issues raised by the review panel and public comments, and to explain how comments were incorporated into the final IA.

1.5.3 Funding

The project is entirely funded by the University of Michigan. The project is expected to cost at least $600,000 with support coming from U-M's Graham Institute, Energy Institute and Risk Science Center. Current funding sources are limited to the U-M General Fund and gift funds, all of which are governed solely by the University of Michigan

1.5.4 Ensuring a rigorous, scientific analysis

It is imperative that no aspect of the Integrated Assessment process be compromised by real or apparent conflicts of interest. For this initiative, the term "conflict of interest" means any financial or other interest that conflicts with the service of the individual because it (1) could significantly impair the individual's objectivity or (2) could create an unfair competitive advantage for any person or organization. Therefore, all Technical Report authors, IA Report and Integration Team members, and peer reviewers have completed or will complete conflict of interest forms (adapted from National Academy of Sciences materials) indicating they have no conflicts (financial or otherwise) related to their contributions to this initiative.

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CHAPTER 2: PUBLIC PARTICIPATION

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2.1 OVERVIEW

Unconventional shale gas development through high volume hydraulic fracturing (HVHF) has garnered considerable public attention and controversy. While some praise HVHF for enabling development of previously inaccessible resources, others worry that HVHF poses unacceptable risks to human health, the environment, and local communities. In Michigan, for example, a public opinion poll found that while a slight majority (52%) of respondents believes the benefits of "fracking" will outweigh its risks, significant concerns remain about its potential impacts on water quality and human health.[1] Another thirty-six percent (36%) of respondents strongly agreed that Michigan should impose a moratorium on "fracking" until its potential risks are better known. These tensions about the costs and benefits of HVHF are echoed in the positions taken by various nonprofit and grassroots organizations throughout the state. Meanwhile, state agency and industry groups contend that HVHF is safe.[2]

Given these differing viewpoints, governing the risks of HVHF in a manner that is socially acceptable can be challenging. Past technologies such as nuclear power plants and hazardous waste facilities have provoked similar dilemmas. In these contexts, 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 more participatory role.[3,4,5,6,7]

Public participation has been interpreted in many ways. In the context of public policy, it often takes the form of public comment periods and hearings, where the public might be described as having a consultative role.[8,9] Other forms of public participation such as moderated workshops and deliberative polling may allow for more interactive discussions that encourage collaborative decision making. Although no unified theory of public participation exists, scholars generally agree that good public participation should:

(1) Lead to higher-quality decisions by appropriately incorporating stakeholder information and values,[10,11,12]
(2) Be legitimate and perceived as fair,[13,14]
(3) Reduce conflict and build trust in institutions,[15]
(4) Lead to a shared understanding of the issues,[16] and
(5) Improve the capacity of all parties to engage in the policy-making.[17,18,19,20]

The extent to which these goals are achieved depends on a number of factors including the nature of the issue, the participatory processes used, and the group dynamics of involved stakeholders.[21,22] For issues where stakeholders are in agreement about what should be done, it may be sufficient to keep the public informed through educational websites and press releases.[23] But for controversial issues, where stakeholders disagree about the issue or misunderstand each other's perspective, more involved forms of public participation are generally needed.[24] In these contexts, research has shown that participation is more likely to lead to desirable outcomes when people are invited to the decision making process early and often, when the goals and expectations of a participation process are made clear upfront, and when the viewpoints of participants are considered in the final decision.[25] Public participation tends to be less successful when stakeholders are invited to the table late in the process, when the mechanisms for inviting public input are insufficient, or when people are put in a position of having to react to a near-final plan.

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.[26] 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."[27] As the authors note, however, the existing policy process in the U.S. makes implementing this recommendation challenging.

The oil and gas industry is also paying more attention to the role of public engagement in its operations. The American Petroleum Institute (API), for example, recently released community engagement guidelines that outline how operators can "responsibly develop" oil and gas resources while considering community concerns.[28] These guidelines describe principles for how well operators should interact with a community as well as a recommended process for engaging stakeholders through each phase of an oil and gas project. Notably, one of the key principles for operating responsibly is to communicate effectively through a "two-way process of giving and receiving information."[29] The API Community Engagement Guidelines (page 2) suggest that effective communication may involve practices such as:

- "Promot[ing] education, awareness and learning" during each phase of an oil and gas project;
- "Provid[ing] clear information to all stakeholders… in addressing challenges and issues that can impact them;"
- "Provid[ing] structured forums for dialogue, planning, and implementation of projects and programs affecting the greater regional area;"
- "Establish[ing] a process to collect, assess, and manage issues of concerned stakeholders;" and
- "Design[ing] and carry[ing] out a communication strategy that addresses the community, cultural, economic, and environmental context where a project occurs, and that considers the norms, values, and beliefs of local stakeholders, and the way in which they live and interact with each other."[30]

By contrast, 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. As discussed in the Public Perceptions Technical Report, relying on these one-way forms of communication where the public is, at best, consulted but unable to engage in genuine discussions about HVHF can contribute to feelings that the public's voice does not matter or that HVHF is being involuntarily imposed. These feelings may, in turn, further perpetuate controversy surrounding HVHF and hinder efforts to arrive at publicly-acceptable policies.

The remainder of this chapter 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 land leasing decisions and well permitting. We have focused on these two activities as both affect a question of primary importance to the public: where will HVHF occur.

For each of the above topics (i.e., HVHF policy in general, state land leasing, and well-permitting), we begin by providing a high-level summary of how various states have approached public engagement in the issue. We then describe and analyze a set of policy options that the State of Michigan might consider to incorporate public values into HVHF policy—including the option to keep Michigan's existing policy. For each option, we briefly describe the proposed policy and then examine its strengths and weaknesses in terms of potential environmental, economic, health, community, and governance impacts.

How the public is involved in other, more specific aspects of an HVHF operation, such as water and chemical use, are examined in-depth in later chapters of the report.

2.2 INCORPORATING PUBLIC VALUES IN UNCONVENTIONAL SHALE GAS DECISION MAKING

2.2.1 Introduction

Historically, the public has had few opportunities to significantly influence oil and gas policy. Given the potential risks of HVHF to human health and the environment, many have questioned not only whether existing regulations are adequate, but also whether the public has been sufficiently involved in deciding the future of this practice.[31,32] As the following sections illustrate, the degree to which the public is able to influence HVHF-related policies varies widely across the U.S.; some states offer few to no opportunities for public input while others make a concerted effort to give the public a voice in setting future shale gas policy.

2.2.2 Range of approaches

2.2.2.1 Treat HVHF as an extension of other oil and gas activities

Most states, including Michigan, have dealt with HVHF by treating it as an extension of other oil and gas activities. Under these circumstances, rules or instructions may be issued regarding chemical disclosure and the physical aspects of HVHF (e.g., well spacing and setbacks) but the public is typically not afforded a meaningful opportunity to weigh in on whether or how unconventional shale gas development should occur. In such cases, the public's ability to influence HVHF development is limited to whatever public participation mechanisms are built into the state's existing oil and gas regulations. In the majority of states, oil and gas regulations afford the public limited opportunity to learn of proposed HVHF wells or to voice concerns about their development. Notice of well permit applications is typically limited to surface owners of the well site (e.g., Arkansas,[33] Oklahoma,[34] and Texas[35]) and in some states, owners of nearby property (e.g., Illinois,[36] New Mexico,[37] North Dakota,[38] Ohio,[39] and proposed in Alaska[40)]. In Michigan, the DEQ informally accepts comments on permit applications through its website. Only a few states mandate that the public be allowed to comment on permit applications (e.g., Colorado,[41] Illinois[42], proposed in Maryland[43]), or for adversely affected parties to request a public hearing before permits are approved permits (e.g, Illinois,[44] proposed in Maryland[45]). In Michigan[46] and North Dakota,[47] adversely affected parties may contest an approved permit. If new HVHF-specific rules are promulgated, most states allow the public to submit comments on the rules or to testify in public hearings.

2.2.2.2 Public information

In states where HVHF is treated as an extension of other oil and gas practices, efforts to "engage" the public often focus on educating and informing the public about HVHF. Evidence of this can be seen in many of the reviews conducted on state oil and gas programs conducted by STRONGER, the State Review of Oil & Natural Gas Environmental Regulations (e.g., Arkansas[48] and Oklahoma[49]). These public outreach efforts might include posting notice of proposed state mineral auctions and well permit applications on agency websites or presenting educational information about HVHF online and at informal public meetings. While providing this type of information is important for creating transparency about HVHF-related activities, this strategy, by itself, has been criticized for promoting an expert-knows-best model of decision making that ignores democratic ideals. Research has shown that for controversial issues such as HVHF, attempts to assuage public concerns through education and information alone can backfire (for more discussion on this topic, please see section 3.3 of the Public Perceptions Technical Report[50]).

2.2.2.3 Development moratoria and state-wide studies of HVHF

In response to public concerns, many states (including Michigan, North Carolina, New Jersey, New York, Ohio, and Pennsylvania), have introduced bills to impose a moratorium on HVHF.[51,52,53,54] Typically, the intention of the moratorium is to allow a development "time out" so that the state can gather more information about potential environmental, health, and economic impacts; devise HVHF-specific regulations; or generally postpone HVHF until its risks and long-term impacts are better known. North Carolina passed such a bill in 2012. The Clean Energy and Economic Security Act placed a moratorium on hydraulic fracturing (HF) permits until appropriate HF-specific regulations were in place.[55] This moratorium was lifted as of June 2014.

In New York, a de facto moratorium on HVHF permitting has been in place since 2008, when Governor David Paterson ordered the Department of Environmental Conservation to revise the 1992 Generic Environmental Impact Statement (GEIS) to account for HVHF impacts.[56,57] As part of this revision the New York State Department of Health (DOH) was asked to review the potential health impacts of HVHF. The DOH's report, released in December 2014, recommended that HVHF should not proceed in New York until there is sufficient scientific information to determine the level of risk that HVHF poses to public health.[58] Governor Andrew Cuomo's administration subsequently announced a ban on HF, and the Department of Environmental Conservation is expected to issue a legally binding statement to prohibit HVHF sometime in early 2015.[59]

2.2.2.4 Multi-stakeholder advisory boards and regulatory bodies

Given the potential for HVHF to have far reaching impacts on human health, the environment, and the local economy, a few states have created multi-stakeholder advisory groups to review oil and gas policy and to determine whether changes are needed to prevent adverse risks. For example, in Maryland, a special Advisory Commission was created as part of the Marcellus Shale Safe Drilling Initiative.[60] This initiative charged the Department of the Environment and the Department of Natural Resources, in consultation with the Advisory Commission, to conduct a study on "the short-term, long-term, and cumulative effects of natural gas exploration and production in the Marcellus shale," and to identify best practices to mitigate those risks. By executive order, the Advisory Commission included an expert on geology or natural gas production from a college or university, one representative from an oil and gas company, one from an environmental organization, and four representatives from communities in the Marcellus shale region, including a private citizen, a representative from the business community, and two representatives from local governments.

In Colorado, the composition of the Colorado Oil and Gas Conservation Commission (COGCC), the body that regulates oil and gas drilling and production, was reconfigured to better represent public interests in the state.[61] Formerly composed of seven members, the COGCC was expanded to nine, with two additional seats given to the directors of the Department of Natural Resources and the Department of Public Health and Environment. In addition, the composition of the remaining seven seats was altered, such that the number of seats for oil and gas industry representatives was reduced from five to three. By mandate, COGCC must also include a local government official, a member with expertise in environmental or wildlife protections, a member with expertise in soil conservation or reclamation, and a member actively engaged in agricultural production who is also a royalty owner. Furthermore, the bill stipulates that excluding the directors of the Department of Natural Resources and the Department of Public Health and Environment, the remaining seven members shall be appointed by the governor and no more than four members can be from the same political party.

2.2.2.5 State-wide studies of HVHF impacts and best management practices

As previously mentioned, a few states such as New York and Maryland have conducted statewide studies to better understand the impacts of HVHF and to identify best management practices. As part of this process, both states invited the public to review and comment on the study's findings and proposed recommendations. New York also held a public hearing during the comment period,[62] and both states prepared responsiveness summaries of comments received.[63,64]

2.2.2.6 Town halls and public workshops to solicit public input

Some states and local municipalities have engaged the public in more deliberative discussions about HVHF. For example, after the reconfiguration of the Colorado Oil and Gas Conservation Commission (COGCC), the COGCC traveled the state for nine months to conduct public meetings and facilitate stakeholder work groups in communities with large oil and gas plays.[65,66] Information gathered from these public forums was used to inform COGCC's draft rules for HVHF. Similarly in California, the Division of Oil, Gas, and Geothermal Resources (DOGGR) conducted multiple stakeholder workshops to discuss "pre-draft" versions of proposed regulations, before the formal rulemaking process was initiated. These full-day, moderated meetings involved very brief presentations about HVHF regulatory issues, with the majority of time dedicated to public questions, suggestions and discussion.[67,68,69]

2.2.3 Analysis of policy options

The following subsections examine policy options that can be used separately or in combination to improve transparency about HVHF in Michigan and better incorporate public values into unconventional shale gas development policies. These include:

- Keep existing Michigan policy
- Option A: Revise Department of Environmental Quality (DEQ) website to improve transparency
- Option B: Require risk communication training for DEQ and Department of Natural Resources (DNR) employees
- Option C: Conduct public workshops to engage Michigan residents in HVHF decision making
- Option D: Impose a state-wide moratorium on HVHF
- Option E: Ban HVHF
- Option F: Create a multi-stakeholder advisory group to study HVHF impacts
- Option G: Increase stakeholder representation on Oil and Gas Advisory Committee

Policies that address public concerns about water resources and chemical use in HVHF are discussed in Chapter 3 and 4 respectively.

2.2.3.1 Keep existing Michigan policy for public engagement

In Michigan, there are few mechanisms for incorporating public values into HVHF-related policies. The rules governing public participation around HVHF-related activities are the same as for other types of oil and gas activities. As will be discussed in sections 2.3.3 and 2.4.3 of this chapter, the public can submit comments on state mineral rights auctions, but there is no mandatory public notice and comment period for well permit applications... The most that the public may be able to influence HVHF policy is if new rules are being promulgated. Under the Michigan Administrative Procedures Act, the public can submit comments on proposed rules and provide testimony at public hearings.[70] This process recently occurred in response to proposed rules concerning HVHF permitting.

Other efforts to engage the public are focused on informing or educating residents about HVHF. This occurs primarily through the DEQ website as well as presentations at public meetings and outreach events. In 2013 the DEQ held three public meetings on HF. DEQ staff have also participated on over 200 public engagement events on HF (H. Fitch, DEQ, personal communication, January 30, 2015).

The DEQ website provides users very basic information about HVHF, including notice of permit applications, a map of HVHF wells, information about the regulations that govern it, and a broad overview of how HVHF compares to other oil and gas activities. The site, however, is neither intuitive to navigate nor particularly responsive to public concerns. In both online materials and public forums, the DEQ appears to focus on persuading the public that "fracking" is safe. A commonly cited statistic, for example, is that Michigan has successfully regulated "fracking" for over 60 years and that over 12,000 wells have been safely fracked; there is no acknowledgement that that safety record is predominantly about conventional low-volume HF. Other materials similarly blur the distinctions between HVHF and low-volume HF. Sections 2.3.3 and 3.1 of the Public Perceptions Technical Report provide a more detailed discussion of DEQ communications.[71]

Finally, public interests are also represented, to a limited extent, on Michigan's Oil and Gas Advisory Committee. This committee, which meets four times a year, advises the DEQ on matters related to oil and gas policy and procedures. Appointed by the Director of the DEQ, the committee is comprised of eight members, only two of which represent the public sector. The remaining six are from the oil and gas industry.[72]

Table 2.1: Strengths and weaknesses of existing Michigan policy for public engagement

	Strengths	**Weaknesses**
Environmental Impacts	*Policy may be more protective of state lands than in other states (e.g., CO, NM, and TX) where the public cannot comment on proposed state mineral leases*	*May lead to poorer environmental outcomes* • Important environmental considerations may be overlooked as current policy offers few opportunities to solicit local knowledge or expert opinions • Development may occur in piecemeal fashion without consideration of how HVHF is affecting larger landscape
Economic Impacts	*Mineral rights owners, oil and gas companies, and state may benefit from faster development of resource*	
Health Impacts		*May lead to poorer health outcomes* • Important health considerations may be overlooked as there are few opportunities to solicit local knowledge or expert opinions • No public health experts sit on the Oil and Gas Advisory Committee

		May contribute to stress and anxiety in impacted communities By excluding the public from decision making, HVHF may feel involuntarily imposed. This may contribute to psychological distress for individuals in affected areas as well as create more outrage about HVHF. (See Public Perceptions Technical Report[73])
Community Impacts		*May lead to worse outcomes for impacted communities* May result in undesirable impacts that could have been lessened or avoided if the public had been involved (e.g., in the siting of well pads, the routing of truck traffic, etc.)
Governance Impacts	*May be easier to implement and have lower administrative costs than alternatives*	*May not address potential inequities in resource development* • Neighboring landowners and community members may bear the risks and potential impacts of HVHF without any of the benefits *Public may feel DNR and DEQ are not as transparent as they could be* • Limited public notice and reliance on one-way forms of communication may create the perception that information about HVHF-related activities is being withheld *May make it difficult for MI residents to become adequately informed about HVHF-related issues* *May increase distrust of DEQ* • DEQ statements that fail to differentiate HVHF from HF may decrease trust in DEQ (e.g., statements that Michigan has safely "fracked" for over 60 years, when HVHF is relatively new) • DEQ and members of the public use the term "fracking" differently. This discrepancy can result in materials (such as the FAQ sheet online) that fail to fully acknowledge the public's concerns about deep shale gas development. Claims, for example, that "fracking" has not led to any environmental damage can seem misleading when the public can observe obvious physical changes to the landscape as a result of natural gas development through HVHF. • Limited opportunities for

		participation may contribute to feelings that HVHF is involuntarily imposed *Current processes may reduce legitimacy of decision making* There are no formal provisions to guarantee that public input and values are considered in decision making.

Like many other states, Michigan's existing policies provide the public few opportunities to weigh in on unconventional shale gas development. Given the controversial nature of HVHF and the uncertainty of its long-term impacts, this approach may have unintended negative consequences. In the short term, the lack of opportunities for public participation may contribute to feelings that unconventional shale gas development is being involuntarily imposed and, thus, lead to greater distrust of state agencies. In the long term, leaving the public out of HVHF-related decision making may result in decisions that inadequately account for local conditions and cultural values.

2.2.3.2 Option A: Revise the DEQ website to improve transparency and usability

Currently, the DEQ website does not offer Michigan residents a user-friendly way to find answers to questions they may have about shale gas activities in the state. A first step toward improving transparency about HVHF would be to restructure the DEQ website to improve navigability. For example, the website for Ohio's Division of Oil and Gas Resources,[74] organizes information based on the type of user (e.g., industry, citizens, and local governments). The Ohio site also explains oil and gas regulations using lay language in an easy to follow FAQ format.[75]

Besides improving navigation, informational content on the DEQ site could be revised to address common public concerns and to better differentiate HVHF from low-volume HF. Revised content might include more detailed information about the potential impacts of unconventional shale gas activities on human health, water supplies, and the environment. The information could also more thoroughly explain why some perceived risks are unlikely and provide links to reputable references and resources where individuals can learn more. The "Visitor FAQS" page of Exploreshale.org, a public service site created by Penn State Public Broadcasting, provides an example of how common questions could be better addressed. The DEQ website could expand upon this approach by also providing an online forum where visitors can submit comments and questions about HVHF.

Finally, this policy option could require that the website undergo user testing and review by a neutral third party to ensure that it remains unbiased in its content and meets the public's needs.

Table 2.2: Strengths and weaknesses of revising DEQ website

	Strengths	**Weaknesses**
Environmental Impacts		*Does not provide an opportunity for the public to inform decision making about potential environmental impacts*

Economic Impacts		*State may incur costs to revise site and have it reviewed*
Health Impacts		*Does not provide an opportunity for the public to inform decision making about potential health impacts*
Community Impacts	*Public may be better informed to make decisions about leasing their own land*	*Does not provide an opportunity for the public to inform decision making about potential community impacts*
Governance Impacts	*May increase perceived transparency of DEQ if information is easier to access and addresses public's questions* *May increase trust in DEQ, especially if site is reviewed by a neutral third-party and/or if the public is invited to provide feedback on the site's content and design* *Public may be better informed when given other opportunities to weigh in on shale gas policy*	

If perceived to be user-friendly and credible, a revised website may help improve transparency about HVHF-related activities as well as potentially increase the public's trust in the DEQ. However, as a website remains a one-way form of communication, this policy—if implemented alone—is unlikely to fully address stakeholder concerns. To be more effective, this option should be combined with other mechanisms that enable stakeholders to provide direct input on HVHF policies (see e.g., Option C).

2.2.3.3 Option B: Require risk communication training for DEQ and DNR employees

This policy option would require risk communication training for DEQ employees in the Office of Oil, Gas, and Minerals, as well as DNR employees who manage state mineral rights leasing auctions. The National Research Council defines risk communication as an interactive process that facilitates the:

> "exchange of information and opinion among individuals, groups, and institutions… [R]isk communication is successful only to the extent that it raises the level of understanding of relevant issues or actions and satisfies those involved that they are adequately informed within the limits of available knowledge."[76]

The intent of this policy option would be to improve agency communication and listening skills in order to increase transparency about HVHF, increase stakeholders' capacity to make informed decisions about HVHF, and to better incorporate public values into HVHF-related rules and instructions. The U.S. Environmental Protection Agency (EPA) defines seven cardinal rules of risk communication:[77]

1. Accept and involve the public as a legitimate partner.
2. Plan carefully and evaluate your efforts.
3. Listen to the public's specific concern.

4. Be honest, frank, and open.
5. Coordinate and collaborate with other credible sources.
6. Meet the needs of the media.
7. Speak clearly and with compassion.

An underlying theme of these rules is that the public's concerns and perceptions of risk are valid and should not be dismissed—even if they conflict with technical assessments of risk.

Table 2.3: Strengths and weaknesses of requiring risk communication training for DEQ and DNR staff

	Strengths	Weaknesses
Environmental Impacts	*May lead to better environmental outcomes* • Agency staff may be more responsive to the public's concerns about particular ecological impacts	
Economic Impacts		*DEQ and DNR may incur costs to implement this option.*
Health Impacts	*May reduce stress among certain groups* • When individuals feel they can trust agency staff and that their concerns have been acknowledged, they may experience less anxiety about HVHF • Agency staff may be more responsive to the public's concerns about potential health impacts	
Community Impacts	*May reduce community impacts* • Agency staff may be more responsive to the public's concerns about particular localized impacts	
Governance Impacts	*May increase trust in DEQ and DNR* • When members of the public feel they have been listened to and treated fairly, they are more likely trust the institutions involved[78] *May increase legitimacy of decisions if DEQ and DNR truly consider public input* *Public may be better informed to weigh in on shale gas policy*	

If staff members take risk communication training seriously, this option has the potential to have far reaching effects. By learning how to better acknowledge and address public concerns, agency staff may be better equipped to engage the public in productive conversations about HVHF. This may be beneficial, for example, when DEQ and DNR staff participate in public meetings, give public presentations, or write content for agency websites.

2.2.3.4 Option C: Conduct public workshops to engage Michigan residents in HVHF decision making

Under this option, the state could conduct a series of interactive workshops with the public. Beyond answering questions about HVHF, the purpose of these workshops would be to involve the public in defining the key risks of concern with HVHF as well as policy options that could be used to mitigate them. For these workshops to be successful, it is important that they be led by skilled facilitators trained in risk communication and public participation techniques.[79,80]

Table 2.4: Strengths and weaknesses of conducting public workshops

	Strengths	**Weaknesses**
Environmental Impacts	*Environmental impacts may be better accounted for in HVHF-related policies*	*Some environmental concerns may not be adequately represented depending on who attends the meetings*
Economic Impacts		*Economic cost to state to hold workshops and hire third-party moderators/facilitators*
Health Impacts	*Health impacts may be better accounted for in HVHF-related policies*	*Some health concerns may not be adequately represented depending on who attends the meetings*
Community Impacts	*Community impacts may be better accounted for in HVHF-related policies* *May decrease stress and anxiety about HVHF if workshops help state focus on issues of key concern to public*	*Some community concerns may not be adequately represented depending on who attends the meetings*
Governance Impacts	*May increase trust in DEQ* • When the public feels they have been listened to and treated fairly, they are more likely trust the institutions involved[81,82] *May increase perceived transparency of DEQ* *May increase perceived legitimacy of decisions* *May lead to higher-quality decisions and policies if public input is incorporated* *Public may be better informed to weigh in on future shale gas policies*	*Increased administrative burden to organize workshops and integrate learnings into DEQ policies*

As described in the Public Perceptions Technical Report,[83] state and industry technical risk assessments are unlikely to account for all of the risks that the public associates with HVHF and unconventional shale gas development. Moderated workshops would offer a means for the public to ask questions, raise concerns, and engage in two-way discussions with state agency representatives. These interactive discussions may help stakeholders move past disagreements about, for example, the safety of HVHF, toward identifying priority issues that HVHF-related policies should address. The success of these workshops may depend on the skill of the facilitator(s) and the degree to which agency staff treat the public's concerns as important and legitimate (see Option B).

2.2.3.5 Option D: Impose a state-wide moratorium on HVHF

To address public concerns about HVHF, the state could impose a moratorium on HVHF permitting. During the moratorium, the state could do one or more of the following:

(1) Conduct studies on Michigan-specific HVHF impacts; (see Option F)
(2) Identify best practices for mitigating HVHF impacts and devise additional HVHF-specific regulations to mitigate them (see Option F).
(3) Engage Michigan residents in an analytical-deliberative process, so that public values may be more accurately accounted for in HVHF policy (see Option C).

A statewide moratorium is supported by several municipalities[i] in the state[84] as well as several grassroots and nonprofit organizations, including the Michigan Chapter of the Sierra Club.[85,86,87]

Table 2.5: Strengths and weaknesses of imposing a moratorium on HVHF

	Strengths	**Weaknesses**
Environmental Impacts	*Delays all known and unknown environmental impacts* *May provide time for protective policies to be put in place*	
Economic Impacts	*Would avoid costs that may be incurred (e.g., from accidents, unknown health impacts, etc.) if deep shale gas development proceeds before its risks are fully known or adequate regulations are in place.*	*May delay economic gains to state, industry, and mineral rights owners*
Health Impacts	*Delays all known and unknown health impacts* *May provide time for protective policies to be put in place*	
Community Impacts	*Delays all known and unknown community impacts* *May provide time for protective policies to be put in place*	
Governance Impacts	*May provide an opportunity for the public to influence unconventional shale gas policy before additional policy decisions are made or additional wells are fracked* *May lead to higher quality decisions if the moratorium is used to gather more information*	*May lead to pushback from industry*

[i] Burleigh Township, Canon Township, Courtland Township, Reno Township, Scio Township, and West Bloomfield Township. Another 11 communities have passed ordinances in support of a statewide ban.

While a moratorium, by itself, does not ensure that public values will be incorporated into HVHF policy, this "time-out" from development provides an opportunity to do so. Pausing development may ease tensions while policies are refined. Imposing a moratorium may also send a signal to the public that the state is taking their concerns seriously.

2.2.3.6 Option E: Ban HVHF

To address public concerns about HVHF, Michigan could impose a ban on HVHF permitting. As with a moratorium, further study of HVHF's impacts could be conducted, and a ban could be reversed if science indicated minimum negative impacts and/or if public opinion shifted positively toward HVHF. A statewide ban is supported by at least eleven communities throughout the state, including Dearborn Heights,[88] Detroit,[89] Ferndale,[90] Ingham County,[91] Wayne County,[92] and Ypsilanti.[93] Several grassroots and nonprofit groups also support a HVHF ban (and HF in general), including Don't Frack Michigan,[94] Ban Michigan Fracking,[95] Friends of the Jordan River Watershed,[96] Friends of the Boyne River,[97] Michigan Citizens for Water Conservation,[98] Northern Michigan Environmental Action Council (NMEAC),[99] and Food and Water Watch.[100]

Table 2.6: Strengths and weaknesses of banning HVHF

	Strengths	**Weaknesses**
Environmental Impacts	*Prevents all known and unknown environmental impacts of HVHF* *May encourage development of renewable energy industries*	
Economic Impacts	*Enables DNR and DEQ to dedicate limited staff resources to other activities under their jurisdictions*	*Prevents all economic gains from HVHF* *State may be subject to legal action as a result of taking property*
Health Impacts	*Prevents all known and unknown health impacts, including stress associated with HVHF operations that occur nearby*	
Community Impacts	*Prevents all known and unknown local impacts (e.g., changed landscapes, road damage, noise, odors, surface spills, etc.)*	*Mineral rights owners may feel they are unfairly having to sacrifice potential royalties*
Governance Impacts	*May provide adequate time for study and analysis of HVHF's potential impacts*	*If short and long-term impacts of HVHF are found to be minimal, reversing ban would require political momentum* *Does not involve the public in the decision making process*

Banning HVHF provides the most comprehensive solution for addressing concerns about the potential risks of unconventional shale gas development. However, this option comes at the cost of reducing income to the mineral rights owners, industry, and the state by preventing development of the resource. A ban may also lead to other conflicts if mineral rights owners feel they are unfairly forced to give up potential income.

2.2.3.7 Option F: Appoint a multi-stakeholder advisory commission to study HVHF impacts and identify best practices for mitigating them

Many of the public's concerns about HVHF arise from the uncertainty of its impacts. Following Maryland's lead, Michigan could undertake a multi-part study to further investigate the environmental, economic, and health risks of HVHF specific to Michigan.[101] This study could build off of the University of Michigan Integrated Assessment by collecting data in communities likely to be impacted by HVHF as well as making specific recommendations to address issues of greatest concern to Michigan. To balance stakeholder interests, the study could be led by an advisory commission comprised of experts in public health, ecology, economics, hydrogeology, and oil and gas production. House Bill 4901, sponsored by Hovey and Wright in 2013 proposed a similar policy.[102]

Table 2.7: Strengths and weaknesses of appointing an advisory commission to further study HVHF

	Strengths	**Weaknesses**
Environmental Impacts	*Environmental impacts may be better accounted for in HVHF-related policies*	*Does not provide an opportunity for the public to inform decision making about potential environmental impacts*
Economic Impacts		*State may incur cost to appoint commission*
Health Impacts	*Health impacts may be better accounted for in HVHF-related policies*	*Does not provide an opportunity for the public to inform decision making about potential health impacts*
Community Impacts	*Community impacts may be better accounted for in HVHF-related policies*	*Does not provide an opportunity for the public to inform decision making about potential community impacts*
Governance Impacts	*May better represent public interests and values in HVHF policy* *May increase public trust in State* *May increase perceived legitimacy of HVHF policies*	*Organizing the commission may increase administrative burden to State* *Does not directly involve the public*

Encouraging further study of potential HVHF impacts in Michigan could help ensure that unconventional shale gas policies are adequately protective. At the same time, implementing this option may help demonstrate that the public's concerns have been heard. To promote greater involvement of the public, this option could be combined with Option C so that public workshops inform the advisory commission's recommendations. A similar process was used in 2013 when Governor Rick Snyder called for a one-year study of Michigan's energy future. A workgroup co-chaired by leaders of the Michigan Public Service Commission and the Michigan Energy Office conducted seven public forums to gather public input from around the state.

2.2.3.8 Option G: Increase stakeholder representation on Oil and Gas Advisory Committee

To help ensure that stakeholder interests are represented in oil and gas policy on an ongoing basis, the composition of Michigan's Oil and Gas Advisory Committee could be revised. Following the leads of other states, this could involve adding two seats to the 8-person committee as well as creating greater balance among stakeholder interests. For example, the number of seats held by the oil and gas industry could be reduced from six to three. The remaining seven seats could be allocated to a geology or oil and gas expert from a college or university, two representatives of different environmental organizations, a member with expertise in environmental or wildlife protection, a representative from the state's Department of Community Health (DCH), a public health expert from a college or university, and a representative from a local government in an area where HVHF is likely to occur. In addition, the responsibility for appointing committee members could be split among the directors of the DEQ, DNR, and DCH.

Table 2.8: Strengths and weaknesses of modifying Oil and Gas Advisory Committee composition

	Strengths	**Weaknesses**
Environmental Impacts	*Environmental impacts may be better accounted for in HVHF-specific and other oil and gas policy*	*Does not provide an opportunity for the public to inform decision making about potential environmental impacts*
Health Impacts	*Health impacts may be better accounted for in HVHF-specific and other oil and gas policy*	*Does not provide an opportunity for the public to inform decision making about potential health impacts*
Community Impacts	*Community impacts may be better accounted for in HVHF-specific and other oil and gas policy*	*Does not provide an opportunity for the public to inform decision making about potential community impacts*
Governance Impacts	*May help ensure that public interests and values are considered in HVHF-related policy on an on-going basis*	*Does not directly involve the public in decision making*

Overall, the strength of this option is that it increases the likelihood that a broad range of potential impacts—many of which are of concern to the public—will be considered on an on-going basis in HVHF-related policies. However, this option, alone, does not address any concerns regarding the public's level of participation in decision making.

2.2.4 Summary of options for improving public involvement in unconventional shale gas policy

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 land leasing and well permitting practices (which will be discussed in the next two sections), the state could consider implementing a number of options to better represent public values in unconventional shale gas policies. As a first step toward building the public's trust and signaling that public concerns have been heard, the state could revise the content and usability of the DEQ website as well as require risk communication training for DEQ and DNR staff. DEQ could augment these efforts by providing 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. Information generated during these discussions may help ease some of the public's concerns as well as inform state decision making.

To help ensure that potential impacts to human health, the environment, and local communities are adequately considered in HVHF policies, the state could increase stakeholder representation on the Oil and Gas Advisory Committee as well as appoint a multi-stakeholder advisory commission to further study the potential impacts of HVHF in Michigan. Finally, to ease tensions around HVHF and provide an opportunity to engage the public in more analytic-deliberative discussions about unconventional shale gas development, the state could impose a moratorium or ban on HVHF permitting.

2.3 PUBLIC INPUT IN STATE LAND LEASING

2.3.1 Introduction

The state is the largest owner of mineral interests in Michigan with over 3.8 million acres of combined surface and mineral rights, 2.1 million acres of mineral rights (without surface rights), and 25 million acres of Great Lakes bottomlands.[103] Under current policy, the Department of Natural Resources (DNR) is responsible for running the state's oil and gas land lease auctions and determining the extent to which state-owned land can be developed for oil and gas activity.

As many state lands include areas of scenic, ecological, or recreational value, the leasing of oil and gas rights for possible oil and gas development can create significant concerns among the public. While a lease by itself does not guarantee that oil or gas development will occur, the public may nonetheless worry that approving state-owned mineral rights for development moves those parcels of land one step closer to being drilled. Such concerns have been raised in public comments and lawsuits related to several recent leases in Michigan. For example, in a lawsuit challenging planned leases in Allegan State Game Area (Allegan County), Barry State Game Reserve and Yankee Springs Parks and Recreation Area (Barry County), nearby property owners questioned the impact of oil and gas leasing on ecologically-valuable land, citing the possibility of groundwater contamination and the destruction of unique wildlife habitat if drilling were to occur.[104] Similarly, in the case of the approved lease of the Holy Waters of the Au Sable River (Crawford County), a coalition of 17 nonprofits, businesses, and local municipalities wrote a letter to the director of the DNR voicing concerns that oil and gas activities would ruin the area's essential aesthetic and recreational character as well as threaten the endangered Kirtland Warbler.[105] The group also expressed a desire for greater public involvement in state land lease decisions: "…[I]n the future, let's have a process where we can say there are some areas in the state's ownership that aren't appropriate for oil and gas development because there are competing and incompatible uses."[106]

2.3.2 Range of approaches

Mechanisms for involving the public in state leasing decisions vary by state, ranging from no mechanism for public input to more complex policies that ensure public input is widely solicited and reviewed.[ii] In most states, public input on state oil and gas leases is solicited through a formal public comment period. Notice of this public comment period is usually posted in local newspapers and on agency websites, anywhere from one to 60 days before leases are awarded. Some states, such as Alaska, advertise more broadly by posting in public places (libraries, post-offices, etc.), sending paper mailings and emails to self-identified subscribers, and notifying parties known or likely to be affected.[107] A few states, including Alaska and New York, hold public hearings or workshops to directly solicit public comments.[108,109] Following the comment period, a decision is made whether to auction the land for leasing. In New York, a responsiveness summary of public comments received is also provided to any interested party.[110]

2.3.3 Analysis of policy options

This section considers five policy options for addressing public concerns about the leasing of state mineral rights:

- Keep Michigan's existing policy
- Option A: Increase public notice
- Option B: Require a responsiveness summary
- Option C: Require public workshops prior to state land auctions
- Option D: Increase public notice and comment when lessees submit an application to revise or reclassify a lease

These options may be used independently or implemented together.

2.3.3.1 Keep Michigan's existing state land leasing policy

The Natural Resource Commission (NRC) and Director of the Department of Natural Resources (DNR) are responsible for managing state-owned lands and mineral resources "to ensure protection and enhancement of the public trust."[111] As such, the DNR runs its own leasing program for state-owned lands and is responsible for collecting royalties if production occurs. The majority of leases are made available through public auction twice per year, though in limited cases the DNR is authorized to enter into oil and gas leases directly. Michigan's constitution requires that the revenue generated from leasing state-owned oil and gas rights goes into the Michigan State Parks Endowment Fund and the Game and Fish Protection Trust Fund,

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[ii] States reviewed include Alaska, Arkansas, Colorado, Illinois, Louisiana, Maryland, Michigan, New Mexico, New York, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, and West Virginia.

which allows for improvements in parks and increased opportunities for recreation.[112]

DNR staff classifies Michigan's oil and gas rights into categories that determine whether the mineral rights can be leased as well as the extent to which development can occur on the surface.[113] These categories include:

- **Non-leasable:** Mineral rights cannot be leased and surface land is protected from development. However, this classification does not prevent possible drainage of minerals by others.
- **Non-development**: Mineral rights are leasable, but surface use is not allowed without separate written permissions. These leases prevent drainage by others, thereby preventing loss of state revenue. This classification applies to public parks and recreation areas, wetlands, dunes, and other areas that have cultural or ecological value, including the bottomlands of all inland lakes and streams (excluding the Great Lakes).
- **Development**: Mineral rights are leasable and surface use may be allowed after written permission is obtained following review of development plans. Standard lease procedures apply to this classification.
- **Development with restriction**: Mineral rights are leasable and surface use may be allowed under specific conditions following review of submitted development plans. These leases may have restrictions based on natural features of the parcels and/or other current surface uses.

In Michigan, the process for auctioning oil and gas leases begins with advertisements to the oil and gas industry, which then nominates public oil and gas rights it wishes to lease.[114] The DNR then compiles an auction list based on leasable lands, mails out individual notifications to surface owners of publically owned mineral rights on the list, and publishes a notice of all auction list lands and their development classifications for public comment and review.[115] The notice is published in counties where the lands are located and in major regional newspapers at least 30 days in advance of the DNR Director's decision to hold the auction. In addition, the DNR sends information regarding proposed leases to the counties and townships where parcels are located. Information regarding the procedures and forms used to lease public lands in the State of Michigan as well as a list of lands that have been nominated for lease are also posted on the DNR website. Following public notice, the DNR then prepares a memo for the Director incorporating public comments.[116] Although there is no requirement for the state to formally respond to public input, the DNR, in practice, responds to every comment received (T. Newcomb, DNR, personal communication, January 30, 2015). Direct leases, which are only used in limited circumstances and make up a small percentage of total leases, go through the same public comment procedure 30 days before the Director's decision.[117] Auction results are made available online.[118] After a lease is awarded, the lessee may submit an application to the DNR to request a reclassification of the lease, variances from the lease terms, or a change in restrictions associated with the lease.[119,120,121] The DNR posts information about these activities on its online department calendar. When a lessee submits an application to reclassify a lease, the DNR notifies self-subscribed members of its email list.[122]

Table 2.9: Strengths and weaknesses of keeping Michigan's existing state land leasing policy

	Strengths	**Weaknesses**
Environmental Impacts	*May help protect environmentally valued land*	*Some environmental considerations may not be accounted for* • Limited distribution of public notice may prevent some stakeholders from voicing relevant concerns
Health Impacts		*Some health considerations may not be accounted for* • Limited distribution of public notice may prevent some stakeholders from voicing relevant concerns
Community Impacts	*May help protect culturally valued areas* • Comment process allows public to identify valued areas that should be protected from shale gas development activities.	*Some community impacts may not be accounted for* • Limited distribution of public notice may prevent some stakeholders from voicing relevant concerns
Governance Impacts	*May increase legitimacy of DNR decisions* • Policy is more participatory than states that do not have any public notice or comment.	*Transparency and legitimacy of decision making could be improved* • Posting public notice in newspapers and online may not reach all interested stakeholders • It is unclear how public comments influence DNR decision. • Stakeholder groups have criticized Michigan's policy for allowing the DNR to administratively modify the terms of authorized leases without first seeking public input through a formal public notice and comment period.[123,124] As a result of this process, parcels designated as non-development, which prohibits surface activities, may later have pipelines, roads, or other infrastructure built on the surface.

Michigan's policy is more participatory than other states that do not have a public comment period for state mineral rights leases. As evidenced by past proposed leases, the process for notifying the public and inviting comments can be effective. For example, in the case of the Au Sable River Holy Waters, an outpouring of negative public comments directed the agency to change the classification of nine proposed "restricted development" leases to "non-development."[125] Likewise, the classification for some proposed leases within Hartwick Pines State Park, the State's largest stand of old growth white pine in the Lower Peninsula, was changed from non-development to non-leasable after the public comment period.[126] While these examples illustrate that the DNR can be responsive to the public's input, concerns remain that the process is one-way and does not allow the public to engage in a dialogue with the state about where and whether HVHF should occur on public land. There are also concerns that the DNR may modify lease terms without a formal public notice and comment period.[127,128]

2.3.3.2 Option A: Increase public notice

Under this option, Michigan's existing policy would be revised to expand the distribution of public notice. Currently, Michigan requires public notice in newspapers in the counties and regions where the lands nominated for leasing are located. Notice is also sent to the local DNR office, township supervisors, county commissioners, legislators and surface owners. This information is also posted on the DNR website and sent to subscribers of the DNR's mailing list. To ensure that potentially affected parties are notified of the proposed leases, notification could be required to all landowners whose property lies adjacent to the nominated land or within one-quarter (1/4) mile of the parcel's boundaries. For land that is used by the public for recreational purposes, public notice could also be required at the parcel itself to ensure that users of the affected lands are notified.

Table 2.10: Strengths and weaknesses of increasing public notice about proposed state land leases

	Strengths	***Weaknesses***
Environmental Impacts	*May improve environmental outcomes* • Through increased notice, DNR may learn of additional environmental conditions that should be considered in its decision making	
Economic Impacts		*More expensive for DNR to execute*
Health Impacts	*May improve health outcomes* • Through increased notice, DNR may learn of additional conditions that should be considered in its decision making	*May cause stress for some local residents* • Increasing public notice may distress some community members who would otherwise not have known about proposed leases
Community Impacts	*May improve community outcomes* • Through increased notice, DNR may learn of additional local conditions or culturally valued aspects of the land that should be considered in its decision making	
Governance Impacts	*Easy to implement and enforce* *May increase perceived transparency of DNR decision making* *May increase legitimacy of DNR decision* • Increases likelihood that potentially affected parties have an opportunity to comment on proposed leases	*Increased administrative burden* DNR would have to identify and mail notices to nearby landowners

Expanding public notice offers a relatively inexpensive way to increase transparency about potential state land leasing and ensure that affected parties have an opportunity to comment. This may, in turn, lead to more favorable impressions of how the DNR handles state land leasing—provided that the DNR is responsive to the public comments received.

2.3.3.3 Option B: Require DNR to prepare a responsiveness summary

Currently, the DNR is not required to respond in any way to public comments on state land leases. This policy option would require the DNR to prepare a responsiveness summary that includes a summary of the public's comments, suggestions, and criticisms as well as the DNR's responses to those comments. The responsiveness summary should also describe how public input influenced the DNR's final decision regarding the lease classification of each nominated parcel and, where applicable, an explanation of why specific suggestions made by the public were rejected. The responsiveness summary would be made publicly available through the DNR website and to any interested party who requests it. Other state programs such as Michigan's Air Pollution Control Program (under the DEQ) provide these types of responsiveness summaries.[129]

Table 2.11: Strengths and weaknesses of requiring DNR to prepare a responsiveness summary

	Strengths	**Weaknesses**
Governance Impacts	*Easy to implement and enforce* *May increase transparency about DNR decision making* *May increase trust in DNR* *May increase perceived legitimacy of DNR decision* • Requiring a responsiveness summary would demonstrate that public comments have been dutifully considered • May increase public trust in process	*May increase administrative burden* • DNR would have to dedicate more resources to process public comments. • May delay timeline for holding auction.

The strength of this option is that it could make the DNR more accountable to public comments. By directly answering the public's questions and addressing their concerns, responsiveness summaries help demonstrate that the public's opinions are valued. Implementing this option may, in turn, increase public trust in the DNR.

2.3.3.4 Option C: Require public workshops prior to state land auctions

Under this option, the DNR would be required to host public workshops before state land auctions so that the public has an opportunity to ask questions and engage in conversations with DNR staff. Input received during these workshops would be factored into DNR's decision making along with other written comments received.

Table 2.12: Strengths and weaknesses of requiring a public workshop before auctioning state mineral rights

	Strengths	Weaknesses
Environmental Impacts	*May improve environmental outcomes* • By allowing public comment, DNR may learn of important local conditions that should be considered in its decision making	
Economic Impacts		*Economic cost to state to hold workshops and hire third-party moderators/facilitators*
Health Impacts	*May improve health outcomes* • Allowing the public to engage in conversations with DNR staff about proposed leases may reduce the stress associated with the uncertainty of having HVHF operations nearby • Public comments may bring to light public health considerations that will improve DNR's decision making	
Community Impacts	*May improve community outcomes* • Inviting public comments would allow affected parties to identify potential concerns before well construction, such that some impacts may be lessened or avoided	
Governance Impacts	*May increase legitimacy of DNR's decision* *May increase public sense of procedural fairness* *May increase public trust in DNR*	*Increased administrative burden* • DNR may have to dedicate more resources to host workshops and find appropriate facilitators

This option could augment Michigan's existing policy by providing a mechanism for the public to engage in a two-way dialogue with the DNR about proposed state land leases. Workshops may enable the public to ask questions of the DNR as well as contribute important local knowledge that may not be adequately captured in written comments. As a result, this option may help increase not only the transparency of DNR's decision making, but also its legitimacy.

2.3.3.5 Option D: Increase public notice and comment when lessees submit an application to revise or reclassify a lease

Currently, the DNR posts notice of applications to modify a lease on its website and to subscribers of its email list. This option would require the DNR to have a formal public notice and comment period with notice posted in regional newspapers and at the parcel where the lease is held. The public notice and comment period could follow the same procedure as used for lease auctions, with public notice made at least 30 days before a decision is made. Ideally, nearby landowners and users of the land would also be notified, in accordance with proposed Option A.

Table 2.13: Strengths and weaknesses of requiring public notice and comment for lease modifications

	Strengths	**Weaknesses**
Environmental Impacts	*May improve environmental outcomes* • By allowing public comment, DNR may learn of important environmental conditions that should be considered in its decision making	
Economic Impacts		*May delay well development* *Increased economic burden to DNR, particularly if nearby landowners are notified*
Health Impacts	*May improve health outcomes* • DNR may learn of potential community impacts or concerns that should be considered when evaluating variances from the lease's terms or restrictions • Allowing public comment and improving transparency may reduce stress and anxiety for some nearby residents	*May cause stress for local residents* • Increasing public notice may distress some community members who would otherwise not have known about planned changes to the lease
Community Impacts	*May improve community outcomes* • DNR may learn of potential community impacts or concerns that should be considered when evaluating variances from the terms of the lease or changes in restrictions.	
Governance Impacts	*Easy to implement and enforce* *May increase public's sense of procedural fairness* *May increase public trust in DNR* *May increase transparency about DNR decision making* *May increase legitimacy of DNR decision* • May increase public trust in process	*Increased administrative burden* • DNR would have to dedicate more resources to collect and process public comments.

This final option would address stakeholder concerns that state land leases may be modified without public input. Subjecting lease modifications to public notice and comment in regional newspapers could increase transparency about DNR's decision making as well as increase trust in the DNR. As a result of inviting broader public comment, the DNR may learn of important local considerations that should be factored into its review of the lease modification application.

2.3.4 Summary of options for improving public involvement in state land leasing

Michigan's existing policy of requiring public notice and comment before auctioning state mineral rights has been reasonably responsive to public concerns. The existing policy could be strengthened, however, by 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, and/or requiring public notice and comment when well operators request modifications of existing state land leases. Each of these steps could enhance transparency about state land leasing as well as increase the likelihood that the DNR's decisions will be informed by relevant environmental, health, and community considerations.

2.4 PUBLIC PARTICIPATION AND WELL PERMITTING

2.4.1 Introduction

Once an oil and gas company obtains a lease for either privately or publicly-owned mineral rights, it must obtain a drilling permit from the Michigan DEQ. DEQ staff has a period of 50 days to review a permit application before issuing or denying the permit, or requesting further information from the applicant. While there is no formal public notice and comment period, the DEQ maintains a weekly list on its website of oil and gas well permits that have been applied for and issued. A hyperlinked e-mail address enables site visitors to submit comments about applications that are being considered.[130] The DEQ also regularly updates a map of HVHF activity in the state, including active applications. When reviewing a permit application, the DEQ considers whether the applicant will comply with conservation measures, the number of other wells in the area, and the well's proximity to natural and cultural resources (see the Policy and Law Technical Report[131] for a more detailed description of the permitting process and permit considerations). .

Numerous stakeholder groups in Michigan have advocated for greater transparency about the location of wells to be completed with HVHF as well as greater opportunity for the public to participate in decisions about permits and drilling activities.[132,133,134,135] As nearby shale gas operations can have negative impacts on neighboring landowners and community members, many people feel they have, at minimum, a right to know where HVHF operations are planned, if not a say in whether HVHF should occur in certain locations. From the perspective of mineral rights owners, however, public involvement may be unwelcome as it may impede development of the resource.

The following discussion examines approaches and policy options for involving the public in well permitting decisions. Policies related to water use and chemical disclosure requirements for each well site are explored in Chapters 3 and 4, respectively.

2.4.2 Range of approaches

The extent to which the public can influence well permitting decisions varies from state to state. In several states, the public has limited opportunity to learn of permit applications as notice is only required to surface owners (e.g., Arkansas[136], Michigan[137], Oklahoma,[138] Pennsylvania,[139] Texas[140]) and/or to local units of government (e.g., Michigan,[141] New Mexico[142] Pennsylvania[143]; proposed in New York before ban[144]). In other states, public notice is extended to property owners within a certain distance of the proposed well site (e.g., Louisiana,[145] , North Dakota[146], Ohio[147], Pennsylvania[148]) and to newspapers in the county in which the proposed well site resides (e.g., Illinois[149] and Maryland[150]). In Michigan, members of the general public can only learn of well permit applications by submitting a written request to the state or by browsing the state's website. In Illinois, by contrast, public notice and comment periods are mandated as part of the permitting process.[151,152] Some states also allow parties who may be adversely affected to request a public hearing before a permit is issued (e.g., Illinois[153] and Maryland,[154]) or to contest approved permits (Michigan[155] and North Dakota[156]).

2.4.3 Analysis of policy options

This section considers four policy options for involving the public in HVHF permitting decisions:

- Keep Michigan's existing policy
- Option A: Increase public notice of permit applications
- Option B: Require a public comment period with mandatory DEQ response
- Option C: Allow adversely affected parties to request a public hearing before a HVHF well permit is approved

Policy options related to water and chemical use are discussed, respectively, in Chapter 3: Water Resources and Chapter 4: Chemical Use.

2.4.3.1 Keep existing Michigan well permitting policy

The DEQ is required to give notice of permit applications to the surface owner, the county in which the well is proposed, and the city, village, or township in which the oil or gas well is proposed *if* that city, village, or township has a population of 70,000 or more.[157] As a matter of practice, the DEQ also provides notice to every city, village, or township, regardless of population size. A copy of the application is also mailed to the county clerk. The public notice contains the name and address of the applicant, the location of the proposed well, the well name and number, the proposed depth of the well, the proposed formation, the surface owner, and whether hydrogen sulfide gas is expected.[158] Any city, village, township, or county in which a well is proposed can provide written comments and recommendations on the permit application to the DEQ, which the DEQ is required by statute to consider. The DEQ is not required, however, to summarize or formally respond to input received.

Though not mandatory, the DEQ also posts notices of permit applications through its website and an email list of self-subscribed interested parties.[159] In addition, while there is no requirement to solicit public input on permit applications, the DEQ informally accepts any comments that are submitted.[160]

Table 2.14: Strengths and weaknesses of keeping Michigan's existing well permitting policy

	Strengths	**Weaknesses**
Environmental Impacts		*Potentially worse environmental outcomes* • By limiting public notice and comment, DEQ may not learn of important local environmental conditions that may be impacted by shale gas activities
Economic Impacts	*May benefit mineral rights owners, well operators, and the state through faster development of the resource*	
Health Impacts		*May contribute to adverse health outcomes* • Uncertainty about where HVHF activities are proposed may distress nearby community members who fear changes to their local landscape and/or possible health consequences[161] • By limiting public notice and comment, DEQ may not learn of important public health considerations that may be impacted by shale gas activities
Community Impacts		*May contribute to adverse community impacts* • By limiting public notice and comment, DEQ may not learn of potential community impacts that could be lessened or avoided
Governance Impacts	*Limited distribution of public notice may reduce administrative burden on DEQ*	*Less participatory than other states* *Policy may be perceived as procedurally unfair and non-transparent* • Population criterion for public notice means that the local communities most likely to be impacted by HVHF are not given notice. Only 21 cities, villages and townships in the State of Michigan have more than 70,000 inhabitants[162], and few, if any, are in areas conducive to HVHF. • Citizens – including those who may be directly affected by nearby shale gas development operations – are excluded from public notice and comment. • Residents seeking permit application information must look to the DEQ website, which is counterintuitive and difficult to navigate. *May contribute to distrust of DEQ and public outrage about HVHF*

		• Policy and lack of transparency may be perceived as procedurally unfair. *Lack of public participation may heighten controversy around HVHF* *Unclear how comments received are incorporated into DEQ decision making* • While DEQ is required to considercomments from local units of government, this requirement is broad and difficult to enforce. • The DEQ informally accepts public comments, but there is no assurance that these comments inform its decision.

When it comes to notifying the public of well permitting applications and inviting public comment, Michigan's current practices are more inclusive than some states and less inclusive than others. DEQ's practices of posting information about oil and gas applications on its website and allowing members of the public to submit comments are a positive step toward incorporating public values in its decision making. However, in the absence of a formal public notice and comment period, affected communities may feel that HVHF is being involuntarily imposed. Finally, while the current procedures may facilitate expedient processing of permit applications, they may also cause some important environmental, health, and community considerations to be overlooked.

2.4.3.2 Option A: Increase notification of permit applications

Under this option, existing Michigan policy would be revised to increase public notice of permit applications. This would include removing the population threshold from the current statute, such that all cities, villages, and townships are notified of permit applications for wells to be constructed within their boundaries, regardless of the area's population size. Michigan legislators introduced a similar bill in 2013.[163] In addition, this policy option could require public notice in local newspapers as well as to landowners whose property lies in close proximity to the land where the proposed well will be drilled. To reduce burden on DEQ, this requirement could be fulfilled by the permit applicant. Illinois, for example, requires HVHF permit applicants to post notice in county newspapers and to mail notices to all landowners within 1500 ft. of the proposed well.[164]

Table 2.15: Strengths and weaknesses of increasing notice of permit applications

	Strengths	**Weaknesses**
Environmental Impacts	*May improve environmental outcomes* • By increasing notice to other local units of government, DEQ may learn of important local conditions that should be considered in its decision making	

Economic Impacts		*May delay well development*
Health Impacts	*May decrease stress for some* • Increased transparency about where HVHF is planned may decrease stress for some community members by reducing uncertainty	*May increase stress for others* • Increasing public notice may distress some community members who would otherwise not have known about potential nearby shale gas activities
Community Impacts	*May improve community outcomes* • Increased public notice may ensure that local units of government have ample opportunity to consider and comment on potential adverse impacts (e.g., noise, light, smells, road wear, etc.).	
Governance Impacts	*Easy to implement and enforce* *May increase perceived transparency* • Ensures all units of government are notified of potential wells • Ensures nearby landowners are aware of planned HF operations nearby *May increase public trust in DEQ*	*Increased administrative burden* *This option, if used alone, does not promote public participation*

Increasing public notice of well permit applications would increase transparency about where HVHF operations may occur. In addition, by notifying all local units of government where a well is proposed—regardless of population size—the DEQ may learn of other important environmental, health, and community factors that should be considered in its decision making. The benefits of this option would be magnified if it were combined with an option that formally allowed the public to comment on proposed well permits (see Option B).

2.4.3.3 Option B: Require a public comment period with mandatory DEQ response

While DEQ informally accepts comments from the public about proposed wells, there is no formal mechanism to ensure that Michigan residents have a say in whether HVHF occurs in their communities. This policy option would mandate a 30 day public comment period following public notice of a permit application. To demonstrate that public comments have been heard and dutifully considered, this option could require the DEQ to prepare a responsiveness summary for all substantive comments received. DEQ prepares a similar "Response to Comment Document" as part of Michigan's Air Pollution Control Program.[165] Furthermore, the DEQ could require the well operator applying for the permit to address any substantive public comments received. Illinois included a similar provision in its Hydraulic Fracturing Regulatory Act.[166]

Table 2.16: Strengths and weaknesses of requiring public comment with DEQ response

	Strengths	***Weaknesses***
Environmental Impacts	*May improve environmental outcomes* • By allowing public comment, DEQ may learn of important local	

	conditions that should be considered in its decision making	
Economic Impacts		*May delay well development* *Potential loss of revenue for mineral rights owners and lessees* • Policy may result in fewer permits being approved. Mineral rights owners would lose out on royalties. Oil and gas companies would lose bonuses paid to mineral rights owners as well as income from the untapped resource.
Health Impacts	*May improve health outcomes* • Allowing the public to comment on well permit applications may reduce the stress associated with being involuntarily subjected to the risks of HVHF • Public comments may bring to light public health considerations that will improve DEQ's decision making	
Community Impacts	*May improve community outcomes* • Inviting public comments would allow impacted communities to identify potential concerns before well construction, such that some impacts may be lessened or avoided	
Governance Impacts	*Easy to enforce* *May increase legitimacy of DEQ's decision* *May increase public sense of procedural fairness* *May increase public trust in DEQ and well operator* *Compatible with industry guidelines* • The API's community engagement guidelines advocate that well operators communicate effectively with local communities through a two-way process of giving and receiving information that respects local stakeholders' concerns.[167]	*Increased administrative burden* • DEQ may have to dedicate more resources to collect and process public comments.

While this option may increase DEQ's administrative burden, it may have several positive benefits. By inviting the public to comment on permit applications, the DEQ may learn of important local considerations that should be factored into its decision making. At the same time, including the public in this decision making process may help relieve stress in affected communities as well as increase perceptions that DEQ is being transparent and treating the public fairly.

2.4.3.4 Option C: Allow adversely affected parties to request a public hearing before a HVHF well permit is approved

Another option to address public concerns about HVHF well permitting would be to allow local units of governments as well as parties who may be adversely affected to petition for a public hearing. Illinois recently enacted such a policy as part of its Hydraulic Fracturing Regulatory Act[168], and legislators in the Michigan House proposed a similar policy in 2013.[169] Under this option, DEQ would be required, if requested, to hold a public hearing in the city, village, township, or county where the well is to be located prior to making a decision on the application. Similar to Illinois' policy, the DEQ could deny "frivolous" requests. During the hearing, interested parties could provide testimony or submit written comments to the DEQ, which the DEQ would be required to consider. The hearing could be followed by a 15-day public comment period, during which the public could respond to evidence and testimony provided at the hearing.[170] To demonstrate transparency in its decision making, the DEQ could provide a summary of the public hearing and an explanation of how testimony was considered. A variation of this option would be to also require participation of the permit applicant so that government officials and the public could directly ask questions of the well operator.

Table 2.17: Strengths and weaknesses of allowing parties who may be adversely affected by a proposed HVHF well to request a public hearing

	Strengths	**Weaknesses**
Environmental Impacts	*May improve environmental outcomes* • Public hearings may bring to light to environmental considerations that will improve DEQ's decision making	
Economic Impacts		*May delay well development* *Potential loss of revenue for mineral rights owners and lessees* • Policy may result in fewer permits being approved. Mineral rights owners would lose out on royalties. Oil and gas companies would lose bonuses paid to mineral rights owners as well as income from the untapped resource.
Health Impacts	*May improve health outcomes* • Allowing adversely affected parties to petition for a public hearing may reduce the stress associated with being involuntarily subjected to the risks of HVHF • Public hearings may bring to light public health considerations that will improve DEQ's decision making	

Community Impacts	*May improve community outcomes* • A public hearing would allow parties directly affected by a proposed well to identify potential communication impacts that the well operator may be able to lessen or avoid	
Governance Impacts	*May increase transparency* • Requiring a responsiveness summary would increase transparency about DEQ's decision making. *May increase legitimacy of DEQ's decision* • If hearing participants feel that their concerns were genuinely heard and considered, the perceived legitimacy of DEQ's decision may increase *May increase public sense of procedural fairness and concerns about HVHF being involuntarily imposed* *Participation of the well operator would be compatible with industry guidelines* • The API's community engagement guidelines advocate that well operators communicate effectively with local communities through a two-way process of giving and receiving information that respects local stakeholders' concerns.[171]	*May increase administrative burden* • DEQ would have to dedicate more resources to conduct and summarize public hearings *May not be sufficiently participatory to alleviate or address public concerns* • Public hearings remain a weak form of participation as they do not encourage dialogue or discussion about the issues. If the public views public hearings as pro forma, they may not achieve their intended outcomes.

The strength of this option is that it gives a voice to parties who may be adversely affected by a proposed unconventional shale gas operation. This may help ensure that DEQ's decisions on permit applications account for impacts to nearby landowners who will not personally benefit from a well's operation.

2.4.4 Summary of options for improving public involvement in well permitting

Michigan's existing policy for involving the public in well permitting decisions is more inclusive that 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 that should be legitimately considered in DEQ's decision making. Increasing public notice, requiring a public comment period, and allowing adversely affected parties to petition for a public hearing are all options that can help address these concerns. To be most effective, these options should be implemented together.

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CHAPTER 3: WATER RESOURCES

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3.1 INTRODUCTION

The water wealth of the State of Michigan is derived not only from the Great Lakes that give the state its moniker, but it also extends to the many rivers, wetlands and inland lakes that perfuse the landscape, providing habitat for many types of fish species, from largemouth bass in warmer waters to brook trout found in the cold waters of the state. While the presence of so many trout streams in the state represents significant cultural pride and identity for many Michiganders, their presence is due to the rich groundwater reserves that feed these streams that provide the state with a class of fish that is naturally found only in snow-and-glacier-fed mountain streams. It is with this recognition and understanding that many of Michigan's high quality rivers crucially rely on groundwater that brought the concern of large-scale water withdrawals to the minds of many Michiganders. This intimate link between fish populations and groundwater formed a basis for the state's regulation of water withdrawals under the current water withdrawal assessment program (WWAP).[1]

Since 2009, the State of Michigan has been managing almost all large-scale water withdrawals within the state through the WWAP. Anyone wishing to make a large volume water withdrawal must first determine whether their proposed water withdrawal would require simple registration or the obtainment of a water withdrawal permit from the Michigan Department of Environmental Quality (DEQ) (Table 3.1). In addition, the proposed water withdrawal cannot cause an adverse resource impact (ARI).

Table 3.1: Different requirements for registration and permitting of large-volume water withdrawals in the State of Michigan

	Withdrawal Rate[i] Lower threshold		Average pumping duration Lower threshold	Cost ($)
Registration	100,000 gpd	(70 gpm)	30 days	$200.00
Permit[ii]	2,000,000 gpd	(1,388 gpm)	N/A	$2,000.00
Permit[iii]	1,000,000 gpd	(694 gpm)	N/A	$2,000.00
Permit[iv]	100,000 gpd	(70 gpm)	90 days	$2,000.00

[i] Water withdrawal rates are presented as both gallons per day (gpd) and gallons per minute (gpm). The legislation cites all water withdrawals as rates of gallons per day (gpd). However, this report uses the far more common metric of gallons per minute (gpm).
[ii] For water withdrawal permits in Policy Zone A and B subwatersheds. Referred to as a "General

water withdrawal permit" in the text.
[iii] For water withdrawal permits in Policy Zone C subwatersheds. Referred to as a "Zone C water withdrawal permit" in the text.
[iv] For water withdrawal permits for intrabasin water withdrawals. Referred to as an "Intrabasin water withdrawal permit" in the text (See Box 3.1).

The WWAP accomplishes its regulatory function through a series of regulatory tools meant to provide greater information and a streamlined assessment process for a potential water user. The major piece within the WWAP is the Water Withdrawal Assessment Tool (WWAT), which is an automated assessment screening tool used to provide an initial assessment of whether a proposed water withdrawal from groundwater is likely to cause an ARI. A proposed water withdrawal is inputted to the tool via the online interface.[2] Each query will immediately return a designation, based on the "Policy Zone" into which the scientific models determine how a proposed withdrawal will affect the subwatershed unit in which the withdrawal is to be made (see Box 3.1). The Policy Zone determinations trigger what regulatory action will take place, from an automatic go-ahead to withdraw the water to the requirement of a site-specific review (SSR). As an increasing amount of water is withdrawn for use in a subwatershed, the Policy Zone designation changes toward increasing regulation until it reaches a determination of an ARI, after which no additional water may be withdrawn from that subwatershed. For more information, see Box 3.1.

The WWAP is supposed to undergo regular assessments and adaptive updates. The models underlying the WWAT were developed based on data and scientific models available at the time. The regulatory framework of the WWAP was also developed based on untested assumptions of conservation based on specific thresholds for action. The entire process was originally meant to be adaptive and malleable, with periodic assessments to determine how to improve it for better water conservation goals.[3]

Box 3.1 The WWAP

A major part of the Water Withdrawal Assessment Process (WWAP) used by the State of Michigan in governing the water conservation goals outlined by the Great Lakes Compact is the automated water withdrawal assessment tool (WWAT), whose primary public access portal is a free, web-based interface, accessed at miwwat.org. Behind the interface is a set of science-based, spatially defined groundwater, surface water, and fish ecology models (Figure 3.1).[4] The WWAT defines the water temperature profile, upstream drainage area, and index flow of 5,356 subwatersheds throughout the State. The watercourse wending its way through each subwatershed is defined as one of 11 river types, based on each subwatershed's water temperature (cold, cold-transitional, cool, and warm) and upstream watershed area (streams, small-rivers, and large-rivers). Finally, a fish curve is associated with each river type, based on data-derived ecological relationships.

Using the modeled index flow value for each subwatershed, the WWAT determines the percent-withdrawal limits, based on the fish curve for the subwatershed. These percent-withdrawal limits define the boundaries of four Policy Zones (A, B, C, and D).

When a proposed water withdrawal is submitted to the WWAT, the proposed withdrawal capacity will be added to the existing registered water withdrawals in that subwatershed. This total withdrawal value will be compared against the percent withdrawal limits for the subwatershed, and a Policy Zone determination will be made for the proposed withdrawal, based on the amount of calculated water.

Figure 3.1: Background structure and process of the WWAT

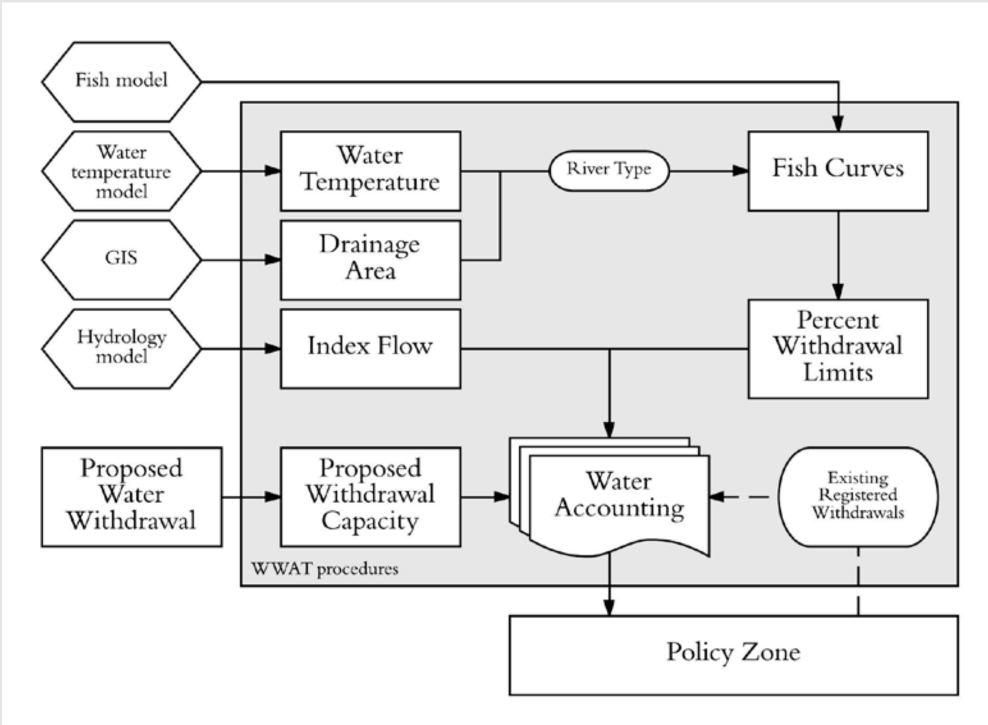


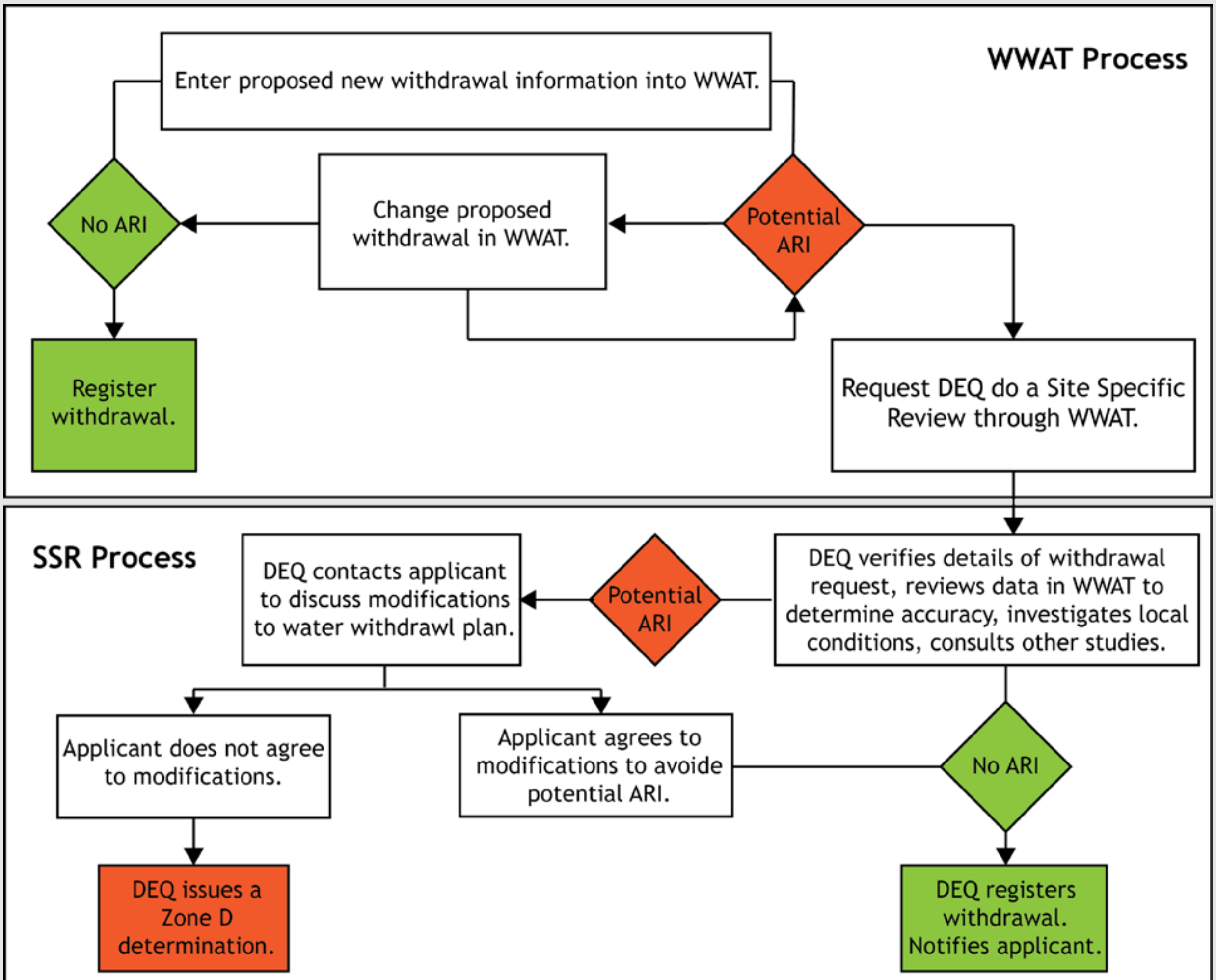
Figure taken from Lacy, 2013.[5]

For each Policy Zone, there is an associated action that the Department of Environmental Quality (DEQ) will carry out, as follows:

Zone A: The proposed water withdrawal is accepted. The withdrawal is registered automatically with the DEQ. No further action taken.
Zone B: The proposed water withdrawal is accepted. Large water withdrawal permit holders—such as utilities—are to be notified.
Zone C: The proposed water withdrawal is not accepted. A site-specific review must be conducted. All water withdrawers are to be notified. Water users committees are to be formed.
Zone D: Adverse resource impact. The proposed water withdrawal is rejected. A site-specific review must be conducted if the proposed withdrawal is continued to be desired.

If a proposed water withdrawal project has the potential to cause an ARI (i.e., is in Zone C or Zone D), then as SSR must be completed (Figure 3.2). In an SSR, the DEQ examines the accuracy of the modeled data within WWAT at the location of the proposed water withdrawal project. In addition, the DEQ may conduct an investigation of local conditions or consult other studies about the site. If it then determines that no ARI is likely to occur, then it registers the withdrawal and notifies the applicant. If the potential for an ARI remains after the initial assessment, the DEQ contacts the applicant to discuss potential modifications to the water withdrawal plan. If the applicant agrees to modifications that avoid an ARI, then the DEQ registers the withdrawal. If the applicant does not agree to modifications that avoid an ARI, then the DEQ issues a Zone D determination.

Figure 3.2: Flow diagram of the process of registering a water withdrawal through the WWAT and potential SSR process



Flow chart based on SWMWRC, 2014.[6]

3.1.1 Water use and high volume hydraulic fracturing

High volume hydraulic fracturing (HVHF) as currently practiced requires water as a primary component in its operation. This need for large volumes of water means that regulating water withdrawal within the state provides a mechanism to regulate HVHF operations. Depending on the type of regulation enacted to address large-scale water withdrawals like those used for HVHF, operators may respond in a variety of ways, including transporting water from other jurisdictions or withdraw smaller volumes from many more sources. Other Eastern states have recognized this association between hydraulic fracturing and water withdrawal and have used water withdrawal regulation as a mechanism for governing the scope and scale of HVHF activities for the protection of water-related resources.

Water withdrawal for use in hydraulic fracturing does have a history in Michigan (see Figure 3 from the Geology/Hydrogeology Technical Report[7]), but at far lower rates of water withdrawal than projected in future HVHF operations. For example, in the northern portion of the Lower Peninsula, the historic hydraulic fracturing operations in the northern Antrim Shale have, for many decades, been using withdrawn water for their operations at rates far below the current regulatory thresholds. Similarly, more recent high volume water withdrawals for hydraulic fracturing have occurred in various locations around the Lower Peninsula unassociated with any shale formation (otherwise known as “continuous plays”). In contrast, to these types of water use, the expected rates of water withdrawal in the Utica-Collingwood Shale are expected to withdraw an order of magnitude more of water for their fracturing operations (Table 3.2).

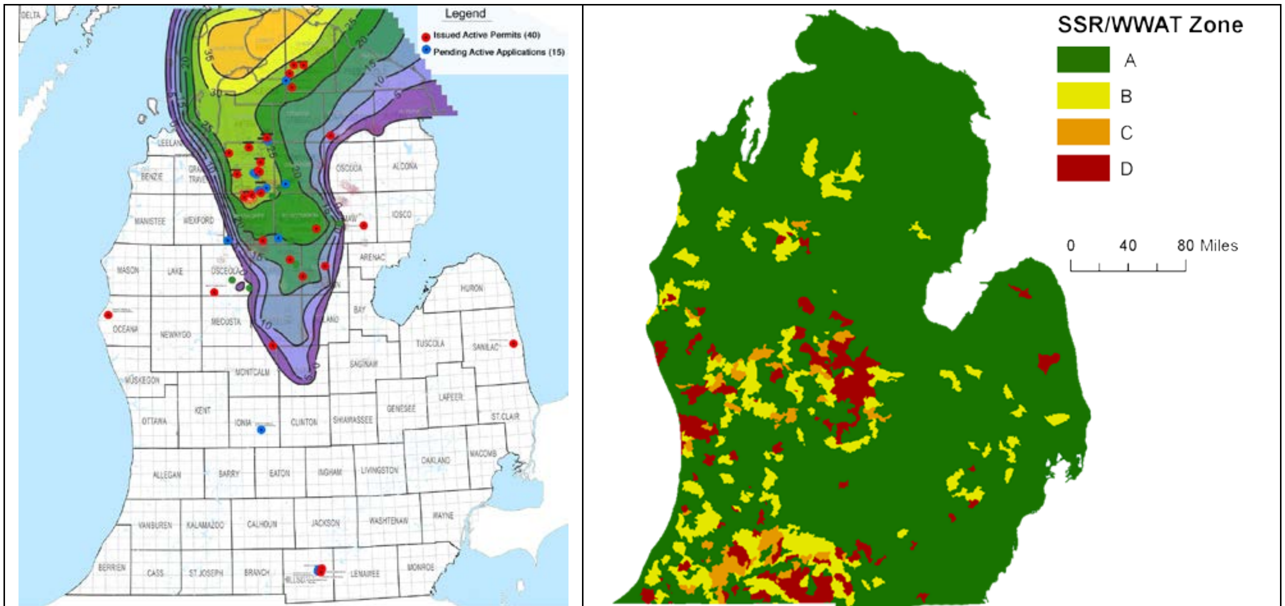
NOTE: Although the volumes associated with continuous plays may define them as “high volume hydraulic fracturing,” this chapter will focus on the order-of-magnitude-greater withdrawals expected to occur with operations within the Utica-Collingwood Shale formation. Therefore, for the purpose of this chapter, all further references to “high volume hydraulic fracturing” or “HVHF” in the context of Michigan will refer (except where noted) to the type of operation that is expected to drill to 9,000 feet or more, and use 10,000,000 gallons or more of water.

Table 3.2: Relative water use rates associated with different types of hydraulic fracturing[8]

	Northern Antrim Shale	Continuous Plays	Utica-Collingwood Shale
Natural gas depth	800–2,000 ft	3,000–5,000 ft	9,000–10,000 ft
Water withdrawal volume*	~50,000 gallons	<~1,000,000 gallons	>10,000,000 gallons[9]
Water withdrawal rate**	~5 gpm	~100 gpm	>900 gpm
Water regulation***	No regulation	Registration	Registration/Permit

* Water withdrawal volumes refer to orders of magnitude, and not absolute cut-off volumes for types of hydraulic fracturing.
** Presumes all water needed for hydraulic fracturing is stored onsite and water is only withdrawn 24 hours a day for a 7-day period. Individual operating procedures and local geologies will change undoubtedly the water withdrawal rate for any specific well.
*** Presumes that hydraulic fracturing operations falls under the regulation of the WWAP (which it currently does not), regardless of the number of days of water withdrawal the operation uses.

Figure 3.3: Location of Utica-Collingwood Shale and existing and pending large-scale water withdrawals associated with HVHF (left) and existing policy zone designations through January 2014 (right)



Left image taken from Ellis, B.[10]

The recent HVHF operations in the Utica-Collingwood Shale have been a response to the economic feasibility to extract shale gas from deep geological formations under parts of the Lower Peninsula that the technology allows. It is important to recognize the high geographic association between natural gas extraction through HVHF and the Utica-Collingwood Shale, much like the historic presence of shale gas associated with the Northern Antrim Shale.[11] Due to the geographic extent of the Utica-Collingwood Shale, and the high likelihood that HVHF operations—if approved—will be concentrated above this shale formation (see Figure 3.3[12]), it is primarily within this region that the large volumes of water associated with HVHF will be withdrawn.

One point to recognize is that, according to Michigan regulations, it is prohibited to use surface waters for drilling fluids,[13] meaning that HVHF operations will have to source their drilling water needs from groundwater. The hydraulic fracturing fluid, however, can be sourced from either groundwater or surface water, since such water is classified as "completion fluid" and not "drilling fluid." HVHF activities are not currently governed by the WWAP. However, the the DEQ does account for the water withdrawn for HVHF activities,[14] since water withdrawn for HVHF does have an impact on local water availability (see Box 3.2). Furthermore, the Supervisor of Wells requires all HVHF water withdrawals to conduct an assessment of their withdrawals using the WWAT.[15] However, there is no requirement that an SSR be conducted, nor does the Supervisor of Wells instructions indicate that a withdrawal associated with an ARI be modified, curtailed, or abandoned, as would be the case with any other water withdrawal governed directly by the WWAP. This places them within the general framework of the WWAP, alongside existing water withdrawal uses, even if the current regulations do not treat such withdrawals in exactly the same way as others.

Could HVHF operations shift a subwatershed unit to the edge of an ARI? It is important to recognize that non-HVHF activities can and have already pushed subwatershed units to their withdrawal maxima, with many nearby subwatersheds in Policy Zones C and B (Figure 3.3). By examining six stream-sized subwatershed units whose water withdrawal registrations have placed them into subsequently increased Policy Zone status (Table 3.3),[16] it is possible to observe a few salient points. First, each subwatershed unit is unique in the registered withdrawal volumes necessary in shifting its Policy Zone determination. Next, all the cool- and warm-water streams were able to accommodate well over 1,000 gpm of pumping before the WWAT or a subsequent SSR returned a determination of an ARI for a proposed water withdrawal. Even the cold-water stream could accommodate the better part of 1,000 gpm. Finally, all of the water withdrawals for these six streams were registered as irrigation withdrawals; a traditional water use. From this perspective, HVHF withdrawals are not special in and of themselves, and one cannot simply make a blanket statement about how any large quantity water withdrawals will affect subwatersheds, since each is effectively unique in the amount of water available and the numbers of registered (and unregistered) users. In short, while HVHF water withdrawals are new, they are–in general–unlikely to become the sole cause of a potential ARI.

Table 3.3: Comparison of registered water withdrawal capacities in six stream-sized subwatershed units in the State of Michigan that have no more available water for withdrawal

Subwatershed	**Major Watershed**	**Stream Type**	**Area sq mi**	**Registered Withdrawals* (gpm)**				**Irrigate %**
				A**	**B****	**C****	**D****	
N. Branch Chippewa River	Chippewa River	Cold	2.9	347	–	764	1111	100%
Pony Creek	Chippewa River	Cold-transitional	11.9	–	590	–	938	100%
Pigeon River	Macatawa Lake	Cool	21.7	3167	3861	5528	5771	100%
Flower Creek	White Lake	Cool	18.4	1997	3125	4167	4514	100%
Bear Creek	St. Joseph River	Warm	20.2	903	1389	2326	2547	100%
Bass River	Grand River	Warm	30	1840	4948	5885	6024	100%

* All values represent registered withdrawal capacity; all values represent intermittent withdrawals; most withdrawals during June, July, and August; values are through January 2014
** Original values reported in gpd; values converted to gpm to remain consistent with the chapter. Values for A, B, and C represent the net registered withdrawals registered within each policy zone. Values for D represent the net minimum reported capacity that would trigger an ARI. Note: all cases of Policy Zone D withdrawal applications were noted as being rejected.

Based on the projected near-term HVHF water withdrawals for the Utica-Collingwood (Figure 3.3), there will likely be impacts in some subwatershed units. Cold-transitional units will have the greatest impact, followed by cold-water units. In comparison, cool and warm-water units will have far fewer impacts. This is due primarily to the ways in which allowable limits for water withdrawal are determined for these types of rivers. See Hamilton & Seelbach[17] for more technical information beyond that presented in this report.

Finally, it is crucial to recognize that HVHF was not a consideration during the development of the WWAP (2006-2008). Specifically, the online WWAT (which is the centerpiece of the WWAP) might not be adequate to the task of accurately assessing the impacts of high volume, short-duration water extractions associated with HVHF, since it was designed to look at long-term, effectively continuous water withdrawals. Despite this potential weakness, the WWAP is the regulatory process through which large water withdrawals are governed in the State of Michigan. It is necessary to recognize that any large-scale water withdrawal will have physical impacts, and governing water use and conservation within the framework of the WWAP is the best way to manage a shared resource (Box 3.2). If, however, the WWAP is to serve as the water governance mechanism for all water uses in the state—including HVHF—then it must be amended and/or updated in order to address the different levels of water extraction that HVHF operations entail. To those ends, this chapter will present modifications to the WWAP as a means to govern HVHF activities within the state as well as a means of improving the WWAP itself.

Box 3.2 Why use WWAP if it wasn't designed for HVHF?

At the same time as there have been calls from early in the process of governing HVHF through the WWAP, there have also been calls to not use the WWAP, due to the various known issues that its central piece—the online and automated WWAT—has in dealing with the intense, short-duration water withdrawals associated with HVHF. The argument against using the WWAT is that it was never designed to address water withdrawals associated with HVHF—and that HVHF is currently exempt—and thus it shouldn't be used. This argument, on the surface, seems to have merit. After all, if a model (and the WWAT rests atop a series of models) was not designed to do address a task that it was not designed to do, it might be best to not use it at all.

This form of reasoning, however, is based on the fundamental and implicit assumption that the decision to use the model in question is independent of anything else that is happening. In this specific case, it assumes that there are no models being used for assessing water withdrawals in the state; it assumes that there is no law requiring the monitoring and assessment of water withdrawals in the state;[18] and it assumes that there is no pre-existing mechanism by which water withdrawals are monitored and governed within the state. However, this argument is incorrect with respect to all of these implicit assumptions. The Great Lakes Compact presently exists as the actual framework for monitoring and governing water withdrawals within the State of Michigan, and the WWAT is the major existing mechanism that monitors the volumes of water withdrawn within the state in order to meet the legal requirements of the Great Lakes Compact. In short, the argument that the WWAP should not be used would place an increased burden upon the State of Michigan to create a separate ledger of water accounting for the specific uses for HVHF and—to ensure compliance with the Great Lakes Compact—ensure that the individual water accounting for HVHF comports with and is included in the water accounting already being done within the WWAP.

In addition, the argument to not use the WWAP is problematic from the point of view of governing physical systems. After all, water withdrawn from the water table for the purposes of HVHF is equally as gone as from its source aquifer as water withdrawn from that same aquifer for more conventional purposes, such as irrigation, drinking water supply, or manufacturing. The DEQ has recognized this association, and have been including reported HVHF water withdrawals in their assessments of water availability through the SSR process within the WWAP. Indeed, since these conventional water withdrawals are regulated under WWAP and accounted for under WWAP. By *not* including HVHF water withdrawals under WWAP, cumulative impacts to water resources (which are required by the Great Lakes Compact to be monitored and governed[19]) will be more likely to occur, since volumes of water withdrawal will no longer be monitored as volumes of water withdrawn from a common source.

While the WWAP does not—at present—provide a perfect approach to governing water withdrawals associated with HVHF, it is the regulatory framework enacted within the State of Michigan to meet the requirements of the Great Lakes Compact. As such, it is the pre-existing means by which all significant water withdrawals are monitored and governed. Requiring a separate system of water withdrawal governance would be treating water withdrawals from HVHF as somehow physically different from more traditional water withdrawals already governed by WWAP, and would create a fundamentally different system of governing a resource that is shared across multiple uses, thus creating difficulties in governance and oversight.

3.1.2 HVHF and water quality

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, within the popular media, scientific literature, and governmental reports. The process of HVHF utilizes a suite of chemicals (see Chapter 4, Chemical Use), which effectively contaminate the water used in the HVHF process, some of which returns back to the surface. Contact with or spills of this water could pose risks to human and environmental health, and there should therefore be appropriate regulation and oversight of these pollutants' treatment and disposal.

However, just like concerns surrounding the use of chemicals during the active period of a well, so, too, are there concerns about the holding, treatment, and disposal of the wastewater from HVHF. Unlike the framework governing water withdrawals, issues of water quality are governed by both state and federal regulations. Furthermore, at the present time, Michigan law only prescribes wastewater disposal in deep-injection wells. However, recent technological advances in water treatment technology, as well as the (sometimes painful) lessons learned in neighboring states—which have a longer history of dealing with HVHF—can provide insight into different ways of addressing concerns over the handling, treatment, and disposal of hydraulic fracturing wastewater.

3.1.3 Chapter overview

This chapter is organized into two major sections. The first explores the various methods in which improvements to 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.[20] The section is broken up into various major categories of water withdrawal regulation, such as lowered thresholds for regulation, fees for water use, etc. Following an introduction for each major category for regulation, regional comparisons are presented (where appropriate), followed by a brief description of the current condition in Michigan under the WWAP. Following this review, a number of policy options are presented that would improve or alter the WWAP in order to implement the respective regulatory policy. Since these policy options are alterations to the overall WWAP, additional information is provided to explain how such an alteration would provide benefits in governing HVHF in Michigan. In addition, where applicable, the proposed draft rules changes from the DEQ are provided as a policy option. Within some of these major categories for regulation, policy options for regulating only HVHF are explored.

NOTE: Remember that HVHF activities are technically exempt from the WWAP.[21] The policy options presented in the following section require that HVHF-related water withdrawals at least be regulated by the findings of the WWAT and SSRs in effectively the same way as most other non-HVHF large-scale water withdrawals (i.e., that the proposed rule from the Supervisor of Wells—laid out in Section 3.2.1.3.3—be adopted) or that HVHF water withdrawals be included in the WWAP (i.e., that the policy option laid out in Section 3.2.1.3.2 be adopted).

It is important to recognize that some changes to the WWAP are being considered outside of the process of HVHF regulation. Furthermore, it is important to understand that any general change to the WWAP will have impacts across several water-use sectors in the state. For example, if the threshold for registering a water withdrawal were reduced from 70 gpm, this could have significant impacts on agricultural users (who may choose to withdraw water up to the regulatory threshold) but may have a lesser impact on mine dewatering (which tend to have a water withdrawal rate far above 70 gpm). Conversely, if water withdrawals were no longer averaged over 30 days, this would affect short-term users (such as mine dewatering operations) far more than continual users (such as agricultural uses).

The second section explores regulatory rules changes concerning waste management of water used in HVHF. Since the WWAP does not consider questions of water quality, these proposed policy options are presented within a separate framework of policy options. Furthermore, since issues of water quality are governed through the federal Clean Water Act (CWA) in addition to the state's various water quality and wastewater discharge laws, it is necessary to first outline the various ways in which state and federal regulations govern HVHF wastewaters. Finally, since the policy options presented in this chapter are meant for decision makers in the State of Michigan, policy options that would require federal legislation or alterations to federal regulations will not be proposed.

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[22]), which places them in a similar framework regarding their approach to governing water withdrawals. While lessons from Western states, which use a system of water law in which rights to volumes of water can be purchased, traded, and enforced, more direct lessons can be gleaned by examining the processes by which other regulated riparian states operate. Furthermore, both the SRBC and the DRBC provide examples of watershed-based regulation and planning within a single regulatory framework that is an analogue of Michigan's single regulatory framework of water governance under the Great Lakes Compact.

3.2 REGULATING HVHF BY MODIFYING THE WWAP

The WWAP (MCL 324.327) was implemented in Michigan in 2009 as part of the Great Lakes-St. Lawrence River Basin Water Resources Compact (aka., Great Lakes Compact). As such, the goal of the WWAP is to conserve the waters and water-dependent natural resources of the state from diversions out of the Great Lakes Basin or from cumulative uses.[23] The State of Michigan is unique among other Great Lakes states in that its process of managing water withdrawals is based in an online, automated screening tool, the WWAT, which provides water users with a determination of whether a proposed withdrawal will cause an ARI in their subwatershed unit. At the present time, however, HVHF water withdrawals are exempt from the process that governs most of the rest of the water of the State.[24]

Given the innate requirement of water by HVHF operations, one way in which many states and river commissions have regulated the practice is through regulations of water withdrawals and water use. An extreme case that demonstrates the potential power of such regulation is the DRBC, which in 2010 issued a moratorium on the issuance of all future water withdrawal permits for water withdrawals associated with all types of hydraulic fracturing until a set of rules for this use were passed.[25] While hydraulic fracturing operations could conceivably continue within the Delaware River Basin, all water would need to be transported from outside of the watershed, and all wastewater would need to be transported back out of the watershed, which would drastically increase the costs of operation. The neighboring SRBC instituted a special fee for all hydraulic fracturing water withdrawals, and regulates all such water withdrawals, down to "gallon one."[26] States neighboring Michigan also have general requirements in place for large-scale water withdrawal, including the requirement to obtain a permit (such as in Ohio and Indiana) or a threshold for regulation that is far lower than Michigan's (such as in Minnesota).

All of these types of regulatory control could be handled independently of the existing WWAP framework, but instituting a completely separate system for managing water withdrawals associated with hydraulic fracturing would create an independent standard and method for water conservation. (See Box 3.2 for more information.) Recognizing that the WWAP was designed with adaptive management in mind, with periodic assessments of the overall water conservation program, the current iteration—"WWAP version 1.0"—was under review by Water Use Advisory Council.[27] While updates and modifications to various parts of WWAP may happen, not all of them relate directly to governance of HVHF activities. This section presents a number of major categories of water withdrawal management. Of course, in order for any of these modifications and alterations to the WWAP to be effective in governing HVHF activities, water withdrawals associated with HVHF need to be specifically included within the WWAP.

3.2.1 Requirements for water withdrawal approval

Given strong sentiments about the conservation of water quantity, especially with HVHF operations, one means of regulating such operations would be to have more stringent water withdrawal requirements associated with HVHF.

3.2.1.1 Current regional standards

The State of Pennsylvania requires that any water withdrawal associated specifically with hydraulic fracturing must be approved in the form of a water management plan submitted to the Department of Environmental Protection, regardless of whether the withdrawal occurs on the same property where the gas well is located.[28] The plan must include the location, quantity, withdrawal rate, and timing of the water withdrawal.[29] Furthermore, the plan must show that the withdrawal will not adversely affect the quantity or quality of the water,[30] will protect and maintain existing water uses,[31] and will not cause an adverse resource impact to water quality throughout the watershed,[32] as well as include a reuse plan for the hydraulic fracturing fluids.[33] Within the Susquehanna River Basin, the Commission regulates all surface and groundwater withdrawals associated with hydraulic fracturing, beginning with "gallon one."[34]

At present, the DRBC has a moratorium on all water withdrawals associated with hydraulic fracturing that has been in place since 2010,[35] which represents an extreme example of a more stringent water withdrawal requirement.

3.2.1.2 Michigan's current policy status

Within the context of Michigan's water withdrawal assessment process, the Policy Zone determination from the WWAT provides the policy action taken, including the determination of an ARI. Due to the way in which the Policy Zones are determined, it would make little sense to re-define the water withdrawal percentages for each Policy Zone. All water withdrawals are treated equally in determining environmental impact, and all registered and permitted water withdrawals are treated equally under Zone B and Zone C conditions. Finally, there is the formalized–if presently untested–process of Water Users Committees (WUCs) that are in place to determine how water withdrawals ought to be managed under conditions of water scarcity with the possibility of the DEQ requiring water permit holders to diminish their withdrawals.

At the present time, HVHF-related water withdrawals are exempt from regulation under the WWAP framework, but are governed by the Supervisor of Wells (Part 615), with DEQ stating that they will not allow any HVHF-related water withdrawals that will cause an ARI.[36]

3.2.1.3 Analysis of HVHF-specific WWAP policy options

3.2.1.3.1 Keep existing Michigan policy for water withdrawal approval

The WWAP requires that no cumulative water withdrawals in a subwatershed unit may cause an adverse resource impact, defined as that subwatershed unit passing into a Policy Zone D. All water withdrawals are considered in determining the Policy Zone status of a subwatershed unit, although certain types of water withdrawal (such as municipal water use) are exempt from potential water withdrawal restrictions associated with drought or passing into Policy Zone D. The WWAP currently does not include HVHF water uses as governable water withdrawals, but DEQ assures that no ARI-causing withdrawal will be allowed.

Table 3.4: Strengths and weaknesses of existing Michigan policy for water withdrawal approval

	Strengths	**Weaknesses**
Environmental Impacts	*The WWAP provides a series of "Policy Zones" to ensure the conservation of water resources.*	*HVHF impacts–which have a different sort of impact to water quantities–will be treated equally as all other withdrawals.* *Water withdrawals could theoretically be allowed to continue into Policy Zone D.*
Economic Impacts	*Provide cheap source of water for HVHF operators.*	
Community Impacts	*WUCs present a means for local governance of water withdrawals among registered users.*	*No WUCs have been implemented to date.*
Governance Impacts		*HVHF withdrawals are not included in the WWAP. Unclear if a rejection of a ARI-causing HVHF withdrawal could stand a legal challenge.*

<u>3.2.1.3.2 Remove the HVHF exemption from the WWAP</u>

Presently, HVHF activities are exempted from the WWAP. Even though the Supervisor of Wells requires HVHF water withdrawals be assessed using the WWAT, there is little strong regulatory language that would require the curtailment or abandonment of a withdrawal that is determined to cause an ARI. Furthermore, the instructions from the Supervisor of Wells only apply to the initial finding of the WWAT (or SSR if one is chosen to be conducted), and not to any of the additional portions of the WWAP (such as Water Users Committees and fee payments). This option would formally include HVHF withdrawals in the WWAP, requiring the same level of regulation that traditional water users currently face.

HVHF Applicability: HVHF water withdrawals will be treated in the same manner as effectively all other water withdrawals in the state.

Table 3.5: Strengths and weaknesses of removing the HVHF exemption from the WWAP

	Strengths	**Weaknesses**
Environmental Impacts	*Increased level of conservation within the state.*	
Economic Impacts		*Could increase HVHF operating costs.*
Community Impacts		*Could increase overland transport if local impacts would cause an ARI.*

Governance Impacts	*The rules governing HVHF water withdrawals will be the same as those governing most other water withdrawals in the state.*	

3.2.1.3.3 Disallow HVHF operation from approaching an ARI (Michigan proposed rule)

The proposed rules formalize the 2011 Supervisor of Wells Instruction that effectively required the use of the online WWAT and Policy Zone assessments for all proposed HVHF water withdrawals; HVHF would still be technically exempt from other WWAP regulations. The rules will not allow HVHF-related water withdrawals from proceeding if an SSR "determines that the proposed withdrawal as a zone B withdrawal in a cold-transitional river system or a zone C or zone D withdrawal," unless the applicant either "self-certifies that he or she is implementing applicable environmentally sound and economically feasible water conservation measures" or applies for a water withdrawal permit.[37] This proposed rule will require the use of the WWAP as the framework within which HVHF-related water withdrawals will be made.

Table 3.6: Strengths and weaknesses of disallowing any HVHF operation from approaching an ARI

	Strengths	**Weaknesses**
Environmental Impacts	*Effectively allows only Zone A and Zone B impacts. This means an increased level of conservation in cold and cold-transitional rivers.*	
Economic Impacts		*Could increase HVHF operating costs.*
Community Impacts		*Potential increase of overland transport.*
Governance Impacts	***Although HVHF would remain technically exempt from WWAP, this option further formalizes the use of WWAP to govern HVHF as laid out in Supervisor of Wells Instruction 1-2011.*** *Pumping within Policy Zone C is not allowed, unless an applicant can successfully obtain a water withdrawal permit. Diminishes the number of SSRs (see Box 3.1).*	

3.2.1.3.4 Adopt additional rules for proposed water withdrawals (Michigan proposed rule)

The proposed rules require additional steps in the WWAT process, including the provision of the location of "available well logs of all recorded fresh water wells and reasonably identifiable fresh water wells within 1,320 feet of water withdrawal location." Furthermore, the applicant must provide "a supplemental plat of the well site showing … the proposed location of water withdrawal wells, [l]ocation of all recorded fresh water wells and reasonably identifiable fresh water wells within 1,320 feet of water withdrawal location(s) or locations, [and p]roposed fresh water pit impoundment, containment, location, and dimensions."[38] Finally, the applicant must provide "a contingency plan, if deemed necessary, to prevent or mitigate potential loss of water availability in the fresh water wells identified…"[39]

Table 3.7: Strengths and weaknesses of adopting additional rules for proposed water withdrawals

	Strengths	**Weaknesses**
Environmental Impacts	*Increased monitoring of groundwater resources.*	*The monitoring is only included in the presence of existing withdrawal wells.*
Economic Impacts		*Additional cost to HVHF operators.*
Community Impacts	*Applicant must identify all existing water withdrawal wells within ¼ mile of their proposed wells.*	*No physical evidence that a radius of ¼ mile is sufficient in protecting existing water withdrawals in the region.*
Governance Impacts	*Increased oversight of HVHF impacts.*	

3.2.1.3.5 Disallow any HVHF operations within a cold-transitional system

Cold-transitional systems have been designated a set of hydrologic systems of special concern within the WWAP. For this reason, they have the lowest allowable water withdrawals, and also lack any designation of Zone B. Due to public concern about the impacts of HVHF activities on water availability, and due to the inherently fragile nature and special conservation concern associated with cold-transitional systems, a complete ban on HVHF operation in cold-transitional streams could be implemented.

Table 3.8: Strengths and weaknesses of disallowing any HVHF operations within a cold transitional system

	Strengths	**Weaknesses**
Environmental Impacts	*Would provide additional protections for the most fragile river systems in the state.*	*In regions many cold-transitional systems, water for HVHF will likely be trucked.*
Economic Impacts		*Could increase costs associated with water acquisition.*

Community Impacts	*Ensures water withdrawals are held for local community uses.*	*Could increase trucking if HVHF operations are within a cold-transitional watershed.*
Governance Impacts	*Simplifies the registration process for HVHF operations by creating an absolute ban on an entire class of river systems.*	

3.2.1.3.6 Overestimate proposed HVHF water withdrawals

Since HVHF water withdrawals are considered by the public to be a special kind of water withdrawal that is wholly consumptive, one way to be conservative when assessing their impacts is to overcompensate for their proposed withdrawal. Multiplying the proposed withdrawal rate by a safety factor would provide an additional level of safety and assurance to the public when assessing the potential impacts from HVHF water withdrawals.

Table 3.9: Strengths and weaknesses of overestimating proposed HVHF water withdrawals

	Strengths	**Weaknesses**
Environmental Impacts	*Would provide increased level of water conservation protections.*	*Could lead to widespread, low-volume water withdrawals.*
Economic Impacts		*Could limit the local amount of water withdrawal; increase costs associated with trucking.*
Community Impacts	*Assures a greater quantity of water uses for local communities.*	*Could increase trucking if HVHF operations are within a cold-transitional watershed.* *Widespread, lower-volume water withdrawals diminishes the local capacities to withdraw water.*
Governance Impacts	*Would provide additional assurance against massive impacts to local systems, given the current WWAT.*	

3.2.2 Water withdrawal regulation thresholds

The Great Lakes Compact, under which Michigan's WWAP operates, requires a threshold for regulation of 70 gpm for achieving water conservation. However, in a recent assessment of watershed-wide impacts of unregulated rates of sectoral water withdrawals just below the threshold,[40] the 70 gpm rate was shown to lead to significant rates of unregulated water consumption that would be banned, but for the minimum threshold rate.[41] Given that there is no significant physical difference between pumping rates of 69 gpm and 70 gpm and given that a minimum regulatory threshold provides a behavioral choice in maximizing returns by approaching the threshold but not crossing it, a widely adopted maximization of a relatively generous (physically speaking) water withdrawal rate of 70 gpm would create a system-wide condition of non-conservation, which goes against the goals of the Compact. Some regions have chosen lower regulatory thresholds, which could be adopted in Michigan.

3.2.2.1 Current regional standards

While all Great Lakes states comply with the common standard required by the Great Lakes Compact, some states have lower thresholds for registration, based on a shorter time-period (such as Ohio, which uses a one-day standard,[42] as opposed to a standard averaged over 30 days) or a lower withdrawal rate (such as Minnesota, which uses a 7 gallons per minute threshold,[43] with an additional threshold of no more than 1,000,000 gallons per *year*[44]).

In addition, some Great Lakes states do not have an option for registration of high volume water withdrawals, requiring permits for all such withdrawals. In New York[45] and Wisconsin,[46] a permit is required if water withdrawal rates exceed an average of 70 gallons per day over a 30-day period for users within the Great Lakes Basin[47] and an average of 1,388 gallons per minute over a 30-day period statewide.[48] In Pennsylvania and New York, river basins that are part of other regional water compacts (i.e., the Susquehanna and Delaware River Compacts) require the obtainment of water withdrawal permits based on those compacts' standards (14 gallons per minute[49,50] and 7 gallons per minute,[51,52] respectively).

3.2.2.2 Michigan's current policy status

Currently, the WWAP requires the registration of a large quantity withdrawal, specifically defined as "[one] or more cumulative total withdrawals of over [70 gallons of water per minute] average in any consecutive 30-day period that supply a common distribution system".[53] At the time of the creation of the WWAP, this limit was discussed in the public as a threshold that might be higher than could reasonably conserve water resources.[54] However, in a modeling assessment of the Muskegon River watershed, the 70 gpm threshold level was demonstrated to provide little regulatory oversight while being non-conservative when widely adopted.[55] In the same analysis, the lower threshold of 7 gpm—used in Minnesota[56]—was shown to provide a far greater level of regulatory oversight, despite also being mildly non-conservative.

In order to conserve all water resources of the state equivalently, any significant volumetric withdrawal of water, withdrawn for any length of time, ought to be understood to be equivalent to any other significant volumetric withdrawal, regardless of the purpose to which that withdrawal will be put. Indeed, the modeled impacts of water withdrawals at just below 70 gpm (as well as at just below 7 gpm) in the Muskegon River shows that ARI conditions could easily result at volumes just below the regulatory threshold.

Furthermore, given that hydraulic fracturing operations are unlikely to meet the dual requirements of volume (70 gpm) and time (30-day consecutive period for registration), high volume hydraulic fracturing operations at any rate of withdrawal are unlikely to be required to register withdrawals or obtain permits under the current requirements of the WWAP, short of the approval of the proposed rules. Two exceptions to this are with proposed water withdrawals of more than 694 gpm[57] in Zone C areas[58] or a water withdrawal that results in an intrabasin water withdrawal of 70 gpm,[59] both of which require a water withdrawal permit, regardless of the duration of water withdrawal (Table 3.1).

3.2.2.3 Analysis of general WWAP policy options

3.2.2.3.1 Keep existing Michigan policy for water withdrawal regulation

The current iteration of the WWAP regulates all water withdrawals above 70 gpm for any 30-day period by requiring registration of such withdrawals. In addition the WWAP requires the obtainment of a permit for withdrawing more than 1,388 gpm, unless the water withdrawal is an inter-basin transfer (which requires a permit for withdrawals of 70 gpm) or is from a subwatershed unit that is in Policy Zone C (which requires a permit for any withdrawal greater than 694 gpm, see Table 3.1.)

HVHF Applicability: Given the expected volumes associated with HVHF operations (>900 gpm by rough estimate, Table 3.2), some operations may require permits, while others might only require registration. In addition, HVHF operators could lower the water withdrawal rate of a withdrawal well to below 694 gpm (i.e., the general threshold to require obtainment of a permit) and collect water from multiple sources.

Table 3.10: Strengths and weaknesses of existing Michigan policy for water withdrawal approval

	Strengths	**Weaknesses**
Environmental Impacts	*WWAP provides statewide water quantity protections.*	*Cumulative maximized unregulated withdrawals will have significant physical impacts on rivers.* *HVHF currently exempt from regulation via WWAP*
Economic Impacts	*No additional costs.*	*No additional revenue to address HVHF issues.*
Governance Impacts	*Continued inclusion of HVHF withdrawals in assessing water availability for other users within the WWAP.*	*Potential major shortfalls in DEQ's capacity to manage significant water withdrawals.* *HVHF currently exempt from regulation via WWAP*

3.2.2.3.2 Lower thresholds for regulation

Any large-scale water withdrawal could be managed in such a way as to take maximum advantage of the regulatory thresholds by optimizing (1) the duration or (2) pumping rate of the water withdrawal. By diminishing duration threshold or by water withdrawal rate threshold, the WWAP would effectively increase the oversight on water conservation within the state by requiring more water uses to be registered. Other states and regions already have lowered regulatory thresholds for pumping duration (such as New York state) and pumping rate (such as Minnesota).

HVHF Applicability: HVHF operators, like other large-scale water users, would have less ability to optimize their water withdrawals to fall below regulatory thresholds. More HVHF water uses will be registered, providing more public knowledge of water use and water availability.

Table 3.11: Strengths and weaknesses of lowering thresholds for regulation

	Strengths	**Weaknesses**
Environmental Impacts	*Greater oversight over the total numbers of water withdrawals can lead to better awareness of an impending ARI.*	
Economic Impacts	*Greater funds to DEQ due to increased number of registrations.*	*Increased costs associated with more people having to register more types of withdrawals*
Community Impacts	*Increased information about local water resources.*	
Governance Impacts	*Greater oversight over the total amount of water in each watershed.*	*Some HVHF water withdrawals might not fall within reporting criteria.*

3.2.2.3.3 Increase water use reporting frequency

Additional specific requirements for HVHF could be implemented, changing the reporting requirement and the reporting fee schedule. Instead of requiring the annual report currently required for registered wells, reporting could be required every 30 days in order to be scaled to match the water withdrawal schedule of the fracking operation. Tied to this increased frequency of reporting water levels to the DEQ, the water reporting fee of $200, currently required to be paid annually by all registrants, could be required for each 30-day reporting period.

Table 3.12: Strengths and weaknesses of increasing water use reporting frequency

	Strengths	**Weaknesses**
Environmental Impacts	*Increased oversight over the changes in available water resources.*	*Increased data reporting will not affect unregulated withdrawals, and the current threshold of 70 gpm has been shown to be potentially non-conservative.*

Economic Impacts	*Increased number of reporting fee payments.*	*Increased costs for water users in providing information.*
Community Impacts	*Greater detail of information about water resource availability, leading to possibility for better planning.*	
Governance Impacts	*Increase the temporal resolution of monitoring water resources in the state.*	*Increased data management costs.* *Increased rates of data collection from regions of relatively constant water use may have lower utility.*

<u>3.2.2.3.4 Set a total volumetric water withdrawal limit</u>

Total volumetric water withdrawal limits could be imposed for high volume hydraulic fracturing operations. A maximum 30-day withdrawal volume could be set for withdrawal operations, such as a maximum of 2 million gallons of water for any 30-day period, which would mimic the threshold for obtaining a water withdrawal permit, save for shifting the withdrawal time period to 30 days.

Table 3.13: Strengths and weaknesses of setting a total volumetric water withdrawal limit

	Strengths	**Weaknesses**
Environmental Impacts	*Will improve water conservation by placing an additional cap on water withdrawals.*	*May create incentives to conduct a series of several unregulated withdrawals, which cumulatively could cause significant environmental impacts.*
Economic Impacts		*Will severely hamper certain types of water users.* *Will increase costs for obtaining water for HVHF operations.*
Community Impacts	*Will limit the impacts from HVHF in any one subwatershed unit.*	*Will likely increase trucking of water from other subwatershed units.*

Box 3.3 Groundwater withdrawal, geographic scale, and the concept of consumptive use

The concept of consumptive use of water is generally defined as the withdrawal (and use) of water that does not return to the hydrologic system. Specifically, the USGS defines consumptive use as, “water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from an immediate water environment.”[60] In the context of the Great Lakes Compact which governs the structure of water governance in Michigan, consumptive uses are never defined, but the Compact does requires all states (including Michigan) to “develop and maintain a compatible base of Water use information … [of] any Person who Withdraws Water in an amount of [70 gallons per minute] or greater average in any 30-day period (including Consumptive Uses).”[61] Both the Great Lakes Compact and Michigan’s WWAP recognize that consumptive uses occur at various scales, and while the Great Lakes Compact and the WWAP are both concerned with consumptive uses at the spatial scale of the Great Lakes, what may be considered a non-consumptive use at this scale changes at spatially smaller (and temporally shorter) scales.

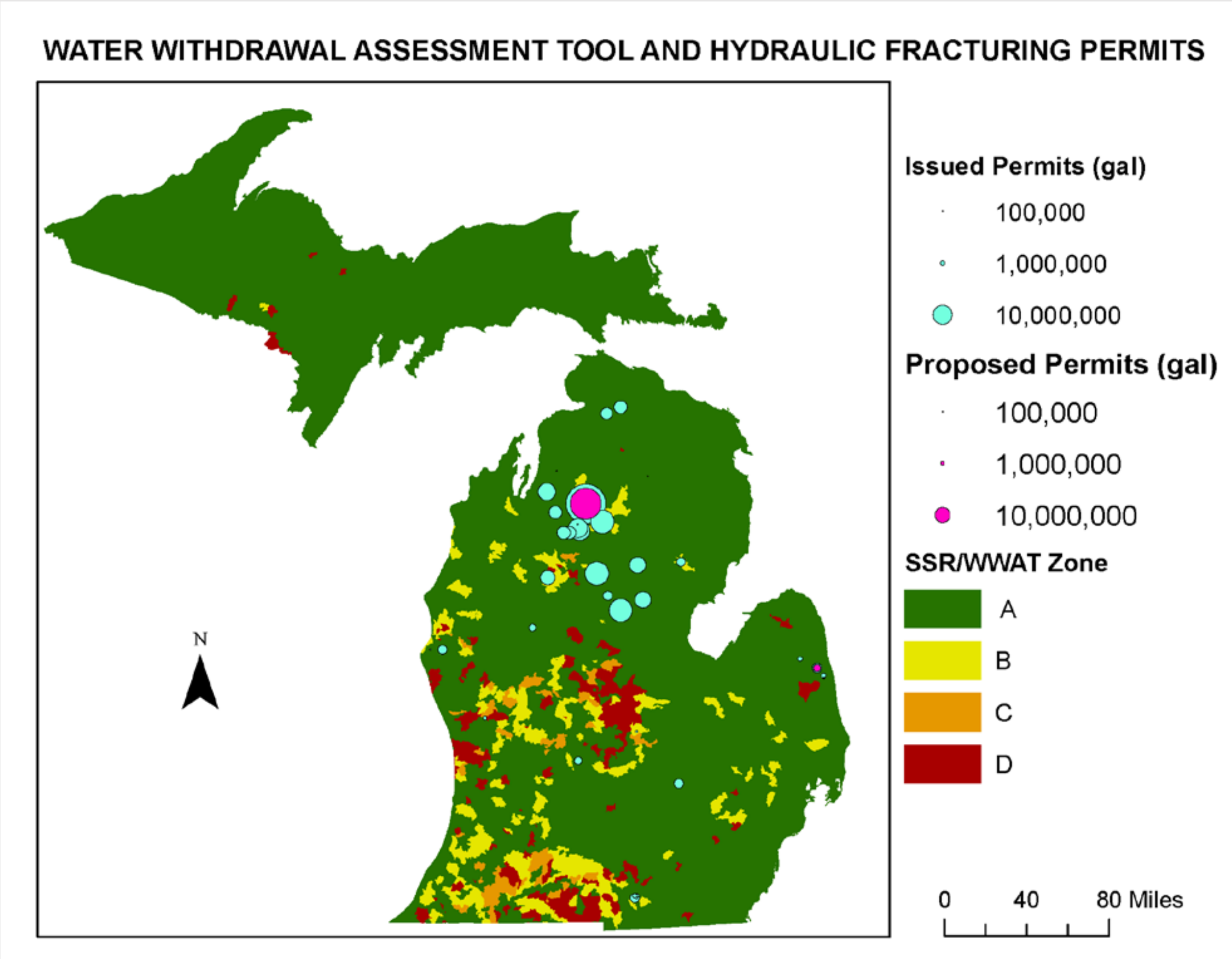
One of the major stated concerns arising from water withdrawals associated with HVHF is that the water use is consumptive; all the water is to be deep-well injected, and not one drop of water used in HVHF is supposed to return to the hydrologic cycle of the Great Lakes. This meets the technical and legal definitions of consumptive use. However, the concerns over water withdrawals that are voices are not based on a concern at the regional level of the Great Lakes, but at a more local level, such as at the scale of individual properties. This comports more closely with the geographic scale of regulation and governance within the WWAP, which is at the subwatershed level.

However, at the subwatershed scale there is little physical distinction between a withdrawal for drinking water (regionally non-consumptive) and an equal-sized withdrawal for HVHF (regionally consumptive). Both withdrawals would remove the same volume of water from the subwatershed and return none of that water back to the groundwaters of that selfsame subwatershed. From the point of view of the water users in that subwatershed, the impacts of both would be equivalent. Analogously, waters withdrawn for agricultural uses are partially consumed (either as being incorporated into the crops or evaporated away) and partially returned to a waterway (but flowing away at a rate far faster than could be used to recharge the aquifer from which they were taken). While the comparable utility of the water uses (e.g., for drinking, agriculture, or fracturing) can be debated, from a volumetric standpoint, any large-scale water withdrawal will effectively be indistinguishable from others at a local level in terms of consumptive use.

To that extent, an argument that HVHF water withdrawals will have a substantially different local impact to groundwater than any other water withdrawal of the same rate is not valid. A valid argument about the effects of consumptive use could be made at the regional scale of the Great Lakes (which is the spatial scale of consumptive use the law is concerned about, and it is at the scale that the WWAP was designed to address water conservation), as determined as a sum of water withdrawals within each regulated subwatershed. In the context of the WWAP, withdrawals need not be wholly non-consumptive to be registered in the system (agriculture and industry are classic examples with significant consumptive use). Indeed, it is almost impossible for any water withdrawal to be perfectly non-consumptive. Instead, the WWAP allows for a certain level of utilization of waters in every subwatershed, with incrementally greater management and governance actions, based on the degree of the total withdrawals in each subwatershed. Within the framework of the WWAP, the waters available for use in all river systems are treated equally in terms of how their volumes are calculated. This means that the water feeding a particular trout stream is no more important in determining ecological impact than the water feeding any other stream (including other trout streams). Analogously, all registered water withdrawals are treated as impacts based on their withdrawal rates and durations, regardless of the amount of water that eventually flows back into the regional hydrologic cycle.

When considering the impacts of water withdrawals, it is necessary to recognize that no water use is perfectly non-consumptive. As such, the WWAP does not ban consumptive water withdrawals, but is there to monitor and regulate all large-scale water withdrawals, regardless of the purpose for their withdrawal. It is important to recognize that from a local perspective, there is little distinction—in terms of consumptive use—between any equally large water withdrawals, be they for agriculture, municipal drinking water, or HVHF. Finally, it is important to understand how large-scale, cumulative, and consistent water withdrawals are affecting the availability of further groundwater withdrawals.

Figure 3.4: Policy Zone assessment and issued and proposed water withdrawal registrations



3.2.3 Improvements to the WWAT

The WWAT relies on a series of models, including a surface water hydrology model,[62] a groundwater hydrology model,[63] and a fish population model.[64] Although these models and the associations between them are robust, they are only as good as the data that defined them and the assumptions used in making them. As the scientific understanding of Michigan's water resources improves, it would be useful for these improvements to be included in the management of the state's waters.

The WWAT was developed in 2008 to serve as a first iteration of an assessment tool that would operate one part of the larger water withdrawal assessment process. The WWAT is based on a series of statistical models and relationships between groundwater, surface water, and fish ecology that have a strong scientific basis. However, it is important to recognize the limitations to what was meant to be a first version of an automated assessment tool; not the be-all-end-all.

As it currently stands, the WWAT is designed to assess the expected impacts of large-scale and persistent water withdrawals, and is best able to predict the changes in characteristic fish populations of medium- and large-sized rivers. In contrast, smaller rivers and streams—especially headwater systems—often have the least amount of data, creating greater levels of uncertainty within the WWAT models.[65] This is purely a function of the type of data that was used to initially create the various models of the WWAT. Presently, updates to the WWAT are only legislated as corrective updates to the predictions via site-specific review[66] and as updates to the water accounting,[67] neither of which would improve the scientific bases upon which future determinations of water withdrawal would be made.

In its current iteration, the WWAT does not consider impacts to ponds, lakes, and wetlands,[68] simply because the underlying models do not apply themselves to these water bodies, even though the Great Lakes Compact is also specifically meant to conserve these waters as well. An improvement to the WWAT so as to include these additional water bodies into the water conservation and management already provided to water courses would improve the standard of the existing WWAT.

3.2.3.1 Analysis of general WWAP policy options

<u>3.2.3.1.1 Keep existing Michigan WWAT</u>

The current WWAT functions adequately to meet the needs it was developed to address in 2008. Not changing the WWAT means that the 2008 water quantity measures, the current regulatory subwatersheds, and the existing Policy Zone determinations thresholds are maintained. Retaining the current WWAT would thus minimize any disruptions to statewide water management that will inevitably occur once updates and improvements are initiated.

HVHF Applicability: The current WWAT does not adequately address the time scales of water withdrawal associated with HVHF. This could mean that local impacts to water quantity may diverge from the predictions of the current WWAT.

Table 3.14: Strengths and weaknesses of existing Michigan WWAT

	Strengths	**Weaknesses**
Environmental Impacts	*Water conservation of the entire state via a scientifically robust, online water withdrawal assessment tool.*	*Potential for overallocation of water resources due to model limitations.*
Economic Impacts	*The impacts of a proposed high-volume water withdrawal are immediately and freely available for any water user.*	
Community Impacts	*Information about local water uses are available via the tool.*	*Due to model limitations, local water overallocation may occur, especially in headwater systems.*
Governance Impacts	*Clear mechanisms for policy action at different levels of cumulative water withdrawal.*	*Current WWAT does not adequately address HVHF-type water withdrawals.*

<u>3.2.3.1.2 Update the scientific models of WWAT</u>

Any scientific model requires data to accurately reproduce current conditions and predict future conditions. As such, the predictions of the WWAT rely on existing hydrologic and fish data. Some regions—especially headwater regions of river systems—are notorious for the dearth of available data, even though they are often the most vulnerable hydrologic changes caused by large water withdrawals. Increased data collection in regions of data scarcity—in addition to the integration of that data into the WWAT—would provide greater precision and accuracy for automated WWAT assessments.

Alternatively, an option for improving the WWAT would be to implement assessments based on mechanistic models, instead of the statistical models it currently rests upon. A mechanistic model would be able to assess the impacts of short-term and constant water withdrawals within subwatershed units, but they need further development.

In addition, the expansion of the WWAT to include models of impacts to lakes and wetlands would meet the requirements of water conservation already mandated in the WWAP. Implementation of lakes and wetlands modules into WWAT would ensure equal technical coverage of both lentic and lotic environments, thus providing a consistent assessment framework across all waters.

HVHF Applicability: The WWAT was not initially designed to assess the impacts of short-term, large-volume water withdrawals associated with HVHF.[69] The effects of water withdrawals from high volume hydraulic fracturing operations would be better modeled with mechanistic models that can account for short-term, high-volume water withdrawals.

Although streams and rivers do cover major portions of the state (and are modeled through the WWAT), the surface-water impacts caused to lakes and wetlands from large-scale groundwater withdrawal (which are not modeled through the WWAT) must also be assessed. The geographic area associated with projected future HVHF activity has many lakes and wetlands that are crucial for the tourism industry. An understanding of the impacts of high volume fracturing to the lakes and wetlands of these areas would provide a crucial planning tool for local residents and government units.

Finally, small streams and headwater systems are the most vulnerable to short-term, large-scale water withdrawals associated with HVHF. Furthermore, data is scarce in the region of the Utica-Collingwood shale, where most future HVHF is planned. Increased data collection of water and fish would provide a more accurate determination of likely ARIs.

Table 3.15: Strengths and weaknesses of updating the scientific models of WWAT

	Strengths	**Weaknesses**
Environmental Impacts	*Updated models will provide a mechanism to assess the impacts of a greater range of water withdrawal types, including high-volume, short-term water withdrawals characteristic of HVHF.*	*The time required for developing new scientific models will likely be longer than the timeline for initiating HVHF operations.* *Without addressing the 70gpm withdrawal threshold, future WWAT versions will continue to suffer from potential overuse from widespread unregulated water withdrawals.*
Economic Impacts	*Improved models can provide better knowledge of available water resources in a subwatershed unit, improving operational efficiency and diminishing operating costs.*	*Will cost money to develop new scientific models.*
Health Impacts	*Linkages of water quantity models with water quality models could improve monitoring around the state.*	*Currently, water quality is managed outside the framework of the WWAP.*
Community Impacts	*Improved scientific models could provide better knowledge of local water resources, thus improving the capabilities of WUCs.*	
Governance Impacts	*Will improve WWAT to include impacts of high-volume, short-term withdrawals, removing the need for proxy metrics.*	*May uncover problems with overallocation associated with the current version of WWAT.*

		Could redefine subwatershed units as more restrictive river types, creating immediate problems of overallocation.

<u>3.2.3.1.3 Implement a mechanism for updating the models underlying WWAT</u>

At the present time, the only ways that the WWAT can be updated is through site-specific review (which would alter the determination of remaining water availability and/or the river type) and through the automated water accounting (which updates the remaining water availability and concomitant Policy Zone designation). If the models that underlie the WWAT—like any technology—are to undergo periodic updates to ensure high-quality decision making, legislation should be passed that explicitly provides a mechanism by which the DEQ can assess and implement new water governance models that incorporate the best scientific tools available at the time.

HVHF Applicability: The type of water withdrawal associated with HVHF—short-term and high-volume consumptive withdrawals—were not envisioned during the development of the WWAT. Furthermore, no mechanism for incorporating modeling updates that could address such withdrawals was included in the WWAP. In order to address this new form of water withdrawal under a consistent governance framework as other large-scale water withdrawals, the WWAT would need to be updated, and to do so, a formal process of assessing model updates would need to be provided to DEQ, a task that could be undertaken by the current or a future Water Use Advisory Council.

Table 3.16: Strengths and weaknesses of implementing a mechanism for updating the models underlying WWAT

	Strengths	**Weaknesses**
Environmental Impacts	*Providing mechanisms to update WWAT will provide for strategies to improve water conservation models that underlie the assessment tool.*	*If mechanisms for updating all significant functions of the WWAT are not enabled, future updates will have a limited impact on water conservation.*
Economic Impacts	*A standardized and defined mechanism for updating the state's water withdrawal regulatory mechanism creates a predictable timeline and process of updating and managing. Greater predictability provides better planning for businesses.*	
Community Impacts		*Updates to water availability models may cause problems with existing registered withdrawals,*

		especially if a subwatershed is redefined as a more conserved river type.
Governance Impacts	*Provides mechanisms to keep the WWAP adaptive.* *Will provide a mechanism to deal with redefinitions of river type that could result in determinations of overallocation.*	*Not a direct means of addressing HVHF water withdrawals.*

3.2.4 Water withdrawal fee schedules

One way in which those who stand to gain significantly from publicly held resources can be made to help defray the public's payment of their oversight of their acquisition and private profit of a public resource is through the imposition of a fee schedule. In the case of water quantity withdrawals, various types of fees have been used in other Great Lakes and Eastern states to defray the costs of government oversight, pay for research, and fund public projects to improve water security within the governed watersheds.

3.2.4.1 Current regional standards

Water withdrawal fee schedules are implemented for all water withdrawal projects above 14 gpm in the Susquehanna River basin and projects above 7 gpm in the Delaware River basin, based on the proposed water withdrawal rate and the type of project in addition to planning fees and annual water use fees.

The SRBC has several project categories, including consumptive water uses from 14 gpm to over 3,400 gpm, surface water withdrawals from 70 gpm to over 6,900 gpm, groundwater withdrawals from 70 gpm to over 6,900 gpm, and diversions into and out of the basin as well as a number of preparatory assessments. For illustrative purposes, a new groundwater withdrawal of 14 gpm (i.e., the minimum threshold for regulation) of private consumptive use, the SRBC would require an aquatic resource survey ($6,800), a pre-drill well site review ($2,250), an aquifer testing plan ($4,650), a groundwater withdrawal fee ($6,125), and a consumptive water use fee ($3,000), totaling $22,825.[70]

In comparison, the DRBC charges project review fees based on the cost of the project, and whether the project is private or public. Private projects costing between $250,001 and $10,000,000 cost 0.4 percent of the project cost (i.e., between $1,000 and $40,000), with fees doubled for out-of-basin diversions.[71]

3.2.4.2 Michigan's current policy status

Presently, the State of Michigan requires an annual $200 water use reporting fee for all registered water withdrawals[72] and a fee of $2,000 for obtaining a water withdrawal permit.[73] Michigan imposes no additional water withdrawal fees apart from these two fees. Water withdrawals that are exempt from the WWAP—such as hydraulic fracturing—do not have to pay these fees.

3.2.4.3 Analysis of general WWAP policy options

<u>3.2.4.3.1 Keep existing Michigan water withdrawal fees</u>

The current fee requirements—$200/year for registration, $2,000/year for a permit—are relatively lower than those of river basin commissions that actively govern water use. Given the number of registrations—over 2,500 registrations since 2009—the State of Michigan currently receives roughly $500,000/year by registrants (assuming water withdrawals are not discontinued) alone.

HVHF Applicability: HVHF operators do not have to pay any water withdrawal-related fees of the WWAP, since their activities are exempted from the WWAP.

Table 3.17: Strengths and weaknesses of existing Michigan water withdrawal fees

	Strengths	**Weaknesses**
Environmental Impacts		*A lack of water withdrawal fees or schedules does not create incentives for considering water conservation mechanisms.*
Economic Impacts	*Extremely low fee costs for all registrants and permit holders, especially when compared to other regions* *No additional fees for HVHF operators.*	*Fees will unlikely cover the additional costs of personnel and monitoring that will be required to ensure the quality of DEQ oversight.*
Governance Impacts		*A glut of registrations into WWAT could require site-specific reviews–which must be completed on a legally defined schedule (see Box 3.1).*

<u>3.2.4.3.2 Modify water withdrawal fee schedules</u>

Instead of a flat-rate fee of $200 per water withdrawal registration, the State of Michigan could institute a fee schedule similar to that used by the SRBC for all water users registering a new or expanded water withdrawal that take into account the volume of water withdrawn, whether the water is for a public or private project, the overall cost of the project, the vulnerability of the surrounding waters, etc.

Another way in which fees could be instituted is project planning fees. Planning fees could be levied against any project deemed to be in areas that are vulnerable to new or expanded water withdrawals. Such areas could include cold-transitional rivers (as defined by the WWAT) and subwatersheds that are in Zone C (or Zone B for cold-transitional rivers). The party that is proposing a new or expanded withdrawal in a vulnerable watershed would be required to pay for planning fees that would allow the DEQ and Michigan Department of Natural Resources (DNR) to conduct site-specific investigations of the expected impacts of the proposed withdrawal.

Another type of fee option would focus on large-scale projects, charging a water withdrawal fee for large-scale water withdrawals based on a percent of the total project's cost, as is done by the DRBC, would provide the opportunity for additional oversight of those projects most likely to have a major impact on water resources.

HVHF Applicability: An across-the-board fee schedule would subject all registered and permitted water users to the new schedule, in addition to high volume hydraulic fracturing operations. **NOTE:** Adopting this policy option would require amending the WWAP to remove the exemption of HVHF operations from the WWAP and/or amending the Supervisor of Wells Instruction to include a fee schedule for HVHF operations.

Planning fees would provide funds to defray the costs for the DEQ and DNR to address issues of water quantity and watershed vulnerability that are at the forefront of popular concern regarding water resources and HVHF. The completion costs for Chesapeake Energy's existing HVHF projects in various parts of the country ranged from $3,100,000 (in the Mississippian Lime of Northern Oklahoma) to $10,100,000 (in the Powder River Basin of Wyoming).[74] If Michigan were to implement planning fees in line with those of the DRBC, this could bring in as much as $404,000 per private HVHF project.

In contrast, capital-intense projects that are expected to use large volumes of water, which may include HVHF operations, would be required to pay fees. In order to assure that costs for water withdrawal are not separated from costs for HVHF, the costs of the water withdrawal would be associated with the cost of the project for which the water withdrawals are proposed.

Table 3.18: Strengths and weaknesses of water withdrawal fee schedules

	Strengths	**Weaknesses**
Environmental Impacts	*Increased costs associated with conducting large-scale water withdrawals will encourage water efficiency.*	
Economic Impacts	*Increased revenues for DEQ that can be used to manage and improve WWAP.*	*Increased costs associated with water withdrawals.*
Governance Impacts	*Projects that are classified as higher risk or higher impact will have greater fees that can be used*	*Can create greater incentives to under-report or to not report water use.*

	to offset potential rehabilitation costs. *Additional funds can mean the hiring of additional personnel in the Water Resources Division.*	

3.2.5 Modify water withdrawal permitting

Local water security is often assured through the acquisition of a water withdrawal permit. In areas that use a regulated riparian framework—such as the State of Michigan—the right to withdraw water is associated with property rights. However, those rights are contingent upon the rights of others to also withdraw and use commonly shared water resources. The issuance of a water withdrawal permit provides a guaranteed allowance by the state for a specified amount of water for a specified period of time and for a specified use (subject to certain responsibilities during periods of water shortage). The obtainment of a water withdrawal permit provides additional certainty in individual planning as well as additional governance responsibility under the law.

3.2.5.1 Current regional standards

Various states around the Great Lakes region require the obtainment of water withdrawal permits for proposed withdrawal rates above 70 gpm. For example, in New York[75] and Wisconsin[76], a permit is required if water withdrawal rates exceed an average of 70 gallons per day over a 30-day period for users within the Great Lakes Basin[77] and an average of 1,388 gallons per minute over a 30-day period statewide.[78] In Pennsylvania and New York, river basins that are part of other regional water compacts (i.e., the Susquehanna and Delaware River Compacts) use those compacts' standards (14 gallons per minute[79,80] and 7 gallons per minute,[81,82] respectively) to determine whether a water withdrawal permit is required.

The DRBC effectively enacted a ban on the issuance of water withdrawal permits for hydraulic fracturing operations until rules were made regarding water withdrawals for hydraulic fracturing.[83] As of the writing of this report, no new rules have been accepted by the DRBC, thus effectively halting hydraulic fracturing expansion within the Delaware River basin since 2010. This is an extreme example of a modification of water withdrawal permitting.

3.2.5.2 Michigan's current policy status

Currently, Michigan requires registration of all proposed water withdrawals with an average withdrawal rate larger than 70 gallons per minute over a 30-day period[84] and requires the obtainment of a water withdrawal permit for water withdrawals greater than 1,388 gallons per minute.[85,86] Water withdrawal permits must also be obtained for withdrawals greater than 70 gpm if the water is moved between watersheds[87] or if the withdrawal is greater than 694 gpm in a Policy Zone C area.[88] One exception is if the withdrawal is less than 1,388 gpm and occurs in a period of less than 90 days[89] (which is considered a "seasonal withdrawal"). Water withdrawal permits can only be obtained for withdrawals larger than 1,388 gpm. At present, the issuance of a water withdrawal permit for its stated purpose is considered to not cause an ARI,[90] but permit holders are the first group that the DEQ can require diminish their withdrawals if there is a determination of an ARI.[91]

Technically, HVHF operations are exempt from the provisions of the WWAP, but currently, HVHF operators must use the WWAT to assess the potential impact of their water withdrawals, and the Supervisor of Wells has the option to "impact" water withdrawals in the case of a Zone B withdrawal in a cold-transitional waterway or a Zone C or D withdrawal elsewhere.[92]

3.2.5.3 Analysis of general WWAP policy options

<u>3.2.5.3.1 Keep existing Michigan policy for water withdrawal permitting</u>

Currently, Michigan only provides the option of obtaining a water permit for withdrawals greater than 1,388 gpm (or 694 gpm in a Policy Zone C area or 70 gpm for intrabasin water transfers).

Table 3.19: Strengths and weaknesses of existing Michigan policy for water withdrawal permitting

	Strengths	**Weaknesses**
Environmental Impacts	*Regulation of all withdrawals greater than 70 gpm.*	*No permits to withdraw water, except for massive quantities or for intrabasin transfers.*
Economic Impacts	*Only $200/year for water withdrawal registration.*	*Little need to obtain a water withdrawal permit for most individual HVHF operations.*
Health Impacts		
Community Impacts	*All permitted water users treated equally.*	*Very few cases of certain water withdrawal behaviors having precedence over others.*
Governance Impacts	*Mechanism for local water users to determine their own water uses.*	*Little capacity for the DEQ to enforce behavioral changes.*

<u>3.2.5.3.2 Open option to obtain a large-scale water withdrawal permit</u>

Provide all current and future long-term water withdrawals above 70 gpm and below 1,388 gpm (i.e., those currently required to register through the WWAT) the additional option of obtaining a large-scale water withdrawal permit instead of merely registering a withdrawal. The obtainment of such a water withdrawal permit would provide the permit holder with a guaranteed access to water in a subwatershed unit. In addition, such permit holders could be given greater decision making power within water-users committees. These permits would be distinct from those issued above 1,388 gpm, which would still be comprised primarily of local government units and quarry operations.[93]

HVHF Applicability: The obtainment of this class of water withdrawal permit would provide local residents a mechanism to negotiate with non-resident water withdrawal proposals and water withdrawals that do not fall under the requirements of registration under the WWAP. On the flip side, it provides local residents who wish to explore HVHF operations on their own land an opportunity to negotiate with gas companies to utilize a portion of a previously obtained water withdrawal permit.

Table 3.20: Strengths and weaknesses of an open option to obtain a large-scale water withdrawal permit

	Strengths	**Weaknesses**
Community Impacts	*All registrants have the option to obtain a water withdrawal permit.* *Provides local users a way to negotiate with HVHF operators to lease the use of a water withdrawal permit.*	*All permit holders are subject to direct DEQ governance.*
Governance Impacts	*Provides a greater capacity to manage water uses in a framework of watershed management.*	*Less direct governance over HVHF operators who may choose to obtain water through permit holders.*

3.2.5.4 Analysis of HVHF-specific WWAP policy options

3.2.5.4.1 Prohibit HVHF operations from obtaining a water withdrawal permit

A prohibition on HVHF operations from obtaining a water withdrawal permit would require a revision to the proposed rules, which provide an option of obtaining a water permit when the WWAT indicates a Policy Zone C condition. However, unlike in the DRBC, where all large-scale water withdrawals require a permit, in Michigan a ban on obtaining a water withdrawal permit would require that HVHF operations would need to keep their water withdrawal rates below 1,388 gpm (or even less in specific conditions; see Table 3.1), and register that withdrawal rate through the WWAT.

Table 3.21: Strengths and weaknesses of a prohibition for HVHF operations obtaining a water withdrawal permit

	Strengths	**Weaknesses**
Environmental Impacts		*HVHF operators may "shop around" for sources of water; may increase overland transport of water.* *HVHF operators may choose to*

		operate a series of water withdrawal wells in multiple subwatersheds, all of which would be below the thresholds for obtaining a water withdrawal permit.
Economic Impacts	*By effectively setting a limit on water supply for HVHF operators, this creates the conditions for a water-use market.*	
Community Impacts	*Ensures that decisions over water uses remain local.*	*Widespread, lower-volume water withdrawals increases the need for overland transport of water.* *Widespread, lower-volume water withdrawals diminishes the local capacities to withdraw water.*
Governance Impacts	*Will simplify water governance standards.*	

3.2.6 Transfer/sale/lease of water withdrawals

In order for HVHF operations to progress, they must have access to a supply of water. Due to possible hindrances that might arise in the legal/regulatory landscape as a public response to HVHF, companies might opt for obtaining water through a pre-existing registered withdrawal or permit. Given the concern surrounding the local impacts of water withdrawals associated with HVHF, providing rules for transferring, selling, or leasing registered water withdrawals or water withdrawal permits would give local water users the ability to negotiate with HVHF operators to coordinate water withdrawals so as to minimize local impacts. Certain safety measures might need to be included in such agreements, so as to ensure that local water users are provided with the appropriate tools to make informed decisions using the best available information.

Such negotiations could also be beneficial for HVHF operators, since they would not need to apply for additional water withdrawals, or the volumes of water withdrawals they apply for would be off-set by the volumes of use they negotiate with local users.

3.2.6.1 Current regional standards

Within the context of regulated riparianism (i.e., Eastern states), water rights are not privately held (as they are in prior appropriation/Western states). As such, the transfer, sale, or lease is not of the water, nor of the right to the water itself, but of the use of water through a registered or permitted withdrawal (and subject to the limitations placed on that registration or permit). The SRBC recognizes the possibility that a private water permit holder might sell a portion of their permitted water withdrawal to a hydraulic fracturing operation located on their lands.[94]

3.2.6.2 Michigan's current policy status

Michigan currently has no law about the transfer, sale, or lease of registered or permitted water withdrawals. However, under current Michigan law, the sale of unprocessed water is illegal. Furthermore, the requirements of obtaining a water withdrawal permit (which is required for nearly all proposed water withdrawals larger than 1,388 gpm) require that the use of the permit is "implemented so as to ensure that it is in compliance with all applicable local, state, and federal laws…,"[95] which may include a prohibition on transfers, sales, or leases of the permit.

3.2.6.3 Analysis of general WWAP policy options

3.2.6.3.1 Keep existing Michigan policy for transfer/sale/lease of water withdrawals

It is currently unclear whether registered or permitted water withdrawals can be used by someone other than the registrant.

HVHF Applicability: Given the uncertainty of whether transfers of existing withdrawals are allowed, HVHF operators will likely proceed to register proposed water withdrawals or obtain a permit independent of negotiating with existing water users in the area.

Table 3.22: Strengths and weaknesses of existing Michigan policy for transfer/sale/lease of water withdrawals

	Strengths	**Weaknesses**
Environmental Impacts		*Effectively no economic incentives for water conservation and water management.*
Economic Impacts		*No water-use market exists.*
Community Impacts		*Communities do not have an economic means of managing their water resources.*
Governance Impacts	*Keeps water law simple.*	

3.2.6.3.2 Provide a mechanism to transfer, sell, lease registered/permitted water withdrawals

Although direct sales and trading of water in Michigan is not legal, since water as a natural resource cannot be owned, the possibility exists of setting up a system in which local water users negotiate–either monetarily or through other mechanisms–with other users in a common subwatershed (as delimited by the WWAT) as to acceptable levels and limits of water withdrawals. Since the WWAT effectively creates a "cap" within each delineated subwatershed in the state, it has effectively signaled the creation of an upper limit of usable water. Furthermore, Michigan's regulated riparianism structure of water law allows any water user "reasonable use" of the water. Given the creation of a cap (caused by the implementation of WWAP) and the simultaneous provision of reasonable use, such an outcome of a "water-use market" appears inevitable. Indeed, given the broad authorities of WUCs to negotiate mechanisms governing local water withdrawal behaviors, it is possible to that such committees could set up negotiated systems of water use based–in part or in whole–on market forces, so long as any transfer of a right to withdraw water also meets the water conservation requirements of the WWAP.

HVHF Applicability: The creation of a mechanism to transfer, sell or lease a registered or permitted water withdrawal will provide local residents with options and opportunities to negotiate with HVHF operators to obtain water within a subwatershed unit over a relatively short period of time without implementing a new or increased water withdrawal.

Table 3.23: Strengths and weaknesses of providing a mechanism to transfer, sell, lease registered/permitted water withdrawals

	Strengths	**Weaknesses**
Environmental Impacts	*Provides an economic framework for water conservation.*	
Economic Impacts	*Creates the opportunity for the creation of a water-use market.*	*No previous experience with water or water-use markets; the price for water-use is not set.*
Community Impacts	*Provides communities with an additional mechanism for determining water uses.*	*Possibility for communities to have the problems associated with local water users making contracts based on unequal knowledge; the "naïve investor problem".*
Governance Impacts		*Need to continue to distinguish between water (a physical commodity that may not be sold) and water-use (a negotiated service that can be leased).*

3.2.6.4 Analysis of HVHF-specific WWAP policy options

3.2.6.4.1 Prohibit transfer or use of registered water withdrawals to HVHF operations

If the State of Michigan were to provide a mechanism for transferring, selling, or leasing existing registered or permitted water withdrawals, then there could be a specific ban on transferring already existing registered or permitted water withdrawals to HVHF operations.

Table 3.24: Strengths and weaknesses of a prohibition of transfer or use of registered water withdrawals to HVHF operations

	Strengths	**Weaknesses**
Environmental Impacts		*May create diffused water withdrawal operations, which will*

		increase overland transportation. *May cause more watersheds to approach ARI status as HVHF operators seek to maximize withdrawals within a subwatershed.*
Economic Impacts		*Removes a mechanism for creating economic incentives for water conservation.*
Community Impacts	*Removes the possibility of communities suffering from the negative consequences of making water-use contracts based on inherently constrained levels of information.*	*Removes the possibility for direct community negotiation with HVHF operators over water resource access and use.*
Governance Impacts	*Each water user must obtain their own permit or registration; keeps water management simple.*	

3.2.7 Additional monitoring

Public concern over potential impacts in much of the areas where HVHF will take place stems from concern that watersheds may be overallocated, due to errors in the predictions of water available made by WWAT.

3.2.7.1 Michigan's current policy status

At present Michigan has the site specific review mechanism to deal with potential overallocation and related impacts to water resources. Site specific reviews are required when a subwatershed is determined to be in Zone C (or Zone B for cold-transitional systems).

In addition to a preemptive site specific review, a site specific review can also be initiated if a suspected ARI is already occurring. Suspected ARIs can be reported to the DEQ's Water Resources Division, and they will conduct a field assessment. Following a field assignment, several things could happen. If no ARI is determined to exist, then a Policy Zone update may be required. If an ARI is determined to exist due to a non-registered well, then the well operator will be fined, be required to register a planned water use, and negotiate with the WUC in order to gain access to that water-scarce subwatershed. If an ARI is determined to exist due to a registered well that is withdrawing water at a rate exceeding its registered rate, it must be diminished.

3.2.7.2 Analysis of HVHF-specific WWAP policy options

<u>3.2.7.2.1 Keep existing Michigan policy for monitoring</u>

The current WWAP allows for an SSR to be conducted when an ARI is suspected, when a subwatershed unit is found to be in Policy Zone C, or when a proposed withdrawal would place a subwatershed unit into Policy Zones C or D (see Box 3.1). The applicant for the SSR may provide additional data to support its application. Additional data from non-applicants might not be considered by the DEQ in its site-specific review process.

Table 3.25: Strengths and weaknesses of existing Michigan policy for monitoring

	Strengths	**Weaknesses**
Environmental Impacts	*SSRs required for all cases where a potential for an ARI is high, thus improving water conservation regulations.*	*All potential harms must be witnessed and observed in situ.* *Only neighbors can request an SSR from the DEQ.*
Community Impacts		*Communities will only have self-reported annual numbers to indicate the condition of water resources.*
Governance Impacts		*On-the-ground ARI impacts will not be assessed until after they have happened.*

3.2.7.2.2 Install additional monitoring wells in the presence of other water withdrawal wells (Michigan proposed rule)

The proposed rules require that "If 1 or more fresh water wells are present within 1,320 feet of a proposed large volume water withdrawal, the permittee shall install a monitor well between the water withdrawal well or wells and the nearest fresh water well before beginning the water withdrawal. … The permittee shall measure and record the water level in the monitor well daily during water withdrawal and weekly thereafter until the water level stabilizes. The permittee shall report all water level data weekly to the supervisor or authorized representative of the supervisor."[96]

Table 3.26: Strengths and weaknesses of installing additional monitoring wells in the presence of other water withdrawal wells

	Strengths	**Weaknesses**
Environmental Impacts	*Provides additional information about changes in local water conditions.*	
Economic Impacts		*Increases costs of operations.*
Community Impacts	*Greater information provides more capacity to make local water decisions.*	

Governance Impacts	*Greater information provides DEQ with more reliable information of local water resources; improves SSR process; provides more time to make a notification of Zone C or ARI.*	

3.2.7.2.3 Collect baseline groundwater data (Michigan proposed rule)

The proposed rules require that, "A permit applicant or permittee of an oil and gas well for which high volume hydraulic fracturing is proposed shall collect baseline samples from all available water sources, up to a maximum of 10, within a 1/4- mile radius of the well location."[97]

Table 3.27: Strengths and weaknesses of collecting baseline groundwater data

	Strengths	**Weaknesses**
Environmental Impacts	*Provides an assessment of initial conditions, which is important for determining the scale of potential impacts.*	
Economic Impacts		*Increases costs of operations.*
Governance Impacts	*Greater spatial groundwater data can be used to update the data and models that underlie WWAT. Allows for a model that better predicts conditions on the ground.*	*Relies on self-reporting.* *Site-specific data may cause revisions to the river classifications of some subwatersheds; such reclassifications will result in different Policy Zone thresholds, which may cause DEQ to intervene with existing water uses.*

3.2.7.2.4 Require site specific reviews for all HVHF water withdrawal proposals

The process of the SSR involves the DEQ assessing the likelihood of a proposed water withdrawal causing an ARI, given the known data of the subwatershed from which the water is proposed to be withdrawn (see Box 3.1). Given that the majority of expected HVHF operations will take place in an area characterized by many groundwater-fed streams, requiring an SSR for all HVHF water withdrawal proposals can provide an additional assessment of the known condition of the water resources in a particular subwatershed.

Table 3.28: Strengths and weaknesses of requiring site-specific reviews for all HVHF water withdrawal proposals

	Strengths	**Weaknesses**
Environmental Impacts	*Increased numbers of SSRs can provide better environmental information among subwatersheds.*	*The requirement to complete all SSRs on a pre-determined deadline may negatively impact their quality.*
Economic Impacts		*Increases time requirement for starting HVHF operations.*
Community Impacts	*Provides assurances to the community that Zone C and ARI withdrawals are unlikely to happen.*	
Governance Impacts	*Can improve the data quality in regions where HVHF water withdrawals will take place.*	*SSRs are only as good as the available data and time to conduct them; a lack of quality data or a lack of sufficient time will not lead to an improved assessment of water availability.* *Will increase the burden on the Water Resources Division to ensure that all SSRs are completed on schedule.* *May incur additional labor costs for DEQ.* *SSRs may cause revisions of some river classifications, thus causing changes in the Policy Zone determinations for those subwatersheds; this may affect existing registered and permitted users.*

3.2.7.2.5 Provide a mechanism to use private monitoring

The WWAP allows the applicant of a water withdrawal to provide data in assessing the condition of water resources in a subwatershed during the process of a SSR.[98] By expanding the sources of data and monitoring, the DEQ would provide a greater assessment of the impacts of a large-scale water withdrawal associated with HVHF. The DEQ could require similar standards for groundwater monitoring for these private monitoring wells as it does for other wells around the state.

Table 3.29: Strengths and weaknesses of providing a mechanism to use private monitoring

	Strengths	**Weaknesses**
Environmental Impacts	*Use of private monitoring of water levels will improve water quantity assessments.*	
Economic Impacts	*No additional public costs for water monitoring.*	
Community Impacts	*Communities will have greater abilities to monitor the state of their water resources and to inform the state of any significant changes.*	*Costs for monitoring well installation and monitoring are borne by the community.* *Costs associated with ensuring data collection standards are borne by the community.*
Governance Impacts	*Provides an additional source of water resources data.*	*Will require the creation of data collection standards in order to have such data be used in official SSRs.*

3.2.8 Public engagement on new water withdrawals

The topic of consumptive water withdrawals has historically been a contentious topic throughout the Great Lakes, and was one of the reasons for the passage of the Great Lakes Compact. Within the State of Michigan, a recent public policy poll found that majorities of Michiganders were concerned about the impacts that HVHF would have on local and state water resources.[99] At the present time, water withdrawals below 1,388 gpm do not generally require any local, regional, or state-wide notification, let alone public input. However, without public notification and public engagement, local governance of a shared resource such as water cannot be equitably or openly pursued.

3.2.8.1 Current regional standards

Outside of public notification procedures existing with any public works project, no public notifications are required for new water withdrawal wells that do not require permitting. However, in cases of the issuance of a permit public notification may be pursued. For example, Wisconsin provides online reporting of the permit application process,[100] while New York may require public hearings on major water withdrawal project, based on the state's Uniform Procedures Act.[101]

3.2.8.2 Michigan's current policy status

Similar to other states, Michigan provides public notification for major water withdrawal projects (i.e., larger than 1,388 gpm), but does not require public reporting or engagement when registering new large-quantity water withdrawals (i.e., larger than 70 gpm and less than 1,388 gpm), unless the local subwatershed unit moves into a "Zone C" status (or a "Zone B" status for cold-transitional systems). In such a case, the DEQ can establish WUCs, made up of registered and permitted water users, who will deliberate voluntary measures to prevent an ARI.[102] The DEQ can—if no agreement is reached within the WUC—order permit holders to restrict their water use to ensure that an ARI does not occur. **NOTE:** Since HVHF operations are technically exempt from the WWAP, it seems unlikely that the DEQ could use this mechanism to order HVHF permit holders to restrict their water use. The Supervisor of Wells Instruction does not indicate what actions should take place if a similar condition occurs.

In addition to the provision to create WUCs, the DEQ can create water resources assessment and education committees (WRAECs) when it issues a registration or permit for a "Zone B" or "Zone C" withdrawal.[103] These committees are to be open to the public and are meant to assist with the provision of educational materials and recommendations concerning a variety of local water-use topics, with the DEQ providing technical information about regional water use and availability.

It is important to note that, at the time of this writing, the DEQ had not instituted any WUCs or WRAECs within the state.

3.2.8.3 Analysis of general WWAP policy options

3.2.8.3.1 Keep existing Michigan policy for public engagement on new water withdrawals

Unless a water permit is being obtained, no public notification for a water withdrawal registration needs to be made.

HVHF Applicability: If an HVHF operation does not cross the threshold of requiring a permit (i.e., 1,388 gpm), then they do not need to notify the public about their proposed water use.

Table 3.30: Strengths and weaknesses of existing Michigan policy for public engagement on new water withdrawals

	Strengths	**Weaknesses**
Community Impacts		*No public notification of increased water use if nothing requires a permit.*
Governance Impacts	*Keeps the process simple.*	*Creates the possibility of surprises, and increased mistrust of the established water withdrawal process.*

3.2.8.3.2 Organize water users committees

The requirement under the WWAP is that WUCs be established whenever a local subwatershed unit moves into a Zone C status (or Zone B for cold-transitional systems). The current lack of any WUCs in Michigan means that there is no formalized local water governance structure available that has state input.

HVHF Applicability: WUCs are the legislated manner by which decision making over competing water uses in conditions of increasing water scarcity are to be made. These committees have the power of determining how to allocate water extraction needs by all registered users and permit holders in a common subwatershed unit and/or to implement alternative water conservation measures. High volume hydraulic fracturing operations would be included in high volume water uses, and as such, the WUC presents a formalized structure through which local residents and gas drillers can negotiate competing water withdrawal demands in water-scarce areas. However, since HVHF operations are technically exempt from the WWAP, and the Supervisor of Wells Instruction does not include language about WUCs, it is unclear how or whether HVHF operators could use WUCs.

Table 3.31: Strengths and weaknesses of organizing WUCs

	Strengths	**Weaknesses**
Environmental Impacts	*Better informed decisions can lead to better environmental outcomes.*	
Community Impacts	*Provides community water users with the ability to make further decisions about water uses.*	*There is no existing model of WUCs.*
Governance Impacts	*Keeps the management of registered water uses at the local level.*	*There is no existing model of how the DEQ will operate within a WUC.* *HVHF operations technically exempt from WWAP, including WUCs.*

3.2.8.3.3 Organize water resources assessment and education committees

WREACs can be created whenever a subwatershed enters a Zone B or Zone C designation in order to increase the technical understanding of available water resources in a subwatershed area as well as providing recommendations for assessing competing water uses. These committees would be public, receive technical input from the DEQ, and can provide educational materials and recommendations about long-term planning, conservation measures, and drought management activities.[104] The current lack of any WREACs in Michigan means that local decision making about reallocation of water resources may be occurring in a setting of unequal information or even a lack of potentially knowable information.

HVHF Applicability: WREACs provide a means by which technical knowledge about available local water resources and likely impacts from various water uses, including HVHF, can be explored.

Table 3.32: Strengths and weaknesses of organizing water resources assessment and education committees

	Strengths	Weaknesses
Environmental Impacts	*Better informed decisions can lead to better environmental outcomes.*	
Community Impacts	*Provides local water users with scientific advice and tools to determine the existing water uses, the remaining water resources, and implications for different water management strategies.*	*There is no existing model of WREACs.*
Governance Impacts	*Provides direct advice to local users. Maintains a devolved governance structure.*	*There is no existing model of how the DEQ should operate within a WREAC.* *Will require additional funds to conduct WREAC studies and analyses.*

3.2.8.3.4 Require public notice on new high-capacity wells

Either in areas with increasing water scarcity (i.e., Zone B in cold-transitional systems; Zone C elsewhere), or more broadly (i.e., with all new high-capacity wells, regardless of Policy Zone), there could be a requirement for public notice on new high-capacity well registrations. This could be done through local DNR, DEQ, or DoA agencies; through the DEQ website; e-mail notifications; or highlighted notifications on the WWAT online interface. This would provide information about the state of local water extraction and provide information that would be useful for local water governance decisions.

HVHF Applicability: Arguably concerns over water quantity security may arise from a perception of a problem, even if the perception may be an overestimate. Concerns surrounding water use associated with HVHF deal heavily with the expected local impacts to the availability of local water resources due to the projected volumes of withdrawal. Public notification of all water withdrawals, including HVHF can provide comparative judgments of water use. At the same time, local residents and governmental units will have a means of assessing projected impacts of publicly disclosed, registered withdrawals, thus increasing transparency.

Table 3.33: Strengths and weaknesses of requiring public notice on new high-capacity wells

	Strengths	**Weaknesses**
Environmental Impacts	*Better informed decisions can lead to better environmental outcomes.*	
Economic Impacts		*Additional minor costs of public notice.*
Community Impacts	*Greater level of information about water withdrawals in a community.*	*May create "information overload."* *Depending on the mode of notification, there may be disparities in public awareness of projects.*
Governance Impacts		*Will create additional obligations for DEQ.*

3.2.8.4 Analysis of HVHF-specific WWAP policy options

3.2.8.4.1 Report to the Supervisor of Wells (Michigan proposed rule)

The proposed rules require the additional step that, "a permittee of a well shall not begin a large volume water withdrawal for a high volume hydraulic fracturing operation without approval of the supervisor or authorized representative of the supervisor. A permit applicant or permittee shall make a written request for approval to conduct a large volume water withdrawal and shall file the request with the supervisor at least 30 days before the permit applicant or permittee intends to begin the withdrawal. The permittee may file the request with the application for a permit to drill and operate a well or may provide the request separately to the supervisor or authorized representative of the supervisor."

Table 3.34: Strengths and weaknesses of reporting to the Supervisor of Wells

	Strengths	**Weaknesses**
Economic Impacts		*Additional cost of creating and filing reports.*
Governance Impacts	*Will require all HVHF large water withdrawals to be filed with the Supervisor of Wells.*	

3.2.9 Summary of water quantity regulation of HVHF

HVHF requires large quantities of water for its operation (Table 3.2), and these numbers are often a source of concern for many citizens when it comes to thinking about the potential impacts caused by HFHV. The State of Michigan has a well-developed system for the management of water withdrawals, the WWAP, which was developed as part of the Great Lakes Compact, and instituted in 2009[105] (see Box 3.1). The WWAP offers a unified mechanism of managing HVHF operations, by managing the water resources of the State. The management of water resources as a central means of managing HVHF operations is currently utilized by both the DRBC and the SRBC. In the same vein, the WWAP provides a singular mechanism for managing HVHF operations by recognizing that their water needs can also fall under the purview of the WWAP, just like all other large-scale water uses in the state.

As sophisticated as the WWAP is in governing water withdrawals, it was not designed to address the specific issues of water withdrawals associated with HVHF, which means that—in order to effectively use the State's core mechanism for water conservation—the various parts of the WWAP need to be updated and modified in order to address the unique technical, physical, and social challenges presented by HVHF.

The different parts of WWAP address different issues associated with water quantity governance, and this section presented different policy options to deal with each of them. Two general means of addressing water quantity governance were provided: enacting changes to the WWAP that would specifically include HVHF and treat it no differently from other water withdrawals or putting policies in place that specifically address only HVHF water withdrawals, specifically to assuage public concerns over the water volumes associated with HVHF operations. The thresholds for regulation could be altered to ensure the inclusion of HVHF water withdrawal operations. These changes could have negative consequences on certain types of water users, but they will also have the benefits of increasing the strength and quality of water conservation throughout the state. The scientific models underlying the central piece of the WWAP—the water withdrawal assessment tool—can be improved in various ways in order to broaden the types of water withdrawals for which it can predict associated impacts as well as to expand its capacity to model impacts to inland lakes, ponds, and wetlands (hydric systems that are not currently included the models). While these improvements will require additional public investments, the long-term benefits of these investments will be a far more predictive, automated, and equitable water governance structure. Furthermore, improvements to the existing public engagement structures outlined in the WWAP—specifically WUCs and Water Resources Education Advisory Committees—can help develop local water use governance, *especially in cases where water resources approach an ARI designation.*

In addition to modifying and updating the existing WWAP structure, a number of additions to the WWAP were presented in this section. 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. In addition, providing opportunities for the public to provide monitoring information to the DEQ allows for civic engagement at little additional governmental cost. Finally, the implementation of a water-use market is presented, which could provide options for minimizing additional water withdrawals by HVHF operations through financial agreements with existing water-withdrawal registrants over the use of a portion of their registered water withdrawals.

The future of water uses in the State of Michigan will undoubtedly become more complex, and the process of governing the State's water resources to ensure they align with the requirements of the Great Lakes Compact will simultaneously require modification. The WWAP provides a unique mechanism for addressing most water conservation decisions through an automated, scientifically based, free online tool as well as a system of human-based reviews for areas with heightened scrutiny in addition to a system of local decision making over water uses. It is necessary to recognize that the current WWAP was meant as only an initial version of an increasingly sophisticated and water governance framework. High volume hydraulic fracturing presents a challenge for the current version of the WWAP, but it is one that can—with sufficient applications of policy options—be addressed effectively without the need of building a completely new water conservation structure.

3.3 WASTEWATER MANAGEMENT AND WATER QUALITY

Management of wastewater produced through HVHF—i.e., flowback fluid—is an issue of wastewater management, since 10 to 70% of the water used can return to the surface, with the historic average in Michigan being 37%.[106] This fluid contains fracturing chemicals in addition to dissolved compounds brought up from the fractured geological layer, and is no longer suitable for human consumption,[107] with many human health impacts due to the possible cumulative and synergistic effects that complex chemical mixtures may have.[108] Furthermore, it may have significant negative environmental impacts.[109] Therefore, while a significant portion of fluid might be recovered during the stimulation of a well, such liquids must be handled appropriately to ensure the quality of other water sources. There are two periods of time when hydraulic fracturing wastewater can impair local water quality: during surface storage and handling and during disposal through deep well injection.[110] While concerns over surface storage and handling are important, this chapter will focus on policy structures and options associated with disposal.

Water quality and governance of quality standards is a multifaceted issue. Laws concerning water quality encompass federal, interstate, and state levels, making water quality a specifically complex parameter to manage. At the federal level, there are many laws concerning water quality, the foremost being the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA).

3.3.1 The Clean Water Act

The CWA provides the basis for a permit program for the National Pollutant Discharge Elimination System (NPDES) and the structure for the regulation of discharge pollutants from point sources. The goal of this law is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters".[111]

Section 301 of the CWA specifically addresses effluent limitations for point source pollution. This section deems "the discharge of any pollutant by any person" to be "unlawful" except for "publicly owned treatment works" (POTWs).[112,113] Effluent limitations for point sources from these publically owned treatment works "require the application of the best practicable control technology currently available as defined by the Administrator pursuant to section 304(b) of [the

CWA]").[114] Furthermore, CWA Section 302 addresses water quality related limitations on point-sources of effluent, requiring protection of public health and public water supplies.[115] However, the CWA has its limitations. There are no specific requirements for the disposal of HVHF wastewater, let alone specific requirements for deep well injection of HVHF wastewater. In effect, the CWA disallows the disposal of HVHF wastewater into surface waters directly. This presents a possibility of sending wastewater to POTWs and having them manage the wastewater. This process was indeed tried in the State of Pennsylvania, but studies demonstrated that POTWs were unable to adequately treat HVHF wastewaters,[116] and recently a lawsuit forced a Pennsylvanian POTW to stop accepting hydraulic fracturing wastewaters until it constructed a wastewater treatment system that could remove 99% of contaminants from the water.[117] Indeed, the volumes of water produced through HVHF operations in the Marcellus shale since 2004 have been far greater than the treatment capacity of POTWs.[118]

Furthermore, in Section 310 of the CWA, which addresses effluent limitations, neither groundwater resources nor discharge limits into groundwaters are discussed. This is significant, because deep-well injection is the means by which HVHF fluids are disposed of in the State of Michigan.

3.3.2 The Safe Drinking Water Act

The SDWA is another federal law managing water quality. Hydraulic fracturing fluids are effectively exempt under the SDWA. However, the wastewater from oil and gas operations, including flowback and produced water, is not exempt if disposed of in deep injection wells under Part 144 of the Federal Underground Injection Control Program (UIC) regulations.[119]

3.3.3 Interstate laws: The Great Lakes Compact

At the interstate level, the Great Lakes-St. Lawrence River Basing Water Resources Compact (Great Lakes Compact) addresses water quality in the Great Lakes region, but only tangentially. This agreement observes the interests of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Wisconsin, and Pennsylvania with regard to the waters of the Great Lakes, which include water quality maintenance as well as "the maintenance of fish and wildlife habitat and a balanced ecosystem."[120] The Compact requires that all water withdrawn from the Basin shall be eventually returned and disallows surface or ground waters to be transferred into the Great Lakes Basin, unless the water "is treated to meet applicable water quality discharge standards," or "is part of a water supply or wastewater treatment system that combines water from inside and outside of the [Great Lakes] Basin."[121,122] If a water source is suspected to have significant adverse impact to quantity of quality of waters and water dependent natural resource of the Great Lakes Basin, it is disallowed from entering the Great Lakes Basin.[123] However, the major purpose of the Great Lakes Compact is water quantity conservation and control over diversions out of the Great Lakes. As such, it only addresses water quality issues through a water quantity framework; it addresses water quality through a "the solution to pollution is dilution" approach, which addresses water quality in a far more indirect manner. Unlike the CWA, which regulates the quantities of *pollutants* entering the nation's waterways, the Great Lakes Compact only addresses the quantity of *water* into which the pollutants enter.

3.3.4 Michigan state laws

In the State of Michigan, the Water Resources Division of the DEQ regulates wastewater discharge to surface waters through the NPDES permit program, which is delegated to the state's authority by the EPA under Michigan's Natural Resources and Environmental Protection Act of 1994, as amended.[124] Furthermore, the DEQ is in charge of responding to surface water spills of hazardous waste.[125] In addition, the DEQ also implements permits to regulate groundwater discharge.[126]

The handling and disposal of wastewater associated with high volume hydraulic fracturing is governed through various regulations associated with the Supervisor of Wells. With much of the wastewater associated with HVHF being contaminated with salts and fracturing chemicals, and with discharge and land application[127] of flowback fluids being forbidden in Michigan, deep well injection is the method favored in the state.[128]

3.3.5 Deep well injection

Deep well injection is defined as liquid waste disposed of through the pumping of waste into or allowing it to flow through a specifically designed and monitored well.[129] Under the UIC Program set up by the Safe Water Drinking Act (SWDA), there are six classes of disposal wells (Class I–Class VI), each with its own disposal purposes and requirements. In the case of hazardous waste, Class I injection wells are determined to be the safest and most effective for disposal. Class I wells are supposed to inject waste materials to a depth below the lowermost underground source of drinking water. However, while HVHF wastewaters could be considered hazardous waste from a public health and environmental health standpoint,[130] HVHF wastewaters are exempted from the legal definition of hazardous wastes, and are statutorily defined as "non-hazardous," which means that oil and gas wastes can be injected into Class II disposal wells. Class II wells are subject to fewer safety requirements and potentially pose a greater risk of contaminating groundwater.[131] There are three types of Class II wells: disposal wells, enhanced recovery wells, and hydrocarbon storage wells. Class II disposal wells are used for the disposal of brines and wastewater associated with oil and gas recovery. Enhanced recovery wells can be used in secondary and tertiary recovery that use diesel fuels in the fluids or in propping agents, although this practice has seldom occurred in Michigan. These are the most numerous type of Class II well nation-wide. Finally, hydrocarbon storage wells are used for the injection of liquid hydrocarbons, generally as part of the US Strategic Petroleum Reserve.[132]

Reports suggest the greatest hazards of deep well injection are the contamination of surface soil, surface water, shallow groundwater by accidental spillage at the wellhead, and contamination of underground source of drinking water by migration or escape of waste components and displaced formation water.[133] The transport of waste to the disposal site poses some potential impact on surface environments.[134] However, subsurface injection has shown to have low potential impact on underground sources of drinking water.[135]

There is a small amount of historical evidence to suggest that wastewater injection into these wells has caused increased hydraulic conductivity in wells in Pennsylvania.[136] However, during the five decades of hydraulic fracturing operations in Michigan, there has been no report of such occurrences in the state,[137] and a recent study of migration of water from HVHF operations in the Marcellus Shale indicates that migration from the fractured layer to the groundwater layer is not happening.[138]

Wells can also fail, posing contamination issues for groundwater (see Chapter 4, Chemical Use). Well failure can arise from lack of consideration of all fluid movements, human error, and failure of well design, construction or operation. Recent studies from outside of Michigan—specifically the Marcellus and Barnett shales—have indicated that some examples of groundwater contamination were caused by casing failure in production wells,[139] and while the study examined production wells and not disposal wells, the findings do appear to confirm that groundwater contamination was a result of well-failure in these cases, and not of migration of hydraulic fracturing fluids from the fracturing zones. Such errors and subsequent consequences can be avoided by designing wells so that local freshwater supplies are protected from contamination by using a separate casing set into the top of the underlying confining layer and cemented back to the land surface, since the confining layer is breached during construction.[140]

3.3.5.1 Michigan's current policy status

In Michigan, the disposal of flowback fluids is governed by both USEPA regulations as well as State of Michigan regulations. Briefly, wastewater from high volume hydraulic fracturing is not allowed to be sent to POTWs, and is required to be injected "into an approved underground formation in a manner that prevents waste. The disposal formation shall be isolated from fresh water strata by an impervious confining formation."[141] The State of Michigan requires a permit and testing in order to practice deep well injection. During operation, thorough records of various parameters are to be kept and reported to well supervisors.[142]

Permitting for the deep well injection[143] of all hydraulic fracturing wastewater in the State of Michigan is the responsibility of the DEQ. Within Michigan state law, Part 615 addresses regulations associated with waste injection wells in Michigan, including produced waters associated with high volume hydraulic fracturing,[144] which the DEQ regards as a form of brine. Although the DEQ is considering submitting a petition for obtaining primary authority over the state UIC program,[145] it currently does not have that authority.[146] Therefore, the USEPA regulates disposal wells through its UIC program in addition to the state regulation. This means that, in addition to an application to the DEQ, a well operator must also apply to the USEPA under its UIC program. Class II wells are the well-type regulated by the DEQ Supervisor of Wells at the state level for use in the disposal of all hydraulic fracturing wastewaters.[147] Currently, Michigan has 1,460 Class II wells.[148]

Under State of Michigan regulations (Part 615), persons may not begin the drilling or operation of a well until they have complied with specific requirements. These requirements include disclosure of well location, explanation of how the well is to be reached, and information of approximate distances and directions from the well site to special hazards or conditions. These special conditions include surface water and environmentally sensitive areas, floodplains, wetlands, rivers, critical dune areas, threatened or endangered species, public water supplies, buildings and local zoning considerations. Information including daily injection rates, pressures, types of fluids to be injected, geological name as well as depths of freshwater strata and more are required to be disclosed during permitting, as well.[149] A permit issued under Part 615 is for the life of the disposal well.

3.3.5.2 Analysis of policy options

3.3.5.2.1 Keep existing Michigan policy for deep well injection

The DEQ and the USEPA manage Class II disposal wells for the disposal of flowback fluids associated with all hydraulic fracturing. These flowback fluids are injected below the layers of groundwater associated with drinking water supply and environmental connectivity. During the long history of hydraulic fracturing in far shallower shale formations than where HVHF will operate, there have been no reported groundwater contamination issues in Michigan.[150]

Table 3.35: Strengths and weaknesses of existing Michigan policy for deep well injection

	Strengths	**Weaknesses**
Environmental Impacts	*Wastewater is injected into Class II disposal wells.*	
Health Impacts	*Wastewater should be injected below any groundwater drinking source.*	*Well casings may fail, causing pollution of groundwater drinking source.*
Governance Impacts	*Maintains the current system in which no reported groundwater contamination has yet occurred in the State.*	

3.3.5.2.2 Increase monitoring and reporting requirements

The presence of public concern over the volumes of wastewater being produced and disposed implies a need for greater transparency and expansion of wastewater disposal information. Reports of the volumes of wastewater injected should be made easily available to the public so that they can to ensure that the volumes reported by drillers are the same as the volumes that are being disposed. Furthermore, a publicly accessible statewide database with wastewater management information could be developed to monitor changes in the sources and volumes of wastewaters.

Table 3.36: Strengths and weaknesses of increasing monitoring and reporting requirements

	Strengths	**Weaknesses**
Economic Impacts		*Increased costs.*
Community Impacts	*Increased monitoring will ease concerns over groundwater contamination.*	
Governance Impacts	*Will provide a better understanding of groundwater*	

	quality and quantity, building on baseline monitoring already in the proposed rules. *Can use existing water monitoring wells already in the proposed rules (See 3.2.7.2.2 Install additional monitoring wells in the presence of other water withdrawal wells).*	

3.3.5.2.3 Require use of Class I hazardous industrial waste disposal wells

The injection of wastewater into a Class II injection well could lead to contamination of drinking water resources. However hydraulic fracturing wastewaters are allowed to be disposed of using Class II wells only due to a legal exemption associated with previous eras of oil and gas extraction technology, and not due to an actual assessment of the current technology's hazards. If HVHF wastewaters were to be considered a hazardous industrial waste, which it is from a human and environmental health point-of-view,[151] such a change in regulatory perspective would require using Class I disposal wells, which are meant to handle the disposal of hazardous industrial wastes. The requirement to obtain a permit for a Class I hazardous industrial waste disposal well (or equivalent) would increase the safety of the injection of polluted waters well below the depth of the underground source of drinking water.

One caveat is that this would either require a definitional change of oversight of these wells by EPA or the creation of a new category of waste disposal to supersede the EPA regulation and to be overseen by the DEQ.

Table 3.37: Strengths and weaknesses of requiring use of Class I hazardous industrial waste disposal wells

	Strengths	**Weaknesses**
Environmental Impacts	*Uses the type of disposal well required for hazardous wastes.*	*Is not proof-positive against faulty wells.*
Economic Impacts		*Increased costs of establishing Class I disposal well facilities.*
Community Impacts	*Greater confidence in disposal of HVHF wastes.*	
Governance Impacts		*Could require readjustment of well oversight with EPA.*

3.3.6 Wastewater recycling

HVHF produces enormous quantities of polluted water per well. In the State of Michigan, all water utilized in the process of HVHF is essentially lost, since wastewater is stored away from existing water supplies and is not reused before it is disposed of through deep-well injection. The opportunity of treating and re-using this polluted water will mean that the volumes of water withdrawals will be diminished, which will lower any local water stresses that would otherwise occur if wastewater recycling were not allowed.

There are many ways that hydraulic fracturing wastewater can be recycled. For example in some states, wastewater is used for dust control on roads, deicing roads during the winter, and sold back to local governments for treatment.[152] This practice is specifically prohibited in Michigan, except in certain conditions.[153] It is important to note, though, that the State of Michigan does not currently provide any preferred options for the recycling of hydraulic fracturing wastewaters. Despite the concerns over potential contamination associated with spills, the technique of on-site recycling is becoming a viable option for some hydraulic fracturing facilities.

A variety of wastewater treatment technologies exist, with some onsite technologies capable of recycling more than 245,000 barrels of both produced and flowback water.[154] Centralizing wastewater recycling operations could save approximately $1.2 billion over five years for a 1,400-well operation the Eagle Ford Shale[155] and could save 10% of the operating cost per well in the Marcellus Shale[156]. These technologies are done onsite of the hydraulic fracturing operation. The recycling of water through this option diminishes both the demand for freshwater as well as the volumes of wastewater.[157, 158]

It is important to recognize, however, that wastewater recycling is not a panacea for all water conservation and water quality issues. Since only a portion of the total volume of water withdrawn returns as flowback fluid (historically 37% in Michigan[159]), supplemental water will always be required to maintain or expand development. Furthermore, there are limitations associated with recycling the produced water, including increased salinity and viscosity, which makes recycling expensive.[160] Furthermore, wastewater recycling requires increased transfer, transport, and treatment; each of these processes bring with it additional possibilities or worker exposure and surface spills, in addition to the burdens of increased energy use, waste disposal, and government oversight.[161]

3.3.6.1 Current regional standards

Hydraulic fracturing wastewater recycling has historically not been a popular management choice, due to additional costs associated with separation and filtration[162] as well as increased costs associated with disposal of flowback fluids.[163] However, wastewater recycling is increasingly being used in the Marcellus Shale because traditional off-site disposal methods are not often available in close proximity to hydraulic fracturing wells.[164] Currently in Pennsylvania, the operator must submit a report to the Department of Environmental Protection after the completion of a well, listing—among other things—the volume of recycled water that was used during the drilling of the well.[165] Further afield, the State of Texas recently changed its laws to allow operators to recycle hydraulic fracturing wastewater without a permit and sell or purchase wastewater from other operators, so long as the recycling takes place on land leased by the operator.[166]

3.3.6.2 Michigan's current policy status

The DEQ notes that on-site wastewater recycling *in general* can be a good technique to ensure that wastewater will not contaminate drinking water supplies, ground or surface waters, and will not be a risk to public health or safety hazards.[167] However, surface spills during the process of wastewater recycling of flowback fluids remain a concern to the DEQ.

Michigan legislation does not currently provide any options for on-site recycling of wastewater from hydraulic fracturing processes, unless the wastewater meets specific quality conditions allowing it then to be used for ice or dust control.[168] If the wastewater does not meet these specific requirements, then current regulations covering wastewater provide deep well injection as the default regulatory option.[169] However, wastewater recycling can offer significant cost and environmental benefits. This is because well operators reduce freshwater consumption and decrease the amount of wastewater to be disposed.

3.3.6.3 Analysis of policy options

3.3.6.3.1 Keep existing Michigan policy for wastewater recycling

There are no specific regulations about wastewater recycling of flowback fluids, leaving deep-well injection of all flowback fluids as the sole defined regulatory option for wastewater management from fracking operations[170].

Table 3.38: Strengths and weaknesses of existing Michigan policy for wastewater recycling

	Strengths	**Weaknesses**
Environmental Impacts	*Minimizes the possibility of surface spills during wastewater processing.*	*Does not conserve water resources.*
Health Impacts	*Minimizes the chances of surface spills due to increased transport and transfer of polluted waters.*	
Governance Impacts	*Maintains the current regulatory system.*	

3.3.6.3.2 Provide options for wastewater recycling

With the recognition that wastewater treatment and recycling can provide benefits in diminished water withdrawals, the option for conducting wastewater recycling in the State of Michigan would provide water conservation opportunities as well as diminish the total volume of wastewater to be injected.

Instead of being injected into disposal wells, wastewater could be treated and reused for gas development. Treatment of wastewater to be reused for hydraulic fracturing operations should focus on the removal of organic contaminant and inorganic constituents. However, treatment of wastewater can be expensive and energy intensive.[171] Still, an estimate of the economic benefits of 100% wastewater treatment and recycling in the nearby Marcellus shale ran an estimated $150,000 per well (or roughly 10% of total costs).[172] Furthermore, wastewater recycling minimized the transport of wastewater across state lines, which obviated other potential costs and risks (see Box 3.5).

Table 3.39: Strengths and weaknesses of providing options for wastewater recycling

	Strengths	**Weaknesses**
Environmental Impacts	*Water recycling means less pristine water withdrawn from groundwater sources.*	*Creates the possibility of surface spills during wastewater processing.*
Economic Impacts	*Diminishes costs of withdrawing and transporting water. Diminishes the volumes (and costs) of disposing wastewater.*	*Increases costs associated with recycling (cost of treatment, costs of using treated HVHF fluids, etc.).*
Health Impacts		*Creates the possibility of exposure to wastewaters and treated waste products during processing.*
Community Impacts	*Diminished amounts of water withdrawals maintains an increased amount of water withdrawals available for local communities.*	*Increased trucking of treated waste products.*
Governance Impacts		*Need regulatory mechanisms to assess performance of current and future technologies in this developing field.* *Need rules to determine how to dispose of the waste products of treatment.*

Box 3.4 Importation of Hydraulic Fracturing Waste into Michigan

Recently, a *Detroit Free Press* article revealed that hydraulic fracturing waste from the outside the state was being imported for disposal.[173] This hydraulic fracturing waste is associated with NORM (naturally occurring radioactive materials) generated in hydraulic fracturing operations outside of the State of Michigan. As such, the question of the management of this hydraulic fracturing waste should be considered in the context of trade and importation policy rather than that of hydraulic fracturing policy.

3.3.6.3.3 Use alternative water sources for HVHF

Providing alternative, non-potable water sources for HVHF operations would diminish the amount of water removed from the local environment. Alternative sources could include treated municipal sewage water or treated wastewater used in conventional mining. In some areas, the diversion of treated sewage or mining waters could also improve local freshwater conditions. However, in more water-stressed regions, the diversion of municipal wastewater may further stress local rivers and streams.

Table 3.40: Strengths and weaknesses of using alternative water sources for HVHF

	Strengths	**Weaknesses**
Environmental Impacts	*Diversion of low-quality POTW discharge to HVHF operations can improve the water quality in some systems, especially those with higher natural water yield.*	*Improvements will only be temporary; when POTW discharges return to normal, any gains to water quality will be lost.* *May diminish water quality in river systems with low natural water yield.* *Will require overland transport from POTWs to the HVHF site.*
Economic Impacts	*Collecting and transporting treated POTW discharge may be cheaper than digging and operating a water withdrawal well.*	*Will require additional costs associated with using non-pure water sources.* *May require additional treatment before use.*
Community Impacts	*Diminished amounts of water withdrawals maintains an increased amount of water withdrawals available for local communities.*	*Will increase trucking of water resources from POTWs to HVHF site.*
Governance Impacts		*Will need to draft new rules associated with using treated POTW discharge.*

3.3.7 Summary of wastewater management and water quality policy options

Presently, the wastewater management and water quality policies of the State of Michigan have been mostly 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 high volume hydraulic fracturing, it is not clear whether the laws and regulations written at a time of small-scale, shallow hydraulic fracturing options will be adequate (see Table 3.2 for relative scales of water use). Where there once were thousands of gallons of wastewater per well to handle from historic small-scale fracturing operations, a future with high-volume hydraulic fracturing will create hundreds-of-thousands (and possibly millions) of gallons of wastewater; one hundred to one thousand times more than historic wells.

A future with high volume hydraulic fracturing in the State of Michigan should be met with the understanding of the vastly different scales of water use and wastewater production associated with each high volume hydraulic fracturing well. Providing additional safeguards could provide better protection of public drinking water supplies and the sources of water for many of the State's prime fishing rivers. Furthermore, providing additional options for managing wastewater use and alternative sources for water acquisition could provide well operators with an option of minimizing the local negative impacts of water withdrawals as well as providing potential economic savings in the operations of the well.

The current process for managing hydraulic fracturing wastewater fluids in the State of Michigan is deep well injection. The UIC program, which is the national governing framework for deep well injection, is managed by the EPA, and, together with Michigan State Law, it requires the disposal of hydraulic fracturing fluids into Class II wells.[174] Although Class II disposal wells are supposed to keep underground drinking water supplies safe from contamination, in view of examples of well casing failures in production wells due to high pressure leading to groundwater contamination, alongside public perceptions of the vulnerability of groundwater resources to hydraulic fracturing operations in general, additional options for managing and monitoring wastewater disposals are presented. One presented option is to increase the amount of groundwater monitoring around deep well injection sites. Another option is to specifically require that hydraulic fracturing fluids be disposed of in Class I wells, which are designed to handle hazardous industrial wastes.

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 provide 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. The State of Michigan also does not allow for the use of treated municipal wastewater as the water source for hydraulic fracturing operations, even though this can be used an alternative water source. Providing opportunities for recycling wastewater and using alternative water resources both hold potential benefits of improved water quality, through diminished demands for groundwater resources. However, neither of these are a total panacea, as they both carry associated environmental risks.

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[19] The Great Lakes Compact defines "Cumulative Impacts" as "the impact on the Basin Ecosystem that results from incremental effects of all aspects of a Withdrawal, Diversion, or Consumptive Use in addition to other past, present, and reasonably foreseeable future Withdrawals, Diversions, and Consumptive Uses regardless of who undertakes the other Withdrawals, Diversions and Consumptive Uses. Cumulative Impacts can result from individually minor but collectively significant Withdrawals, Diversions and Consumptive Uses taking place over a period of time."

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[43] The legislation in Minnesota refers to a *pumping rate* of 10,000 gallons per day. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per minute (10,000 gpd = 6.9444 gpm; 7 gpm = 10,080 gpd).
[44] Minn. Stat. §103G.271.
[45] N.Y. Comp. Codes R. & Regs. tit. 6, § 601.
[46] Wis. Stat. § 30.18.
[47] Wis. Stat. § 281.346.
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[49] Susquehanna River Basin Commission 18 C.F.R. § 806.4.

[50] The regulation of the Susquehanna River Basin Commission refers to a *pumping rate* of 20,000 gallons per day. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per minute (20,000 gpd = 13.8888 gpm; 14 gpm = 20,160 gpd).
[51] Delaware River Basin Commission 18 C.F.R. § 410.1, *available at* http://www.nj.gov/drbc/library/documents/watercode.pdf (2 Del. River Basin Water Code § 20.7).
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[75] N.Y. Comp. Codes R. & Regs. tit. 6, § 601.

[76] Wis. Stat. § 30.18.

[77] Wis. Stat. § 281.346.

[78] Wis. Stat. § 281.346.

[79] Susquehanna River Basin Commission 18 C.F.R. § 806.4.

[80] The regulation of the Susquehanna River Basin Commission refers to a *pumping rate* of 20,000 gallons per day. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per minute (20,000 gpd = 13.8888 gpm; 14 gpm = 20,160 gpd).

[81] Delaware River Basin Commission 18 C.F.R. § 410.1, *available at* http://www.nj.gov/drbc/library/documents/watercode.pdf (2 Del. River Basin Water Code § 20.7).

[82] The regulation of the Delaware River Basin Commission refers to a *pumping rate* of 10,000 gallons per day. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per minute (10,000 gpd = 6.9444 gpm; 7 gpm = 10,080 gpd).

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[85] Mich. Comp. Laws § 324.32723.

[86] The regulation in Michigan refers to a pumping rate of 2,000,000 gallons per *day*. In order to remain consistent with the reported units used in this report for water pumping rates, this rate has been converted to a rate of gallons per *minute* (2,000,000 gpd = 1,388.9 gpm).

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CHAPTER 4: CHEMICAL USE

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4.1 INTRODUCTION

The chemical substances associated with high volume hydraulic fracturing (HVHF) activities are numerous and may be found at every point in the process. For example, between 2005 and 2011, the Environmental Protection Agency (EPA) identified over 1,000 different chemicals that were either used in fracturing fluids or found in associated wastewaters.[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,[2,3,4,5] as well as in other jurisdictions currently engaging in HVHF.[6,7]

These chemicals are either intentionally used, or by-products of, HVHF operations. For example, acetic acid (function: reduces fluid volume), ethylene glycol (function: prevents mineral scale formation in the wellbore), and silica sand (function: props open fractures to allow gas to escape from the shale) have traditionally been used among various other chemicals at well sites across the U.S., including Michigan[8]. Other chemical by-products of HVHF include various naturally-occurring minerals and metals that may contaminate flowback water, as well as the unintentional release of methane and hydrogen sulfide.[9] These chemicals have the potential to give rise to a number of adverse human health effects, with methane, in particular, also known to be flammable in air at certain concentrations. Animal health may also be adversely impacted by the release of chemicals associated with HVHF activities into the surrounding environment.[10] A more comprehensive discussion of the chemicals associated with HVHF operations and their potential human and ecological health implications may be found in the public health technical report from Phase I prepared by Basu et al.[11]

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). For example, the consumption of ethanol in the form of alcoholic beverages carries with it a series of hazards (e.g., intoxication, liver cirrhosis, death), but it is the concentration of the ethanol, frequency of consumption, and timeframe over which consumption takes place that largely determine the risks.[12] In the same light, the chemicals associated with HVHF may have one or more ecological and/or health hazards, but it is the *circumstances of their interactions* (i.e., concentration, route, duration, and frequency of exposure) with humans and other life forms that dictate the risks.

Although HVHF activities are prevalent within the State of Michigan and other areas of the U.S., information on the ecological and/or health risks posed by the chemicals associated with this activity is currently limited. This is especially true in relation to the long-term ecological and human health impact of high-volume chemical use. Much of the information available to date is derived from methods that are not widely accepted by the scientific community (e.g., anecdotes, non-peer-reviewed reports).[13] Several factors challenging our progress in this domain include the relatively recent development of HVHF, latency issues (i.e., time delay between exposure and disease, especially those diseases known to have a long latency period), limited monitoring data, limited baseline health data, and a lack of complete chemical disclosure (e.g., trade secret exemptions) among others.[14] From a public health perspective, for example, epidemiology studies using widely accepted scientific methods are greatly needed, as well as scientifically sound data on the impact of HVHF activities on the ecology surrounding the sites. However, due to the complex mixture of HVHF chemicals, the multi-causal nature of reported health outcomes (e.g., headaches, rashes, asthma), and the absence of systemic data collection on human or ecological impacts, assessing the associations is problematic.[15]

Nevertheless, with increasing HVHF activity, and interest in the potential associated risks by the general public, industry, the epistemic and regulatory communities, combined with continuing advances in scientific research, the coming years are expected to bring a wealth of information on potential risks and/or hazards posed by the chemicals commonly used in HVHF. For example, the potential endocrine-disrupting[16] and developmental effects[17] associated with commonly used fracking chemicals and the potential health risks associated with airborne occupational exposures to silica during the transportation and handling of silica sand[18] has generated concern among stakeholders recently. So, too, have airborne exposures to hydrogen sulfide and volatile hydrocarbons during flowback operations,[19] and human and ecological risks associated with exposure to HVHF chemicals that have contaminated drinking water and other water resources.[20] Given the current dearth of publically available scientific data and their potential risks, it is anticipated that research into such chemicals when associated with HVHF activities shall be a priority in the short to medium term.

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.[21] In its strongest form, the precautionary approach would counsel banning an activity that could result in severe harm.[22] The second is to adopt an adaptive approach. Based on the principles of adaptive management, policymakers may choose to take some regulatory action at the outset, and continually refine the response as further information becomes available.[23] 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.[24]

Twenty-nine states have adopted policies governing HVHF and associated oil and gas production.[25] Of these, twenty-seven states allow HVHF with varying levels of regulation; two states do not allow the practice.[26] Three more states are currently considering taking action.[27] This chapter will focus on the policies of eight of these 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, geography, and policy.[28] Although New York has chosen to ban HVHF rather than proceed with a rulemaking, the state's proposed rules are included in this chapter because they represent a qualitatively different policy approach. A summary of key characteristics of the surveyed states is in Tables 4.1, 4.2, and 4.3.

Table 4.1: Production characteristics of states surveyed

State	Natural Gas Production Ranking (2013)[29]	Shale Gas Production Ranking (2013)[30]	Crude Oil Production Ranking (2014)[31]	Year Conventional Production Began[a]
Arkansas	8	4	20	1921[32]
Colorado	6	13	7	1862[33]
Illinois	26	None	15	1905
New York	22	None	28	Gas: 1821[34] Oil: 1881[35]
North Dakota	14	7	2	Gas: early 1900s[36] Oil: 1951[37]
Ohio	16	9[b]	14	1860[38]
Pennsylvania	2	2	19	1859[39]
Texas	1	1	1	1866[40] - 1894[41]
Michigan	**18**	**9[b]**	**17**	**1925**[42]

[a] Unless otherwise noted, dates in this column refer to oil production, which pre-dates gas production.
[b] Michigan and Ohio both produced 101 billion cubic feet of shale gas in 2013, so they are tied in the ranking.

Table 4.2: Demographic characteristics of states surveyed

State	Population (million, 2010)[43]	Population Density (persons/square mile, 2010)[44]	Median Income (2011-2013)[45]	Geographic Location
Arkansas	2.92	56.0	$40,760	South
Colorado	5.03	48.5	$60,727	West
Illinois	12.83	231.1	$54,044	Midwest
New York	19.38	411.2	$51,554	East
North Dakota	0.67	9.7	$55,946	West
Ohio	11.54	282.3	$45,887	Midwest
Pennsylvania	12.70	283.9	$52,768	East
Texas	25.15	96.3	$52,169	South
Michigan	**9.88**	**174.8**	**$50,056**	**Midwest**

Table 4.3: Policy characteristics of states surveyed

State	Primary Policy Actor	Form of Policy	Year Adopted
Arkansas	State agency	Rules	2010
Colorado	State agency	Rules	2012
Illinois	Legislature	Statute; rules	2013; 2014
New York	State agency	Proposed rules; imposed ban	2011; 2014
North Dakota	State agency	Rules	2012
Ohio	Legislature	Statute	2012
Pennsylvania	Legislature and state agency	Statute; rules	2012; 2011
Texas	State agency	Statute; rules	2011; 2011
Michigan	**State agency**	**Instruction; proposed rules**	**2011; 2013**

In this chapter, we examine 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 or set a performance standard; and response policies manage any contamination through emergency planning, cleanup, and liability requirements. For each type of tool, we present the range of policies adopted by states and describe Michigan's existing policies. Building on the three approaches to uncertainty (precautionary, adaptive, and remedial), we offer combinations of policy options the state could adopt and compare them to the rules proposed by the Michigan DEQ.[46] Summary tables comparing the key components, relative to the current Michigan policy and including strengths and weaknesses, are set out at the end of each section.

4.2 INFORMATION POLICY

4.2.1 Introduction

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 (through such mechanisms as chemical disclosure websites and/or Material Safety Data Sheets (MSDS)), 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.

4.2.2 Range of policies

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.

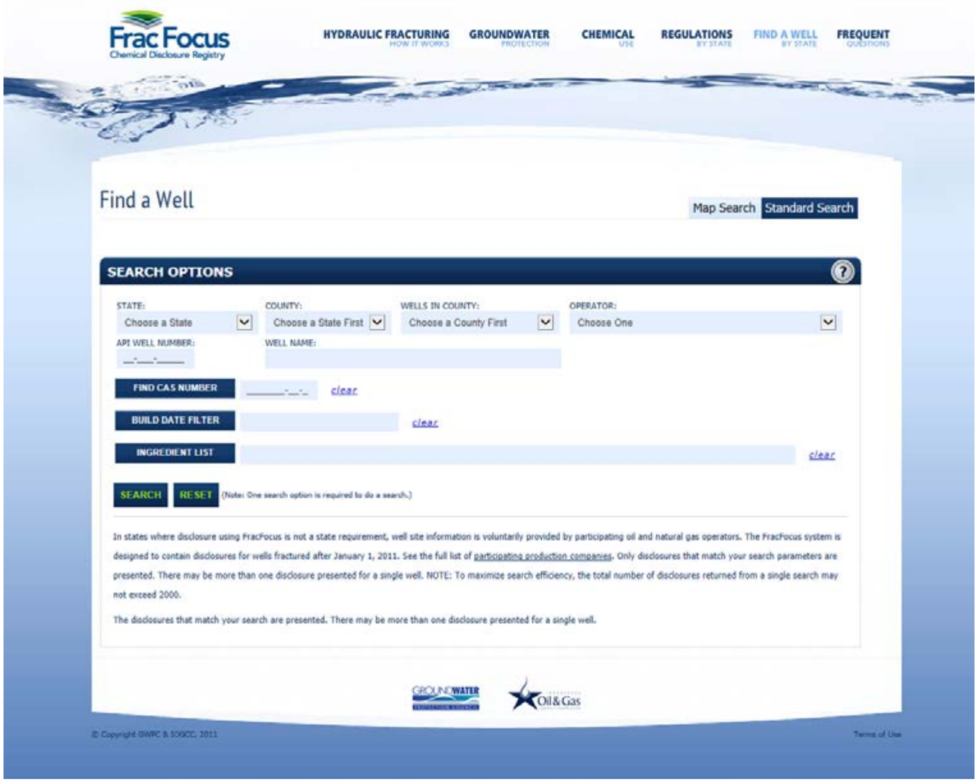
4.2.2.1 Information on chemicals

The most common information policy is disclosure of the chemicals used in hydraulic fracturing fluid. Since 2010, twenty-six states, including Michigan, have adopted such policies.[47] All of the states surveyed require or proposed to require some form of chemical disclosure, and the American Petroleum Institute recommends disclosure in its guidelines.[48] There are four policy elements: (1) the substance of the disclosure; (2) the means of disclosure; (3) the timing of disclosure; and (4) the exceptions to disclosure.

Chemical disclosure policies require the well operator to disclose specific information on the chemical additives in the hydraulic fracturing fluid and on the chemical constituents that comprise each additive. The most common pieces of information are: the identity of each chemical constituent, including the name and the number assigned by the Chemical Abstract Service (CAS) Registry;[49] the concentration of each constituent in the additive and in the total fluid;[50] the trade or product name of each additive;[51] the supplier or vendor of each additive;[52] and the intended use or function of each additive.[53] Six states expressly limit the required disclosures to chemicals that are intentionally added to the base fluid.[54] Less common are the volume of each additive in the fluid[55] and the Material Safety Data Sheet (MSDS), a form of hazard communication required by federal worker safety law, for each additive.[56]

The means and timing of disclosure are closely linked. The primary mechanism for disclosure is posting of the information on a website called FracFocus within thirty to sixty days after hydraulic fracturing. State officials in the Groundwater Protection Council and the Oil and Gas Compact Commission created the website in 2010, initially as a means of voluntary reporting by industry. Well operators submit the information on a standardized form; the public can then view the form through a map-based interface or search by location, operator, chemical name, or CAS number (see Figure 4.1). Six of the eight surveyed states require or allow operators to use FracFocus.[57] The remaining states require disclosure directly to the state regulatory agency;[58] Illinois plans to post the information on its own website.

Figure 4.1: FracFocus chemical disclosure registry search page.



A less common mechanism of disclosure is to require the well operator to disclose the proposed chemical additives and constituents in the application for a well permit, before hydraulic fracturing occurs. The public may have access to the information through a state website or information requests under state records laws. Two of the surveyed states have proposed or have this type of disclosure in addition to post-hydraulic fracturing reporting.[59] In a unique variation, Arkansas and Illinois require each provider of hydraulic fracturing services to disclose a master list of all chemicals that will be used in the state prior to servicing any wells.[60]

All of the surveyed states allow well operators to protect the identity of a chemical from public disclosure if the identity is deemed a trade secret. Seven specifically grant an exception for trade secrets,[61] while North Dakota relies on the reporting requirements of FracFocus, which provide that operators can protect information considered to be a trade secret under federal worker safety law.[62] In addition to the name and CAS number of a chemical, many states allow operators to withhold the concentration or volume of a chemical.[63] Several states require operators to disclose the chemical family, such as polymers, in place of the withheld identity.[64]

The states vary in their treatment of the trade secret claim. Some require written statements, affidavits, or justifications;[65] others require that the information be submitted for review.[66] Yet others allow certain members of the public to contest a claim.[67] In Texas, for example, the surface landowner or adjacent landowner may submit a challenge to the state within twenty-four months of the date a well completion report is filed, and the state must investigate.[68] Because the operator need not provide a basis for the claim, however, it is not clear how effective the right is.

As of November 2014, there have been a few inquiries but no challenges have been filed.[69] Six of the eight states require disclosure of chemicals to healthcare professionals under certain conditions.[70]

Unlike most states, Michigan currently requires a well operator to submit a MSDS and the volume of each chemical additive used in high volume hydraulic fracturing within sixty days after well completion.[71] The MSDSs are then posted on the state's website, sorted by well.[72] Each sheet contains a list of hazardous chemical constituents as defined in worker safety law; the maximum concentration of each constituent in the additive; information on potential human health harms if workers are exposed; and safety precautions. Michigan's current policy does not address trade secrets; however, suppliers may withhold the identity of proprietary chemical constituents from the MSDS under federal worker safety law.[73]

4.2.2.2 Information on well integrity

While chemical disclosure has garnered the most attention, states also require operators to test the soundness of well construction and report the results. Before hydraulic fracturing may commence, five states require or would have required mechanical integrity tests of both the internal and external integrity of at least some wells, which are designed to uncover leaks that could occur under the pressure of injection.[74] Pennsylvania requires operators to inspect operating wells at least quarterly for mechanical integrity.[75] States also require well operators to monitor the integrity of well construction during hydraulic fracturing. The most common means is monitoring pressures at the surface and in the space between casings, known as the annulus (for an overview of the technology involved with HVHF, please see the technology technical report[76]). Seven of the eight states require or would have required operators to monitor pressures during hydraulic fracturing.[77] Colorado requires operators in certain areas to monitor pressures of nearby wells.[78]

Some states direct the operator to take certain steps if these tests indicate a possible leak. For example, North Dakota requires the owner or operator to verbally notify the director if a certain pressure exceeds 350 pounds per square inch during hydraulic fracturing.[79] Ohio requires the operator to notify the state if it discovers any inadequacy in the well's construction and to immediately correct the problem.[80] Similarly, New York's proposed rules would have required operators to suspend hydraulic fracturing and notify the state if any anomalous pressure or flow condition occurred.[81]

Michigan does not currently require operators to conduct mechanical integrity tests of wells before hydraulic fracturing. During HVHF, operators must monitor the surface pressure and the annulus pressure between the injection string and the next string of casing.[82] The recorded annulus pressures must be reported to the state within sixty days of well completion.[83]

4.2.2.3 Information on water quality

Finally, states have responded to concerns about water contamination by requiring operators to gather information on the quality of water resources around the well. Five of the surveyed states mandate or proposed to mandate some form of water quality testing.[84] Pennsylvania does not require testing, but strongly encourages it through a presumption of operator liability for groundwater contamination that can be rebutted by showing that the contamination was present before hydraulic fracturing.[85] Reflecting the focus on groundwater contamination, states most commonly require testing of groundwater wells that supply drinking water.[86] Illinois, however, includes both surface and groundwater.[87]

The elements of each policy vary by timing, area, and reporting requirements. Some states require only baseline testing,[88] while others require operators to monitor water quality after hydraulic fracturing by testing at regular intervals.[89] In Illinois, for example, operators must test water quality at six, eighteen, and thirty months following completion of the oil or gas well.[90] The radius of testing may be from 1,500 feet to one mile from the well pad,[91] and depends on the availability of water sources and the permission of landowners.[92] Some states specify the testing parameters in the policy,[93] while others do not.[94] The operator may be required to report the results to the state regulatory agency or the (surface) property owner;[95] or there may be no designated recipient.[96] In a unique variation, New York would require the operator to report any "significant deviation" from the baseline results to the state environmental agency within five days, in addition to regular reporting to the state and the landowner.[97]

Michigan does not currently require operators to test water quality.

4.2.3 Policy approaches

Information policy responds to scientific uncertainty about risk by gathering information on chemical hazards and the potential for human and ecological exposure. State objectives for collecting information depend on the policy approach. Under a precautionary approach, states collect information on threats prior to HVHF to set preventative limits on the location, construction, and operation of the HVHF well or to decide whether to allow HVHF at all. Under an adaptive approach, states continually collect information so that over time they can better understand risk and refine their HVHF policies. Under a remedial approach, states collect information after HVHF to respond to contamination and to ensure HVHF well operators are held liable for any damage.

Information policy also may respond to public uncertainty about risk by helping members of the public both participate in the democratic process and make individual decisions about property and health. Under a precautionary approach, members of the public use information to participate in setting preventative limits and also to take actions prior to HVHF to reduce the potential for individual exposure. Under an adaptive approach, members of the public use information to participate in the refinement of policies and also to change their behavior over time, such as determining whether to continue to drink water from wells. Under a remedial approach, members of the public use information to take actions to minimize their exposure to contamination and also to decide whether to seek compensation from a well operator.

Of the states surveyed, Colorado has chosen to respond to uncertainty through an adaptive approach. The state has adopted detailed reporting of the chemicals used in HVHF, monitoring of well integrity during HVHF, and monitoring of groundwater quality around a well. These policies help the state to learn more about the risk of HVHF and to refine policies as necessary, although the assessment of risk is limited by a lack of full information on trade secret chemicals.

It is less clear that the policies help the general public to participate in the democratic process or make individual adaptive decisions. For example, while the intent of chemical disclosure is often to inform the public, most members of the public will not understand the import of such technical information.

Illinois has adopted, and New York has considered adopting, a precautionary approach. As part of the permitting process, information is collected on chemical additives, well integrity, and water quality prior to HVHF. Well operators are required to provide information about trade secret chemicals before HVHF so agencies can consider the hazards of these chemicals. The states can use the information to decide whether the HVHF well should be permitted and, if so, what conditions should be imposed on the activity. New York has recently extended the precautionary approach to a ban on HVHF. Just as in the case of the adaptive chemical disclosure policies, it is less clear how the precautionary policies help most members of the public understand the nature of chemical use and take precautionary actions to avoid the threat of harm.

Michigan's current information policy, as in the remaining five states, responds to uncertainty through a remedial approach. Information on hazardous chemicals, when combined with well pressure records, is primarily useful in helping the state to identify the source of any contamination. Broad trade secret protection and lack of monitoring data on water quality make it difficult for the state to use the information in an adaptive way to refine policies. Members of the public are also unlikely to use the information to change their behavior. While the MSDSs provide more information on the hazards of chemicals than does a list of chemical constituents of additives, the sheets are written for trained employees and focus on the risks to workers.

4.2.4 Analysis of policy options

The tools available to the state to enhance, or hinder, access to information relating to HVHF vary significantly. Multiple mechanisms for the supply, and use, of information shall, however, be required by the state in order to deal with HVHF activities. As such, the state will be required to retain the status quo, examine how current policies may be amended to specifically address the desired objective, or look to new policy tools. With this in mind, Section D presents a series of policy options available to policy makers and relevant regulators. Rather than identify each individual mechanism, the following section presents policy tools within the context of a suite of tools; each suite focuses, and addresses, the policy response to uncertainty that the state may wish to pursue in relation to information provision. Importantly, the purpose of Section D is not to recommend or suggest one policy objective, and suite of policy tools, over another. Rather, it is to illustrate what policy tools, and in what combination, shall be needed in order to address a specified policy objective relating to information provision.

Table 4.4: Summary of information policy options for Michigan

Policy Area	Policy Elements	Current Policy	Option A (Proposed Rules)	Option B (Adaptive Approach)	Option C (Precautionary Approach)
Chemical Use	Subject of disclosure	Hazardous constituents	All constituents	All constituents; plain-language description	All constituents; plain-language description of risks and alternatives; studies
	Means of disclosure	MSDS on state website	Permit application; FracFocus	Master list; state website; FracFocus	Permit application; state website
	Timing of disclosure	Within 60 days	Before HVHF and within 30 days after HVHF	Before and within 30 days after HVHF	Before HVHF
	Trade secret claim review	None	Statement of claim; must use family name or other description	Narrow exception for trade secrets	Full information provided to state
Well Construction	Pressure monitoring	Monitored and reported within 60 days	Monitored and reported immediately to state if problem; HVHF ceases until plan of action implemented	Monitored and reported immediately to state and nearby landowners if problem; status placed on website; HVHF ceases until plan of action implemented	Monitored and reported immediately to state and nearby landowners if problem; HVHF ceases until operator demonstrates integrity
	Mechanical integrity test	None	When monitoring indicates problem	When monitoring indicates a problem	Prior to approval of HVHF; when monitoring indicates a problem
Water Quality	Water source	None	Groundwater	Groundwater and surface water	Groundwater and surface water
	Area around well		¼-mile radius around well	Based on characteristics of aquifer/watershed	Based on characteristics of aquifer/watershed
	Number of sources tested		Up to 10	Part of larger monitoring system in area	Variable, based on importance of sources
	Frequency of testing		Once, >7 days but <6 months prior to drilling of new well or HVHF of existing well	Baseline test; long-term regular monitoring	Baseline test; long-term regular monitoring
	Test results		Within 45 days; immediate notification of contaminants of concern; to state and owner	Within 10 days; immediate notification of contaminants of concern; to state, owner, and public (through website)	Prior to approval of well and within 10 days; immediate notification of contaminants of concern; to state and owner

4.2.4.1 Option A: Michigan's proposed rules

Michigan has proposed rules that provide more information on chemical additives, well integrity, and existing water quality than under its current policy.[98] These rules take a more adaptive and even precautionary approach to uncertainty; however, these approaches are limited by trade secret protections and a lack of long-term water quality monitoring. As discussed in subsection C, the technical information is unlikely to improve general public participation in state decisions or to help individuals make adaptive decisions related to HVHF.

<u>Information on chemicals</u>

The proposed policy would help the state to refine its policies over time by providing information on more chemicals within a shorter time period after HVHF occurs. The policy would be very similar to the ones in other states surveyed for this report. Well operators would be required to disclose information on all chemical constituents of HVHF fluid within thirty days after well completion on FracFocus.[99] The information required includes the specific trade name, supplier, and type of each chemical additive; and the specific identity, CAS number, and maximum concentration in the total fluid of each chemical constituent intentionally added.[100]

The proposed policy also could help the state set preventative limits on chemical use by providing information on chemical constituents to the state prior to HVHF. A well operator would be required to disclose in the permit application a list of constituents the operator anticipates will be used in HVHF fluid, including the specific identity and CAS number.[101] The state's ability to take precautionary measures is restricted, however, because operators are expressly allowed to use other chemical constituents in the actual HVHF operation.[102]

Both the adaptive and precautionary approaches are limited by the lack of full information on trade secret chemicals. As in other states, the proposed rule would allow an operator to protect the specific identity, CAS number, and concentration of a constituent as a trade secret. On the permit application and FracFocus form, the operator would be required to replace this information with the chemical family name or a similar description, and state that a claim of trade secret protection has been made.[103] The state would not be able to review the protected information.

The intent of this policy, as in other states, is to give more information to the public by collating the data and making it accessible through a permit application and a map-based website. But because the data is not translated into an easy-to-understand form, it is unclear how members of the public will be able to participate in policy decisions or use the information to adapt their own behavior. It is also unclear whether the public would be able to comment on the proposed chemical constituents during the permitting process.

<u>Information on well construction</u>

The proposed policy would help the state to refine its policies by collecting additional monitoring data on well pressures during HVHF.[104] The data would be reported to the state, by the operator, within sixty days after well completion.[105] If pressures during hydraulic fracturing indicate a lack of well integrity, the proposed rules would require mechanical integrity tests.[106] Utilizing a precautionary approach, the proposed rules would also require the operator to immediately cease hydraulic fracturing, notify the state, and submit a corrective action plan for review.[107] The state would not, however, be able to set preventative limits prior to HVHF through mechanical integrity tests or review of information on well integrity.[108]

Information on water quality

Unlike the other aspects discussed above, the proposed policy would not take an adaptive approach to water quality information. Rather, the policy takes a remedial approach by informing the state and freshwater well owners about prior contamination. Between seven days and six months before a new well is drilled or an existing well is HVHF, operators would be required to conduct a baseline test of no more than ten “available” groundwater sources within one-quarter mile of the oil or gas well.[109] Within forty-five days of the testing, the operator must report the results to the state and the water well owner or landowner.[110] An operator need not conduct another test for wells that are drilled within three years on the same well pad or an adjacent pad.[111]

The policy serves the remedial purpose of identifying whether production activities have caused contamination in the past. For example, the operator would be required to notify the state and freshwater well owners immediately if carcinogens associated with natural gas and oil production—benzene, toluene, ethylbenzene, or xylenes—were detected.[112] If methane were detected, the operator would be required to conduct additional testing to determine the origin of the gas, and thus whether it could be traced to production.[113]

When combined with chemical data, the policy could also serve the remedial purpose of determining whether HVHF is a possible cause of future contamination. If later testing detected a contaminant used in HVHF fluid, the baseline test would demonstrate whether the contaminant was present in groundwater prior to HVHF. But the policy would rely on freshwater well owners to test for the correct contaminants.

4.2.4.2 Option B: Information policy employing an adaptive approach

Option B is concerned with increasing the availability of, and access to, information relating to aspects of HVHF activities so as to ensure that best practices may be followed at all times. Policy makers may adopt such an approach in order to ensure that the evolving state of the scientific art informs the state’s decision-making about HVHF activities, and the operation of HVHF sites. This approach, by virtue of increasing the amount of information collected and disclosed, may also assist in increasing transparency in decision-making processes. This may be especially valuable in relation to issues that relate to potential human and/or ecological health risks. In this way, Option B serves primarily as an adaptive approach; enhanced information provisions enable the public to better understand the potential benefits and risks associated with HVHF, and to make informed decisions over time.

We would argue that the nature of the information requirements should vary based on the degree to which they further the needs of the public. More extensive requirements pertaining to information on chemical use and water quality appear desirable if they are in plain language, given public concern relating to these aspects and their potential public health implications. In contrast, extensive information requirements around the details of well integrity appear to be of a lesser concern to the public generally, except for notice of any potential contamination.

Information on chemical use

Option B would require all well operators in Michigan to disclose information on the chemical constituents they use in the state in a master list, prior to HVHF activities. This policy is similar to the policies in Arkansas and Illinois, but Option B would also require well operators to provide plain-language descriptions of the constituents (i.e., understandable by the lay public)[114] prior to HVHF activities. The information on constituents would be regularly updated as operators alter their use of chemical additives. The means of disclosure would be through a dedicated state website, in a map-based form that is easily accessible; importantly, the information would be tied to other information about the operator, such as permit applications, the permit, results of water quality tests, and enforcement history.

Operators would also be required to disclose the actual constituents used, with plain language descriptions, within thirty days after well completion. The information would be disclosed on the state website and through FracFocus, if it becomes fully searchable. This would enable experts and the lay public to assess chemical constituent use over time across the country.

In order to comply with the policies forming Option B, operators would have the ability to obtain trade secret protection with regard to the specific identity, CAS number, and concentration of a chemical constituent. Protection would, however, be very narrow; any such claim would be subject to review by the state, so as to limit the withholding of such information from the public. When needed for public health purposes, the information would be required to be disclosed.

Because full information is necessary for adaptive management, failure to disclose accurate chemical information would carry a maximum penalty of $1,000 per day of violation.

Information on well construction

Option B would, as with Option A, assist the state to refine its policies by collecting additional monitoring data on well pressures during HVHF. The data would be reported to the state within sixty days after well completion. If pressures during hydraulic fracturing indicate a lack of well integrity, Option B would require this information to be reported to the state immediately. The operator would be required to cease hydraulic fracturing, notify the state, and submit a corrective action plan. Unlike Option A, the well operator would also be required to immediately notify surrounding landowners of the problem and keep them informed of the status of the well. Information about the status of the well would be incorporated into the state website.

Information on water quality

At present, as noted above, Michigan does not require operators to test water quality. Option B would seek to address this by requiring ground and surface water monitoring of sources that could be contaminated by an oil or gas well, at regular intervals. This monitoring would be part of a larger effort to monitor the water quality of the aquifer and watershed in which HVHF is occurring. Accordingly, Option B goes further than Option A, which only requires baseline tests. Option B would require test results to be made available to the state and well owner within a short period of time, such as 10 days. The results would be posted on the state website. Option B would also require the operator to immediately notify the state and well owner of the presence of any contaminant of concern, including those listed in the proposed rule.

4.2.4.3 Option C: Information policy employing a precautionary approach

Option C would impose additional reporting obligations on the operator than currently exist at this time, but would limit public access to trade secret information. Under this suite of policies, the state and, in particular, the regulator, are the primary beneficiaries of the information. This would allow the state to adopt a more precautionary approach to managing HVHF activities within Michigan, including the management of human and/or ecological risks. While members of the public would have greater access to information on HVHF activities within Michigan than they do today, it would be less than that which would be made available to them under Options A and B.

<u>Information on chemical use</u>

Option C would require operators to submit a list of all chemical constituents for use as part of a permit application and disclose any relevant health and safety studies. As in the proposed rules considered by New York, operators would be required to conduct an alternatives analysis to demonstrate that the proposed chemicals pose a smaller risk than other feasible alternatives. Any change in constituents after the permit is issued would require additional approval by the state. After HVHF, operators would verify that the constituents used in the fluid were the same as those in the permit application.

As per Option B, operators would have the ability to file for trade secret protection in relation to the specific identity, CAS number, and concentration of a chemical constituent. The focus of the review process would be on providing data to experts. The operators would be required to submit the information claimed to be a trade secret to the state so that the state experts could have full data on chemical use prior to making a decision on the permit application.

As part of the permit application, the operator would be required to include a plain-language explanation of foreseeable potential human and/or ecological risks associated with the use of chemical constituents, and list the chemical alternatives. This information would be made publicly available via the state's website, in a map-based form that is easily accessible. The public would be provided with an opportunity to comment on the permit application, and object accordingly.

<u>Information on well construction</u>

Pursuant to Option C, operators would be required to conduct mechanical integrity tests of wells and to report the test data to the state prior to state approval of HVHF. If pressures during hydraulic fracturing indicate a lack of well integrity, Option C would require that this information be reported to the state immediately, and as in Option B, the operator would cease any HVHF activity. The operator would be obligated to notify the state, and submit a corrective action plan. Prior to recommencing HVHF, the operator would have the burden of demonstrating that the well's integrity is fully protective of the environment.

Information on water quality

Option C would require the permit applicant to conduct baseline tests to identify the existing quality of groundwater and surface waters around the well, with a specific focus on sources that provide drinking water or are ecologically sensitive. The applicant would be required to submit baseline test results to the state as part of its permit application and to immediately notify the state and the well owner of any contaminant of concern. The state would consider the current uses of water sources and the existing water quality in making its permitting decision. If the permit is approved, the operator would then be required to conduct regular long-term monitoring of the water sources and report the results within a short period of time to the state and the well owner. The operator would have a duty to immediately notify the state and the well owner of any indication of contamination, and would be required to submit a corrective action plan.

Table 4.5: Key strengths and weaknesses of information policy Option A (proposed rules) relative to current Michigan policy

			Option A (Proposed Rules)		
Policy Area	Policy Elements	Current Policy	Option A – Hypothetical Policy	Relative to Current Policy	
				Key Strength	Key Weakness
Chemical Use	Subject of disclosure	Hazardous constituents	All constituents	Increased transparency on chemicals used during HVHF can strengthen partnerships and trust, between industry and the public	Increased reporting requirements for industry
	Means of disclosure	MSDS on state website	Permit application; FracFocus	State has information on chemicals prior to HVHF. One place for public to access information on chemicals used during HVHF, as well as other information relevant to HVHF.	Other chemicals may be used by operators. FracFocus has limited search capabilities and its content may not be readily understood by the public
	Timing of disclosure	Within 60 days	Before HVHF and within 30 days after HVHF	State may impose permitting requirements related to chemicals. Better preparedness (e.g., strengthened infrastructure and response measures) through quicker release of information	Quicker reporting for industry
	Trade secret claim review	None	Statement of claim; must use family name or other description	Disclosure that there are trade secret chemicals being used can increase awareness and help public determine whether or not they want to challenge current trade secret protection	Name of trade secret chemical is not revealed
Well Construction	Pressure monitoring	Monitored, and reported, within 60 days	Monitored and reported immediately to state if problem; HVHF ceases until plan of action implemented	Supplementary administrative measures to ensure remedial action on poor well integrity can reduce potential public health and environmental risks	Increased action and reporting requirements for industry
	Mechanical integrity test	None	When monitoring indicates problem		Financial cost to industry for mechanical integrity tests
Water Quality	Water source	None	Groundwater	Baseline groundwater data can be used to compare with future monitoring data (should that occur) to determine whether or not contamination occurred and remedial action is needed; baseline data can be compared against water quality standards to judge whether or not current conditions pose unacceptable public and environmental risks	Lack of continued monitoring data
	Area around well		¼-mile radius around well		
	Number of sources tested		Up to 10		
	Frequency of testing		Once, >7 days but <6 months prior to drilling of new well or HVHF of existing well		

	Test results		Within 45 days; immediate notification of contaminants of concern; to state and owner		Increased reporting requirements for industry

Table 4.6: Key strengths and weaknesses of information policy Option B (adaptive approach) relative to current Michigan policy

			Option B (Adaptive Approach)		
				Relative to Current Policy	
Policy Area	Policy Elements	Current Policy	Option B – Hypothetical Policy	Key Strength	Key Weakness
Chemical Use	Subject of disclosure	Hazardous constituents	All constituents; plain-language description	Information on chemicals is communicated in a way that is understood by the lay public. This can facilitate awareness by all impacted parties regardless of their knowledge of HVHF	Increased reporting requirements for industry
	Means of disclosure	MSDS on state website	Master list; state website; FracFocus	State has information on chemicals prior to HVHF. Ensures that state has information in record with public accessibility	MSDSs are not on national websites (e.g., FracFocus)
	Timing of disclosure	Within 60 days	Before and within 30 days after HVHF	State may take action before HVHF. Better preparedness (e.g., strengthened infrastructure and response measures) through quicker release of information on chemicals	Quicker reporting requirements for industry
	Trade secret claim review	None	Narrow exception for trade secrets	Information on trade secret chemicals cannot be withheld for public health purposes, which can strengthen public health and environmental preparedness	Restricted intellectual property rights for industry
Well Construction	Pressure monitoring	Monitored and reported within 60 days	Monitored and reported immediately to state and nearby landowners if problem; status placed on website; HVHF ceases until plan of action implemented	Provides prompt information to state, owners, and public about poor well integrity	Increased action and reporting requirements for industry
	Mechanical integrity test	None	When monitoring indicates a problem		Financial cost to industry for mechanical integrity tests
Water Quality	Water source	None	Groundwater and surface water	Groundwater and surface water data can be used to determine whether or not contamination occurred and remedial action is necessary throughout use of HVHF well, based on comparison against water quality standards that are intended to protect the public and environment from unacceptable risks	Financial cost to industry for monitoring 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; immediate notification of contaminants of concern; to state, owner, and public (through website)		Increased reporting requirements for industry

Table 4.7: Key strengths and weaknesses of information policy Option C (precautionary approach) relative to current Michigan policy

Policy Area	Policy Elements	Current Policy	Option C (Precautionary Approach) Option C – Hypothetical Policy	Relative to Current Policy Key Strength	Key Weakness
Chemical Use	Subject of disclosure	Hazardous constituents	All constituents; plain-language description of risks and alternatives; studies	Full information on chemicals ensures states can monitor risk. Information is also communicated in a way that is understood by the lay public. This can facilitate awareness by all impacted parties regardless of their knowledge of HVHF	Increased reporting requirements for industry
	Means of disclosure	MSDS on state website	Permit application; state website	Information is provided so that state and public can review	Limits ability to respond to site conditions
	Timing of disclosure	Within 60 days	Before HVHF	State may take action before HVHF. Better preparedness (e.g., strengthened infrastructure and response measures) through earlier release of information on chemicals	Earlier reporting requirements for industry
	Trade secret claim review	None	Full information provided to state	Complete chemical disclosure permits state to better protect the public and environment via informed decision-making	Restricted intellectual property rights for industry
Well Construction	Pressure monitoring	Monitored and reported within 60 days	Monitored and reported immediately to state and nearby landowners if problem; HVHF ceases until operator demonstrates integrity	Integrity of well can be judged prior to HVHF and can reduce public health and environmental risks posed by HVHF operations	Increased action and reporting requirements for industry
	Mechanical integrity test	None	Prior to approval of HVHF; when monitoring indicates a problem		Financial cost to industry for mechanical integrity tests
Water Quality	Water source	None	Groundwater and surface water	Groundwater and surface water data can be used to determine whether or not contamination occurred and remedial action is necessary throughout use of HVHF well based on comparison against water quality standards that are intended to protect the public and environment from unacceptable risks	Financial cost to industry for monitoring groundwater and surface water
	Area around well		Based on characteristics of aquifer/watershed		
	Number of sources tested		Variable, based on importance of sources		
	Frequency of testing		Baseline test; long-term regular monitoring		
	Test results		Prior to approval of well and within 10 days; immediate notification of contaminants of concern; to state and owner		Increased reporting requirements for industry

As this section has illustrated, the provision of information regarding HVHF is fundamental to the decision-making process. This holds true in relation to decisions being made by experts within government in relation to trade secret reviews, or the public reporting of chemicals used in HVHF activities. That being said, even when the suite of policy tools is designed to specifically enhance transparency and reporting requirements for the public (as proposed in Option B), these policies require individuals to be proactive in seeking out such information. As such, while it can be said that the public may benefit at large, only those individuals who are interested and/or aware of sites such as FracFocus, and have the means to access such sites, will benefit from the policy. State regulators and experts are therefore the most likely beneficiaries of enhanced information polices for HVHF activities.

4.3 PRESCRIPTIVE POLICY

4.3.1 Introduction

The state has traditionally used prescriptive approaches-or 'command and control' regulation-as a mechanism to influence and shape behavior. Legislation, regulations and rules are all instruments available to government to influence actions and, as with activities such as HVHF, respond to scientific uncertainty. Compulsory in nature, prescriptive approaches are often perceived as creating greater regulatory certainty, enhancing accountability and creating a level playfield for actors when compared to no regulation (or, rather, no specific regulation and/or co-regulatory or self-regulatory approaches). Unlike information policy, states have not been uniform in their attention to prescriptive requirements that restrict or control aspects of hydraulic fracturing. As this section illustrates, legislation and regulation can lag behind technological advances. As such, the opportunity to craft a suite of prescriptive regulatory requirements tailored specifically for various activities associated with HVHF currently exist in Michigan, as well as a number of other states.

4.3.2 Range of approaches

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.

4.3.2.1 Restrictions on chemical use

Few of the states surveyed, including Michigan, specifically control chemical use beyond the disclosure requirements in permit applications or completion reports. Illinois prohibits the use of diesel.[115] New York is unique in having proposed state review and approval of chemicals before hydraulic fracturing operations may proceed. The operator would have been required to prove that "proposed chemical additives exhibit reduced aquatic toxicity and pose at least as low a potential risk to water resources and the environment as all known available alternatives," or that any alternatives would be economically unfeasible.[116] New York would also have limited the use of biocides to only those "registered for use in New York . . . for any operation at the well site."[117]

4.3.2.2 Limitations on siting

In contrast to direct regulation of chemical use, all of the surveyed states and Michigan have limitations on siting wells and associated facilities. Three states have adopted or proposed limitations specific to HVHF wells and facilities.[118] The Governor of New York recently announced that no HVHF wells will be sited in the state, after the state Department of Health determined that there were "significant uncertainties about the kinds of adverse health outcomes that may be associated with HVHF, the likelihood of the occurrence of adverse health outcomes, and the effectiveness of some of the mitigation measures in reducing or preventing environmental impacts which could adversely affect public health."[119]

The most common limitation on siting is a requirement that wells and associated facilities be sited away from surface waters. Of the eight states surveyed, six require or proposed to require setbacks from surface waters for oil or gas wells,[120] while two only require setbacks for facilities that store flowback or produced water.[121] Two states require setbacks specifically for wetlands.[122] The distances range from fifty feet in Ohio[123] to three hundred feet in most other states[124] to 2,000 feet proposed by New York for surface public water supplies.[125]

The second most common limitation is a setback from freshwater wells or springs that supply drinking water. Five of the surveyed states require or would have required setbacks from freshwater wells or springs, with distances ranging from fifty feet in Ohio to 2,000 feet in New York.[126] States often require public water supplies to be located further away than private water wells or springs. Illinois, for example, requires HVHF operators to adhere to a 500-foot setback from a water well or developed spring, but a 1,500-foot setback from the groundwater intake of a public water supply.[127]

Least common is a prohibition on the siting of wells and associated facilities within a certain protected area. New York's proposed policy would have expressly protected public lands by prohibiting surface disturbance from HVHF gas wells on state lands, including wildlife management areas, multiple use areas, natural resources management areas, fishing access sites, boat launch sites, hatcheries, game farms and tidal wetlands.[128] Other areas in which siting is prohibited by states include locations that would block natural drainages[129] and 100-year floodplains.[130] Texas prohibits off-site commercial fluid recycling facilities that store flowback in sensitive areas, such as those near surface waters and wetlands.[131]

Michigan requires operators to site all oil or gas wells 300 feet from existing recorded freshwater wells and reasonably identifiable freshwater wells utilized for human consumption.[132] Storage tanks, including those that contain flowback, must be sited 800 feet from small public water supply wells and 2,000 feet from larger public water supply wells.[133]

4.3.2.3 Controls on groundwater risks

To reduce the risk of groundwater contamination, the states focus primarily on the adequacy of well construction. Many states have detailed requirements governing the concentric steel piping known as “casing strings” and the use of cement to fill voids around casing. The purpose of these requirements is to create multiple barriers between substances in the well and the surrounding environment.

Of the states surveyed, all have updated or proposed to update their well construction requirements since HVHF began.[134] The states have adopted several different casing and cementing requirements. Operators may be required to use new casing,[135] reconditioned casing only if tested,[136] or casing that has a minimum pressure rating greater than the maximum pressure anticipated in hydraulic fracturing.[137] Operators may also be required to ensure a certain excess volume of cement,[138] a specific length of cemented casing,[139] or a minimum compressive strength of cement.[140] Michigan’s existing rules contain some of these requirements. All casing must have a minimum strength of 1.2 times the greatest expected wellbore pressure to be encountered.[141] The state must approve of the cement mixture composition and volume, and the cement must reach a minimum compressive strength.[142]

Less commonly, states may require an “area of review” analysis to address potential conduits of contamination around the wellbore. Illinois specifically requires operators to plug all “unplugged well bores within 750 feet of any part of the horizontal well bore that penetrated within 400 vertical feet of the formation that will be stimulated as part of the high volume horizontal hydraulic fracturing operations.”[143] New York’s proposed policy would have required the operator to identify abandoned wells within the spacing unit and one mile from the wellbore.[144] In Michigan, permitting staff conduct an area-of-review analysis for potential conduits within 1,320 feet of deep high volume hydraulically fractured wells.[145] If a conduit is identified, the operator must relocate the proposed well to another location, demonstrate that the hydraulic fracturing will not cause contamination of a fresh water aquifer, or take actions necessary to prevent the potential fluid movement.[146]

4.3.2.4 Controls on surface risks

To reduce the risk of surface contamination from spills, states have focused much of their policy attention on storage of flowback and produced water. The most common prescriptive requirements are specific construction standards and limitations on the length of time the wastewater can be stored. Pit construction standards include the thickness and number of liners and the height of “freeboard” between the top of the pit and the fluid.[147] Some states limit the storage of flowback in pits,[148] with durations that vary widely from seventy-two hours[149] to ninety days[150] to one year.[151] Illinois prohibits and New York proposed to prohibit the use of pits and instead require operators to use storage tanks.[152] The tanks must be water tight[153] and corrosion resistant,[154] with storage limited to 45 to 60 days.[155] Michigan currently prohibits “brine”—defined as “all nonpotable water resulting, obtained, or produced from the exploration, drilling, or production of oil or gas, or both”—from being placed in pits; instead, it must be stored in approved containers.[156]

Less common prescriptive requirements are secondary containment measures and other restrictions on handling of chemicals and flowback. Three of the surveyed states specifically require secondary containment systems for tanks that store flowback on the well site, and chemical additive storage or staging areas.[157] These containment systems can include “dikes, liners, pads, impoundments, curbs, sumps or other structures or equipment capable of containing the substance."[158] New York would also have required hydraulic fracturing additives to be removed from the site when the site is unattended, and vacuum trucks to be on standby at the well site during the pumping of hydraulic fracturing fluid and during flowback.[159] Michigan does not require secondary containment on well sites. As in most other states, secondary containment is required for storage tanks in separate surface facilities, including tanks that store flowback.[160]

4.3.3 Policy approaches

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 flexible 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.

Most states have adopted a combination of approaches in their prescriptive policy. States have adopted a precautionary approach by requiring oil and gas wells to be sited away from natural resources that could be damaged by contamination. States have used both precautionary and adaptive approaches in their well construction programs and surface controls on flowback and chemical additives; these policies seek to prevent contamination but also can be altered to respond to new information about HVHF. Finally, some states use the remedial approach of secondary containment measures that would hold fluid in the event of a spill on site.

One state, New York, has taken the most stringent precautionary approach by banning HVHF. The state's proposed policies, while allowing HVHF, also focused on prevention of harm. The policies would have shifted the burden of uncertainty to well operators, requiring them to come forward with information about the toxicity of chemical additives; included significant setback requirements and prohibitions on siting in certain areas; addressed potential conduits of contamination in addition to well construction; and protected well sites from spills through closed-loop systems and removal of chemical additives from the site when unattended.

Like most states, Michigan has adopted all three approaches. Michigan's well integrity requirements and surface controls are primarily adaptive, made more flexible by the discretion given to permitting staff to set conditions for well construction and surface pad construction under state rules. Yet Michigan also uses both a precautionary approach in its area-of-review analysis and in requiring tanks for flowback, and a remedial approach in mandating secondary containment measures for storage tank areas. Finally, Michigan has adopted precautionary setback requirements for groundwater drinking sources.

4.3.4 Analysis of policy options

Questions, and concerns, regarding scientific uncertainty and associated risks are likely to be central to the state's choice of policies on HVHF activities and chemical use moving forward. As section 3.3 illustrates, the policy options available to the state may reflect the current status quo, be adaptive and responsive to changing information, or take a more precautionary approach than that which is currently the policy in Michigan. However, as evidenced by the experiences of other states, it is most likely that any prescriptive policies adopted by Michigan in relation to

HVHF activities in the future will involve multiple approaches. Certain policy areas may, for example, be more precautionary in nature due to actual and/or perceived uncertainties and greater levels of concern regarding, for example, human and/or ecological risks. Others may be more adaptive in nature, with the ability to respond quickly to the evolving state of the science and/or public pressure. As with those policies dealing with information provision, in the following section, policy tools are set out in the context of a suite of policy tools; each suite focuses on, and addresses, a particular overarching goal that the state may have.

Table 4.8: Summary of prescriptive policy options for Michigan

Policy Area	Policy Elements	Current Policy		Option A (Proposed Rules)	Option B (Adaptive Approach)	Option C (Precautionary Approach)
Restrictions on Chemical Use		None		None	List of prohibited chemicals, amended over time	Approval of chemicals only if reduced toxicity
Limitations on Siting	Object of siting	Oil or gas well	Storage tanks at surface facility	No change	Oil or gas well site; storage tanks	All related facilities
	Resource protected	Freshwater wells	Public water supply wells	No change	Sensitive features	All potentially affected water resources
	Distance	300 feet	800-2000 feet	No change	Change over time based on new findings/best practices	Larger setback; protected areas
Controls on Groundwater Risks	Well construction requirements	Casing and cementing requirements		No change	Change over time based on new findings/best practices	Strict requirements for several levels of safety
	Area of review analysis	Wells within 1320 feet; must relocate well, demonstrate no contamination, or take other actions		No change	Within area affected by HVHF; corrective action or monitoring of conduits	Within area affected by HVHF; relocate well unless no risk from conduits
Controls on Surface Risks	Flowback and chemical additives	"Brine" (including flowback) stored in tanks		Clarification that flowback stored in tanks	Flowback stored in tanks; monitor well site for leaks and spills	Closed loop system for chemical additives, flowback; additive handling requirements
	Secondary containment	Storage tanks at surface facility		No change	Storage tanks at well site and surface facility	Entire well site and surface facility

4.3.4.1 Option A: Michigan's proposed rules

The proposed rules do not change Michigan's current prescriptive policies other than to clarify that flowback is to be stored in tanks, and thus do not alter the state's combination of approaches to uncertainty.

4.3.4.2 Option B: Prescriptive policy that focuses the regulatory program on reducing potential adverse human health impacts and ecological risks through an adaptive approach.

Option B is focused on reducing potential risk to humans and the surrounding ecology through explicit and comprehensive regulatory requirements. The suite of policy tools crafted under Option B provides the state with an adaptive approach to managing potential human and ecological risks in the short and long term. Policy makers may be inclined to adopt this suite of policy tools if additional information and experience will address potential risks.

<u>Restrictions on chemical use</u>

At present, Michigan does not place any restrictions on operators in relation to the types of chemicals used in HVHF activities. Option B would seek to specifically control, and limit, the use of certain chemicals by well operators. The state would have the regulatory authority to prohibit the use of chemicals that exhibit particularly high risk due to their toxicological characteristics (e.g., chemicals that are acutely toxic to organisms in small quantities). The use of diesel would be prohibited outright. As more is known about the risks of specific chemical additives, the state could add or remove chemicals from the prohibited list.

<u>Limitations on siting</u>

Option B would require operators to site HVHF well sites and tanks that store flowback away from sensitive ecological resources, not only fresh water supplies as in Michigan's existing policy. The setback distance would be determined by identifying the risks to the particular resource, and limits could be amended over time in order to take into account new scientific findings, and/or changes to best practice guidance.

<u>Controls on groundwater risks</u>

Option B would utilize existing well construction requirements. The requirements would be reviewed, and adapted, by the state every three years as a way to ensure that best practice continues to be followed. Option B would also utilize an area-of-review analysis to identify potential conduits, but rather than use a set distance, the area of review would be individually determined for each well depending on the length of the horizontal leg and the characteristics of the surrounding area. The operator would be required to address conduits that pose the greatest risk of fluid movement, such as plugging the nearest abandoned wells, and monitor the rest.

<u>Controls on surface risks</u>

As with groundwater risks, Option B would utilize Michigan's existing surface controls by requiring operators to place flowback in tanks and use secondary containment for storage tanks at surface facilities. But Option B would go further and address the risk of spills at the well site by requiring operators to use secondary containment measures for temporary storage tanks and to monitor the site for other spills, such as could occur during the handling of chemical additives.

4.3.4.3 Option C: Prescriptive policy that focuses the regulatory program on precautionary measures.

Option C adopts a precautionary approach to managing HVHF activities. Each component is designed to limit human and environmental exposure to chemicals used in HVHF activities.

<u>Restrictions on chemical use</u>

Option C would adopt the precautionary approach proposed by New York in its regulations. The state would review and approve all chemicals prior to the commencement of HVHF activities; approval of each chemical would be dependent on the operator demonstrating in its application that the chemical poses "at least as low a potential risk to water resources and the environment as all known available alternatives." Option C would therefore represent a significant shift in policy from that which currently exists in Michigan.

<u>Limitations on siting</u>

The current Michigan approach requires an operator to site all oil or gas wells at least 300 feet from freshwater wells that have been recorded, or are reasonably identifiable. Option C would require that all facilities associated with oil and gas wells—including well sites, surface facilities, and pipelines—be set back a greater distance from groundwater wells and surface features. Operators would also be prohibited from siting a well in locations that are particularly important to the public or the environment, such as water supply areas, state parks, or wilderness areas, or that would result in greater risk of contamination, such as floodplains.

<u>Controls on groundwater risks</u>

Option C would require the state to continue to use, and enforce, detailed requirements for all facets of well construction, including requirements relating to casing and cementing. These requirements could be stricter than those set out in the current policy, and include, for example, standards used for disposal wells. Under this option, should an area of review analysis identify potential conduits of contamination around the wellbore, the operator would be required to relocate the proposed well to another location.

<u>Controls on surface risks</u>

Under Option C, operators would use a closed-loop system for HVHF, which would not only prohibit temporary storage of flowback in an on-site pit, but would require all fluids to be transferred through piping to water-tight tanks. Operators would also employ secondary containment measures at the well site to protect the environment from spills and leaks. In addition, this option would take a preventative approach by requiring removal of hydraulic fracturing additives from the site when the site is not attended.

Table 4.9: Key strengths and weaknesses of prescriptive policy Option A (proposed rules) relative to current Michigan policy

Policy Area	Policy Elements	Current Policy		Option A (Proposed Rules)		
				Option A – Hypothetical Policy	Relative to Current Policy	
					Key Strength	Key Weakness
Restrictions on Chemical Use		None		None	None	None
Limitations on Siting	Object of siting	Oil or gas well	Storage tanks at surface facility	No change		
	Resource protected	Freshwater wells	Public water supply wells	No change		
	Distance	300 feet	800-2000 feet	No change		
Controls on Groundwater Risks	Well construction requirements	Casing and cementing requirements		No change	None	None
	Area of review analysis	Wells within 1320 feet; must relocate well, demonstrate no contamination, or take other actions		No change		
Controls on Surface Risks	Flowback and chemical additives	"Brine" (including flowback) stored in tanks		Clarification that flowback stored in tanks	None	None
	Secondary containment	Storage tanks at surface facility		No change	None	None

Table 4.10: Key strengths and weaknesses of prescriptive policy Option B (adaptive approach) relative to current Michigan policy

Policy Area	Policy Elements	Current Policy		Option B (Adaptive Approach): Option B – Hypothetical Policy	Relative to Current Policy: Key Strength	Relative to Current Policy: Key Weakness
Restrictions on Chemical Use		None		List of prohibited chemicals, amended over time	Reduce risks posed by chemicals to the public and environment. This may be more effective than other measures (e.g., engineering or administrative controls), which are subject to error.	Financial costs to industry for modifying operations to function without the use of certain chemicals
Limitations on Siting	Object of siting	Oil or gas well	Storage tanks at surface facility	Oil or gas well site; storage tanks	None	Over time may limit siting possibilities
	Resource protected	Freshwater wells	Public water supply wells	Sensitive features	Added flexibility to modify siting requirements based on the feature, state of scientific opinion, and public views	
	Distance	300 feet	800-2000 feet	Change over time based on new findings/best practices		
Controls on Groundwater Risks	Well construction requirements	Casing and cementing requirements		Change over time based on new findings/best practices	Data can be used to mitigate public health and environment risks that arise due to poor integrity	Financial cost to industry for changes in construction standards
	Area of review analysis	Wells within 1320 feet; must relocate well, demonstrate no contamination, or take other actions		Within area affected by HVHF; corrective action or monitoring of conduits	Increases area of analysis to include all potentially affected areas	Greater costs to industry
Controls on Surface Risks	Flowback and chemical additives	"Brine" stored in tanks		Flowback stored in tanks; monitor well site for leaks and spills	Decreased likelihood for contact of chemicals with the neighboring human and ecological communities	Financial cost to industry for modifying operations
	Secondary containment	Storage tanks at surface facility		Storage tanks at well site and surface facility	Added physical measures to prevent the leakage of HVHF chemicals into the surrounding environment	

Table 4.11: Key strengths and weaknesses of prescriptive policy Option C (precautionary approach) relative to current Michigan policy

Policy Area	Policy Elements	Current Policy		Option C (Precautionary Approach) Option C – Hypothetical Policy	Relative to Current Policy Key Strength	Key Weakness
Restrictions on Chemical Use		None		Approval of chemicals only if reduced toxicity	Ability to restrict the use of chemicals to reduce or eliminate public health and environmental risks	Financial costs to industry for modifying operations to function without the use of certain chemicals
Limitations on Siting	Object of siting	Oil or gas well	Storage tanks at surface facility	All related facilities	Ensures that risks of all facilities are considered	Over time may limit siting possibilities
	Resource protected	Freshwater wells	Public water supply wells	All potentially affected water resources	Additional distance buffer will further minimize the potential impact of HVHF activities on nearby water sources and sensitive areas	Decreased access to natural gas reservoirs for industry and other interested parties
	Distance	300 feet	800-2000 feet	Larger setback; protected areas		
Controls on Groundwater Risks	Well construction requirements	Casing and cementing requirements		Strict requirements for several levels of safety	Conservative approach to well construction and conduits generates additional confidence that nearby groundwater will be protected from potential contamination associated with poor well integrity	Financial cost to industry for complying with conservative well construction conditions
	Area of review analysis	Wells within 1320 feet; must relocate well, demonstrate no contamination, or take other actions		Within area affected by HVHF; relocate well unless no risk from conduits		
Controls on Surface Risks	Flowback and chemical additives	"Brine" stored in tanks		Closed loop system for chemical additives, flowback; additive handling requirements	Decreased likelihood for contact of chemicals with the neighboring human and ecological communities	Financial cost to industry for modifying operations
	Secondary containment	Storage tanks at surface facility		Entire well site and surface facility	Added physical measures to prevent the leakage of HVHF chemicals into the surrounding environment	

The prescriptive policy options discussed in this section focus on restricting and/or limiting the use of chemicals in HVHF activities, the siting of wells and associated facilities, and controlling potential risks to water. As section 3.4 highlights, the prescriptive policies available to the state are, for the most part, highly technical in nature. This means that compliance with any such policy is dependent not only on the actions of the well operator, but also on the state to actively inspect, and enforce, the specific policy. Transparent monitoring and enforcement activities may have the additional benefit of promoting accountability between the relevant stakeholders. Such accountability mechanisms should be a fundamental facet of the prescriptive policies adopted by the state for HVHF activities.

4.4 RESPONSE POLICY

4.4.1 Introduction

Spills, or accidental release, of chemicals used in HVHF activities, and the implications of exposure to these chemicals on humans and the environment, have engendered significant debate and concern among stakeholders and the public generally. Such concern has been, arguably, fueled by a lack of comprehensive policies addressing emergency planning for dealing with chemical discharge, liability for contamination, and public transparency. As with all other facets of HVHF activities, the state has the ability to introduce policies specifically tailored to address emergency planning, and operator response, in the event that spills and/or release occur.

4.4.2 Range of approaches

State spill response policies primarily focus on three areas:

(1) Planning for emergencies;
(2) Cleanup of spills and releases; and
(3) Imposing liability for contamination.

4.4.2.1 Emergency planning

Only three of the surveyed states require or have proposed to require well operators to create emergency response plans or programs.[161] New York's proposed policy included both an emergency response plan[162] and a specific surface spill prevention plan,[163] and required the operator to notify the county emergency management office of the well location.[164] Pennsylvania mandates an emergency response plan for "emergencies that threaten human health and safety for each well site."[165] Colorado requires operators to implement "an emergency spill response program that includes employee training, safety, and maintenance provisions and current contact information for downstream Public Water System(s) located within fifteen stream miles" of well operations.[166] In Michigan, operators of hydrogen sulfide wells must create emergency response plans, but not operators of other types of wells, such as HVHF wells.[167]

4.4.2.2 Cleanup of spills and releases

All of the surveyed states require well operators to notify the state of at least some spills and releases, most commonly within 24 hours.[168] Illinois[169] and Colorado[170] specifically require notification when there has been release of fluid or flowback greater than one barrel, or forty-two gallons. Arkansas requires notification only when a spill escapes from the containment dike.[171] Other states have more general requirements. North Dakota requires verbal and online notification whenever the operator becomes aware of "any fire, leak, spill, blowout, or release of fluid,"[172] while Pennsylvania and Texas require notification when there is reason to believe a spill or discharge has contaminated nearby water resources.[173] Illinois[174] and Pennsylvania[175] provide a process for private parties to notify the state if they have reason to believe contamination from hydraulic fracturing operations has occurred. Both of the states also require the state to notify the public of spills or contamination through a website.[176]

Michigan requires operators to report losses or spills of chemical additives and "brine," which includes flowback, within eight hours of discovery.[177] Operators must also submit a written report within ten days.[178] Operators need not notify the state within eight hours if a spill of less than forty-two gallons of flowback occurs; the flowback does not contact surface waters, groundwater, or other environmentally sensitive resources; and the spill is completely contained and cleaned up within forty-eight hours of discovery.[179]

Few of the states provide detailed cleanup standards. Michigan generally requires that operators clean up and dispose of losses of oil, gas, or brine from wells, flow lines, and associated surface facilities "in a manner consistent" with state and federal laws and regulations.[180] There is no provision in the state's oil and gas laws that specifies a cleanup standard for chemical contamination of water supplies.[181]

To ensure that operators remediate the site, states require firms to post a bond prior to drilling a well. These bonds usually take the form of low-risk securities (such as certificates of deposit or treasury securities), and they may only be recovered by the firm (with interest) after production is completed and the site is remediated. For small firms that cannot post the required minimum bond amount, states typically allow surety bonds, where an insurance company guarantees the firm's environmental performance.

There exists considerable variation across the surveyed states in bonding and insurance requirements. The lowest required per-well bond amount is $5,000, in Ohio.[182] At the other extreme is New York, which requires a bond amount up to $250,000 for wells deeper than 6,000 feet.[183] Most states also have a blanket bond policy in which a single bond can cover many wells at once, thereby reducing the per-well bond amount. In Ohio, a single blanket bond for $15,000 can cover all of a firm's wells in the state,[184] while New York does not require financial insurance beyond $2,000,000.[185] None of these states indexes the required bond amounts to inflation or some other measure of remediation costs.

Michigan currently requires a bond of $10,000/well for wells less than 2,000 feet deep, $20,000/well for wells between 2,000 and 4,000 feet deep, $25,000/well for wells between 4,000 and 7,500 feet deep, and $30,000/well for wells deeper than 7,500 feet.[186] Michigan also permits blanket bonds. Up to 100 wells less than 2,000 feet deep may be covered by a $100,000 bond.[187] Up to 100 wells between 2,000 and 4,000 feet deep may be covered by a $200,000 bond.[188] And an unlimited number of wells greater than 4,000 feet deep may be covered by a $250,000 bond.[189] These obligations may be fulfilled by surety bonds.[190]

Even the largest bonding amounts required by state law are insufficient to cover damages caused by a catastrophic release, which can amount to millions of dollars. Some states therefore require firms to carry liability insurance in addition to posting a bond. This insurance helps to shield taxpayers from remediation costs. As with surety bonds, insurers can experience rate premiums for liability insurance products. Only Colorado, Illinois, and Ohio require liability insurance: Colorado requires a $1,000,000 policy,[191] Illinois requires $5,000,000,[192] and Ohio requires $1,000,000 for rural wells, $3,000,000 for urban vertical wells, and $5,000,000 for urban horizontal wells.[193] Michigan does not require such insurance.

4.4.2.3 Liability for contamination

At common law, oil or gas well operators are required to compensate surface property owners for damages from spills only if the damage is negligently or intentionally caused and is not reasonably necessary for mineral production. Some states have "Surface Damage Acts" that hold operators liable for certain damages. North Dakota expressly requires an operator to compensate a surface owner for loss of agricultural production.[194] Arkansas requires the operator to pay compensation for damaging "real property, growing crops, trees, shrubs, fences, roads, structures, improvements, livestock, personal property or measurable damage to the productive capacity of the soil."[195] Michigan does not have any specific surface damage requirements.

In court, a private property owner generally has the burden to demonstrate that an oil or gas well operator is the source of contamination causing the owner harm. Three of the eight surveyed states shift the burden by imposing a presumption of liability on the operator for ground water contamination within a certain radius from the well site.[196] Pennsylvania presumes an operator is liable if the contaminated water supply is within 2,500 feet of the well or the contamination occurred within twelve months of the well's completion.[197] Ohio limits its rebuttable presumption to within a quarter mile of the well,[198] and Illinois limits its rebuttable presumption to a radius of 1,500 feet, a temporal requirement that the contamination occurred within 30 months of completing the well, and a showing, by water quality data, of a lack of pollution prior to the well activity.[199] Of these three states, two allow well operators to rebut the presumption if the operator can demonstrate that the contamination already existed or is from another source.[200] Some require the operator to replace a contaminated water supply or compensate the owner.[201] Illinois has the strictest standards, requiring the owner to restore the water supply to pre-drilling conditions.[202] There is no presumption of liability in Michigan.

4.4.3 Policy approaches

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.

Most states, including Michigan, have adopted a remedial approach. The primary response policy is to require oil or gas well operators to promptly report incidents and remediate the site. Bonds ensure that the state can recover at least some costs if an operator refuses or is not able to pay for remediation. In some of the states, operators are also liable to private surface owners for damage to the surface environment, including damage from spills and releases. While Michigan does not have a statute on surface damages, operators are liable under common law.

Three states have chosen to require emergency response planning, an adaptive measure that can be changed over time as states and well operators learn more about responding to incidents. A few states, notably Illinois and New York, have adopted or proposed a precautionary approach to ensure that operators take particular care. Precautionary measures include a high bond amount, mandatory liability insurance, and a presumption of liability for groundwater contamination.

4.4.4 Policy options

As illustrated by the range of approaches that have been adopted by states in relation to spills and/or the accidental release of chemicals used in HVHF activities, the policy options available to the state include both proactive approaches to managing any such release and the potential risks thereof (i.e., by requiring a formal emergency response plan or program), or through more reactive responses including the imposition of liability on the operator. As this section seeks to illustrate, these policy options are not mutually exclusive; the state may, should it wish, require an operator to have such a plan in place, clean up a site to a specified level, and be held liable for any contamination associated with the spill or release. To date however, as section 4.2 highlights, states have been reluctant to hold operators to such a high level of accountability and care. Accordingly, the suite of policy options articulated below include continuation of the status quo, through to a suite of policy tools that would draw heavily on a precautionary approach to preventing and managing any such releases.

Table 4.12: Summary of planning, response and liability policy options

Policy Area	Policy Elements	Current Policy	Option A (Proposed Rules)	Option B (Adaptive Approach)	Option C (Precautionary Approach)
Emergency Planning	Emergency response plan	Hydrogen sulfide wells	No change	HVHF wells in sensitive areas; adapt plans over time	All HVHF wells
Cleanup of Spills and Releases	Notification	All losses or spills of chemical additives and “brine,” which includes flowback; larger spills within 8 hours; to state	No change	All losses or spills; larger spills reported immediately; to state and public	Immediate reporting of all losses or spills to state and public
	Standard	Not specified; other cleanup standards could apply	No change	Remediation and long-term monitoring	Restoration of environment
	Bonds and insurance	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	No change	Eliminate blanket bonds	Increase individual well bond to $250,000; liability insurance
Liability for Contamination	Type of contamination	Losses and spills of brine, which includes flowback	No change	Spills of chemical additives and flowback into groundwater	All spills of chemical additives and flowback
	Presumption	None	No change	For liability if do not monitor environment around well	Strict, joint and several liability
	Remedy	Clean up	No change	Remediation and long-term monitoring	Restoration of environment

4.4.4.1 Option A: Michigan's proposed rules

The proposed rules do not change Michigan's current policies, and thus do not alter the state's remedial approach to uncertainty.

4.4.4.2 Option B: Response policy that focuses on protecting the environment from spills by employing an adaptive approach

This suite of policy tools draws upon an adaptive approach, in that it requires the state to collect information from well operators, and apply this knowledge in a way that allows the state and operators to best manage the potential ecological impact of HVHF activities. In doing so, the state has the opportunity to address the public's concern about HVHF in a transparent way, while also displaying leadership on a range of ecological issues relating to planning, response, and liability policies.

<u>Emergency Planning</u>

Pursuant to Option B, operators of HVHF wells in sensitive areas–not just hydrogen sulfide wells–would be required to create emergency response plans. The policy would be similar to that of New York, in that operators would be required to have an emergency response plan and a specific surface spill prevention plan, so as to ensure protection of ground and surface water. As part of these plans, the state would require operators to include employee training, safety and maintenance provisions. Operators would be required to lodge these plans with the state within a short period of time after permit issuance.

The state would retain the power to change the planning areas and criteria over time, as more is known about effective responses to spills at HVHF sites. Because accurate information is critical to adaptive management, failure to comply with these requirements would result in a fine of $1,000 per day.

<u>Cleanup of Spills and Releases</u>

Option B would retain the requirement that operators report losses or spills of chemical additives and flowback to the state. Operators would also be required to immediately notify the state and the public of any large spills. In the event of a release and/or spill, the well operator would be required to cleanup and dispose of the contamination. Large spills would require not only remediation, but long-term monitoring of the site. The operator would submit a comprehensive report of the event, including the nature of the event, the chemicals involved, and the cleanup activities, to the state within 10 business days. This information would be displayed on a state website together with other information about the operator. In recognition of the insufficient nature of current bonding arrangements, Option B would also eliminate blanket bonds to ensure adequate funds for cleanup.

<u>Liability for Contamination</u>

A presumption of liability on the operator for groundwater contamination would be one of the policies adopted as part of Option B. If the operator cannot rebut the presumption by demonstrating that the groundwater surrounding the well was already contaminated, then the operator would be required to clean up the contamination and compensate the surface owner (or other relevant party) for losses sustained.

4.4.4.3 Option C: Response policy that adopts a precautionary approach in order to minimize the risk of spills

Option C is designed to incorporate a range of precautionary practices for all HVHF activities as a way to reduce spills and releases. Financial penalties are incorporated into Option C as a means of incentivizing well operators.

Emergency Planning

Under Option C, Michigan would require operators of all HVHF wells to create emergency response plans. The requirements would be similar to those of Option B; however, certification of training would be required, and the state would have the ability to audit operators in relation to their access to response equipment. Operators would also be required to submit the plans to the state prior to HVHF, so that the state and public could determine whether the procedures and equipment were fully protective.

Cleanup of Spills and Releases

At present, operators in Michigan are required to report losses or spills within eight hours of discovery. Option C would require the immediate notification and reporting of losses and/or spills of greater than one gallon by the operator; this would apply to any chemical used in HVHF activities, as well as chemicals in solution, diluted or concentrated form. In addition to cleaning up and disposing of the contamination, operators would be required to restore the environment to its state ‘but for’ the spill. By this we mean full restoration of the environment prior to the losses/spill. Option C would also revise the current bonding requirements by increasing the individual bond of a HVHF operator from $30,000 to $250,000 per well and requiring the operator to carry a liability insurance policy of $1,000,000.

Liability for Contamination

As part of Option C, the HVHF operator would be held strictly and jointly and severally liable for contamination caused by losses or spills of chemical additives and flowback. This liability would extend to non-water resources and may include, for example, agricultural production and personal property. The operator would be required to restore the environment in accordance with clear restoration standards, and compensate the surface owner (or other relevant party) for losses sustained.

Table 4.13: Key strengths and weaknesses of response policy Option A (proposed rules) relative to current Michigan policy

Policy Area	Policy Elements	Current Policy	Option A (Proposed Rules)		
			Option A – Hypothetical Policy	Relative to Current Policy	
				Key strength	Key Weakness
Emergency Planning	Emergency response plan	Hydrogen sulfide wells	No change	None	None
Cleanup of Spills and Releases	Notification	All losses or spills of chemical additives and "brine," which includes flowback; larger spills within 8 hours; to state	No change	None	None
	Standard	Not specified; other cleanup standards could apply	No change		
	Bonds and insurance	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	No change		
Liability for Contamination	Type of contamination	Losses and spills of brine, which includes flowback	No change	None	None
	Presumption	None	No change		
	Remedy	Clean up	No change		

Table 4.14: Key strengths and weaknesses of response policy Option B (adaptive approach) relative to current Michigan policy

Policy Area	Policy Elements	Current Policy	Option B (Adaptive Approach)		
			Option B – Hypothetical Policy	Relative to Current Policy	
				Key strength	Key Weakness
Emergency Planning	Emergency response plan	Hydrogen sulfide wells	HVHF wells in sensitive areas; adapt plans over time	Emphasis is placed on wells near at-risk environmental features (e.g., ground and surface water), not just wells for H_2S	Potentially a greater number of operators would be required to comply, resulting in increased financial costs across industry
Cleanup of Spills and Releases	Notification	All losses or spills of chemical additives and “brine,” which includes flowback; larger spills within 8 hours; to state	All losses or spills; larger spills reported immediately; to state and public	Quicker action can be taken due to quicker reporting of spills, which increases the chances for containing spills that pose serious public health and/or environmental risks	Increased financial cost to industry for conservative reporting requirements
	Standard	Not specified; other cleanup standards could apply	Remediation and long-term monitoring	Cleanup and monitoring of large spills	Compliance costs
	Bonds and insurance	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	Eliminate blanket bonds	Encourages industry to be environmentally proactive during HVHF activities	May adversely impact smaller firms, potentially weakening competition for leases
Liability for Contamination	Type of contamination	Losses and spills of brine, which includes flowback	Spills of chemical additives and flowback into groundwater	Mirrors public concern for chemicals that are used during HVHF activities	Does not address all contamination
	Presumption	None	For liability if do not monitor environment around well	Encourages industry to monitor the impact of their activities on the environment	Financial cost to industry to monitor the surrounding environment
	Remedy	Clean up	Remediation and long-term monitoring	Cleanup and monitoring of large spills	Compliance costs

Table 4.15: Key strengths and weaknesses of response policy Option C (precautionary approach) relative to current Michigan policy

			Option C (Precautionary Approach)		
			Option C – Hypothetical Policy	Relative to Current Policy	
Policy Area	Policy Elements	Current Policy		Key strength	Key Weakness
Emergency Planning	Emergency response plan	Hydrogen sulfide wells	All HVHF wells	Emphasis is placed on all types of wells not just wells for H_2S, irrespective of their distance to at-risk features (e.g., ground and surface water)	Potentially a greater number of operators would be required to comply, resulting in increased financial costs across industry
Cleanup of Spills and Releases	Notification	All losses or spills of chemical additives and "brine," which includes flowback; larger spills within 8 hours; to state	Immediate reporting of all losses or spills to state and public	Quicker action can be taken due to quicker reporting of spills, which increases the chances for containing spills that pose serious public health and/or environmental risks	Increased financial cost to industry for conservative reporting requirements
	Standard	Not specified; other cleanup standards could apply	Restoration of environment	Standardized restoration criteria	None
	Bonds and insurance	$30,000 for individual HVHF deep wells; blanket bond of $250,000; no liability insurance	Increase individual well bond to $250,000; liability insurance	Encourages industry to be environmentally proactive during HVHF activities	May adversely impact smaller firms, potentially weakening competition for leases
Liability for Contamination	Type of contamination	Losses and spills of brine, which includes flowback	All spills of chemical additives and flowback	Concern for chemicals that are both used on the surface and return to the surface during HVHF activities	None
	Presumption	None	Strict, joint and several liability	Encourages industry to be environmentally proactive during HVHF activities	Financial cost to industry to monitor the environment, and for defense activities (e.g., legal assistance) should claims be brought
	Remedy	Clean up	Restoration of environment	Standardized restoration criteria	None

To date, Michigan's policies on spills and/or the accidental release of chemicals used in HFHV has, in our view, been reactive. As this section illustrates, this approach, which is characterized by a focus on remedial actions, is common across the states surveyed in this report. However, other policy options are available to the state. The state may incorporate, for example, a more proactive approach to managing not only the release of such chemicals, but also the potential human and ecological risks associated with any such release. The adoption of a more adaptive or precautionary approach to response policy would involve a significant shift in Michigan. The costs of these approaches should be weighed against the potential benefits to the public, and the state more generally, with the adoption of a more comprehensive response policy.

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[21] In the Rio Declaration of 1992, the precautionary principle is stated as follows: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." U.N. Conference on Environment & Development (UNCED), June 3-14, 1992, Rio Declaration on Environment and Development, Principle 15, U.N. Doc. A/CONF.151/26 (Aug. 12, 1992).
[22] For example, the Final Declaration of the European Seas at Risk Conference states, "If the 'worst case scenario' for a certain activity is serious enough, then even a small amount of doubt as to safety of that activity is sufficient to stop it taking place." Seas at Risk, The Final Declaration of the First European "Seas At Risk" Conference, Annex 1 (1994).
[23] One scholar describes adaptive management as "an iterative, incremental decisionmaking process built around a continuous process of monitoring the effects of decisions and adjusting decisions accordingly." J.B. Ruhl, *Regulation by Adaptive Management-Is It Possible?*, 7 MINN. J.L. SCI. & TECH. 21, 28 (2005).
[24] In environmental policy, the remedial approach is best typified by the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund Act, and the Oil Pollution Act. Both have detailed liability and restoration requirements. In addition, the Oil Pollution Act governs emergency planning and response.
[25] These states are: Alabama, Alaska, Arkansas, California, Colorado, Idaho, Illinois, Indiana, Kansas, Louisiana, Michigan, Mississippi, Montana, Nebraska, Nevada, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Pennsylvania, South Dakota, Tennessee, Texas, Utah, West Virginia, and Wyoming.
[26] New York has a moratorium on high-volume hydraulic fracturing, and Vermont has banned the practice.
[27] These states are: Florida, Maryland, and Virginia.
[28] The definition of "high volume hydraulic fracturing" differs by state, and some states do not use this term. However, the authors believe this comparison is still valuable because the policies are similar across these states.
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[47] In 2002, Alabama adopted a chemical disclosure policy for hydraulic fracturing fluids used in coal-bed methane wells. Ala. Admin. Code r. 400-3-8-.03 (2002). This early policy, a response to federal court decisions requiring the state to regulate hydraulic fracturing as part of its delegated program under the federal Safe Drinking Water Act, is less specific than more recent ones. *See* Legal Envtl. Assistance Found., Inc. v. U.S. Envtl. Prot. Agency, 118 F.3d 1467 (11th Cir. 1997); Legal Envtl. Assistance Found., Inc. v. U.S. Envtl. Prot. Agency, 276 F.3d 1253 (11th Cir. 2001).

[48] American Petroleum Institute, Practices for Mitigating Surface Impacts Associated with Hydraulic Fracturing 7-8 (2011).

[49] Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:205A (CAS only required if applicable); 225 Ill. Comp. Stat. 732/1-35, 1-75 (same); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.3, 560.5); N.D. Admin. Code 43-02-03-27.1 (requiring operator to post "all elements made viewable by the fracfocus website," which includes the CAS number in its reports); Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. §§ 3203, 3222.1 (requiring operator to complete and post a chemical disclosure form on the FracFocus website, which includes the CAS number in its reports); 25 Pa. Code § 78.122; 16 Tex. Admin. Code § 3.29 (CAS only required if applicable).

[50] *See* Ark. Code R. § 178.00.1-B-19 (actual concentration of each additive); Colo. Code Regs. § 404-1:205A (maximum concentration of each chemical); 225 Ill. Comp. Stat. 732/1-35, -75 (anticipated and actual concentration of each chemical); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.3, 560.5) (proposed concentration of each additive and chemical, actual or maximum concentration of each chemical); N.D. Admin. Code 43-02-03-27.1 (requiring operator to post "all elements made viewable by the fracfocus website," which includes the maximum concentration of each chemical in its reports); Ohio Rev. Code Ann. § 1509.10 (maximum concentration of each chemical and additive used); 58 Pa. Cons. Stat. § 3222.1 (requiring operator to complete and post a chemical disclosure form on the FracFocus website, which includes the maximum concentration of each chemical in its reports); 25 Pa. Code § 78.122 (percent by volume of each additive and each chemical); 16 Tex. Admin. Code § 3.29 (the actual or maximum concentration of each chemical ingredient).

[51] *See* Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:205A; 225 Ill. Comp. Stat. 732/1-35, 1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.3, 560.5); N.D. Admin. Code 43-02-03-27.1 (requiring operator to post "all elements made viewable by the fracfocus website," which includes the trade name in its reports); Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. § 3222.1 (requiring operator to complete and post a chemical disclosure form on the FracFocus website, which includes the trade name in its reports); 16 Tex. Admin. Code § 3.29.

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chemical disclosure form on the FracFocus website, which includes the supplier in its reports); 16 Tex. Admin. Code § 3.29.

[53] *See* Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:205A; 225 Ill. Comp. Stat. 732/1-35, 1-75; N.D. Admin. Code 43-02-03-27.1 (requiring operator to post "all elements made viewable by the fracfocus website," which includes the purpose in its reports); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.3, 560.5); Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. § 3222.1 (requiring operator to complete and post a chemical disclosure form on the FracFocus website, which includes the purpose in its reports); 25 Pa. Code § 78.122 (descriptive list of additives); 16 Tex. Admin. Code § 3.29.

[54] Colo. Code Regs. § 404-1:205A; 225 Ill. Comp. Stat. 732/1-35, 1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.3, 560.5); Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. § 3222.1; 16 Tex. Admin. Code § 3.29.

[55] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.3) ("proposed volume of each product to be used in hydraulic fracturing").

[56] 225 Ill. Comp. Stat. 732/1-35, 1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.3); Ohio Rev. Code Ann. § 1509.10 (if state does not have MSDS).

[57] Colo. Code Regs. § 404-1:205A; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.2, 560.5); N.D. Admin. Code 43-02-03-27.1; Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. §§ 3203, 3222.1; 16 Tex. Admin. Code §§ 3.16, 3.29.

[58] Ark. Code R. § 178.00.1-B-19; 225 Ill. Comp. Stat. 732/1-110.

[59] 225 Ill. Comp. Stat. 732/1-35; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.3).

[60] Ark. Code R. § 178.00.1-B-19; 225 Ill. Comp. Stat. 732/1-77.

[61] Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:205A; 225 Ill. Comp. Stat. 732/1-35, 1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.3, 560.5); Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. § 3222.1; 16 Tex. Admin. Code § 3.29.

[62] N.D. Admin. Code 43-02-03-27.1 (requiring operator to post "all elements made viewable by the fracfocus website," which allows operators to withhold trade secret information under the Hazard Communication Standard).

[63] Colo. Code Regs. § 404-1:205A; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5); Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. § 3222.1; 16 Tex. Admin. Code § 3.29.

[64] Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:205A; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5); 58 Pa. Cons. Stat. § 3222.1; 16 Tex. Admin. Code § 3.29.

[65] Ark. Code R. § 178.00.1-B-19 (claim of entitlement); Colo. Code Regs. § 404-1:205A (claim of entitlement); 58 Pa. Cons. Stat. § 3222.1 (signed written statement); 16 Tex. Admin. Code § 3.29 (information indicating entitled to trade secret).

[66] 225 Ill. Comp. Stat. 732/1-77; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, §§ 560.3, 560.5); 25 Pa. Code § 78.122.

[67] 225 Ill. Comp. Stat. 732/1-77; Ohio Rev. Code Ann. § 1509.10; 16 Tex. Admin. Code § 3.29.

[68] 16 Tex. Admin. Code § 3.29

[69] Email communication, Leslie Savage, Chief Geologist, Oil & Gas Division, Railroad Comm'n of Tex. (Nov. 4, 2014).

[70] Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:205A; 225 Ill. Comp. Stat. 732/1-77; Ohio Rev. Code Ann. § 1509.10; 58 Pa. Cons. Stat. § 3222.1; 16 Tex. Admin. Code § 3.29.

[71] Michigan Department of Environmental Quality, Supervisor of Wells Instruction 1-2011, at 3 (2011).

[72] Michigan Department of Environmental Quality. Hydraulic Fracturing in Michigan. [accessed 2015 Jan 23]. http://www.michigan.gov/deq/0,4561,7-135-3311_4111_4231-262172--,00.html.

[73] Occupational Safety and Health Standards, 29 C.F.R. § 1910.1200.

[74] Colo. Code Regs. § 404-1:317; 225 Ill. Comp. Stat. 732/1-70, 1-75 (cement evaluation or other approved evaluation on intermediate casing); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6); N.D. Admin. Code 43-02-03-27.1 (cement evaluation if hydraulic fracturing performed through intermediate casing string); 16 Tex. Admin. Code § 3.13 (cement evaluation if minimum separation well).

[75] 25 Pa. Code § 78.88.

[76] Wilson J, Schwank J. Hydraulic Fracturing in the State of Michigan: Technology Technical Report. Ann Arbor, (MI): Graham Sustainability Institute, University of Michigan; 2013 [accessed 2014 September 30].http://graham.umich.edu/media/files/HF-02-Technology.pdf.

[77] Ark. Code R. § 178.00.1-B-19; Colo. Code Regs. § 404-1:341; 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6); N.D. Admin. Code 43-02-03-27.1; Ohio Admin. Code 1501:9-1-08; 16 Tex. Admin. Code § 3.13.

[78] Colo. Oil and Gas Conserv. Comm'n, COGCC Policy for Bradenhead Monitoring During Hydraulic Fracturing Treatments in the Greater Wattenberg Area (2012).

[79] N.D. Admin. Code 43-02-03-27.1 ("If during the stimulation, the pressure in the intermediate casing-surface casing annulus exceeds three hundred fifty pounds per square inch [2413 kilopascals] gauge, the owner or operator shall verbally notify the director as soon as practicable but no later than twenty-four hours following the incident.").

[80] Ohio Rev. Code Ann. § 1509.12.

[81] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6).

[82] Michigan Department of Environmental Quality, Supervisor of Wells Instruction 1-2011, at 3 (2011).

[83] Michigan Department of Environmental Quality, Supervisor of Wells Instruction 1-2011, at 3 (2011).

[84] Colo. Code Regs. § 404-1:609; 225 Ill. Comp. Stat. 732/1-80; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5); N.D. Cent. Code § 38-11.2-07; Ohio Rev. Code Ann. § 1509.06.

[85] 58 Pa. Cons. Stat. Ann. § 3218.

[86] Colo. Code Regs. § 404-1:609 (well maintained domestic water wells preferred); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5) (testing of residential water wells, domestic supply springs, and water wells and springs that are used as water supply for livestock or crops); N.D. Cent. Code § 38-11.2-07 (testing of water well or water supply); Ohio Rev. Code Ann. § 1509.06 (testing of water well).

[87] 225 Ill. Comp. Stat. 732/1-80 (all water sources).

[88] N.D. Cent. Code § 38-11.2-07; Ohio Rev. Code Ann. § 1509.06.

[89] Colo. Code Regs. § 404-1:609; 225 Ill. Comp. Stat. 732/1-80; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5).

[90] 225 Ill. Comp. Stat. 732/1-80.

[91] *Compare* Ohio Rev. Code Ann. § 1509.06 *and* 225 Ill. Comp. Stat. 732/1-80 *with* N.D. Cent. Code § 38-11.2-07.

[92] *See, e.g.,* Colo. Code Regs. §§ 404-1:100, 404-1:609 (requires testing of available water sources, which are defined as sources for which the owner has given consent for testing and public dissemination of the results).

[93] Colo. Code Regs. § 404-1:609; 225 Ill. Comp. Stat. 732/1-80; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5).

[94] N.D. Cent. Code § 38-11.2-07; Ohio Rev. Code Ann. § 1509.06.

[95] Colo. Code Regs. § 404-1:609 (state and owner); 225 Ill. Comp. Stat. 732/1-80 (state or owner under non-disclosure agreement); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5) (owner and state); Ohio Rev. Code Ann. § 1509.06 (state).

[96] N.D. Cent. Code § 38-11.2-07.

[97] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5). Colorado's policy requires immediate reporting of results to the state when either certain methane concentrations or benzene, toluene, ethylbenzene and xylene (BTEX) compounds have been detected. Colo. Code Regs. § 404-1:609.

[98] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.101 et seq.).
[99] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1406).
[100] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1406).
[101] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.201).
[102] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.201).
[103] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.201, 324.1406).
[104] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1405).
[105] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1405).
[106] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1405).
[107] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1405).
[108] *See* Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.201) (requiring injection wells, but not production wells, to submit this information).
[109] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1404).
[110] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1404).
[111] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1404).
[112] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1404).
[113] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules (proposed January 14, 2015) (to be codified at Mich. Admin. Code r. 324.1404).
[114] For example, ethylene glycol (antifreeze) would be referred to as such, rather than as 1,2-Dihydroxyethane, Monoethylene glycol, or any one of its other variants. The CAS number for the chemical would also need to be provided.
[115] 225 Ill. Comp. Stat. 732/1-25.
[116] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87445.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.3).
[117] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6).
[118] 225 Ill. Comp. Stat. 732/1-25; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87445.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.4); 58 Pa. Cons. Stat. § 3215.
[119] N.Y. State Department of Health. A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development [Albany (NY)]: N.Y. State Department of Health; 2014.
[120] Colo. Code Regs. § 404-1:317B (surface water supply areas); 225 Ill. Comp. Stat. 732/1-25; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.4); N.D. Admin. Code 43-02-03-19 ("hazardously near" bodies of water); Ohio Rev. Code Ann. § 1509.021; 58 Pa. Cons. Stat. § 3215.
[121] Ark. Code R. § 178.00.1-B-26 (tanks storing produced water); 16 Tex. Admin. Code § 4.272 (off-lease commercial recycling of fluid).
[122] Ark. Code R. § 178.00.1-B-26; 58 Pa. Cons. Stat. § 3215.
[123] Ohio Rev. Code Ann. § 1509.021.
[124] Ark. Code R. § 178.00.1-B-26; Colo. Code Regs. § 404-1:317B; 225 Ill. Comp. Stat. 732/ 1-25.

[125] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.4).
[126] 225 Ill. Comp. Stat. 732/1-25; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.4); Ohio Rev. Code Ann. § 1509.021; 58 Pa. Cons. Stat. § 3215; 16 Tex. Admin. Code § 4.272 (off-lease commercial recycling of fluid).
[127] 225 Ill. Comp. Stat. 732/1-25.
[128] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87455.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 52.3).
[129] N.D. Admin. Code 43-02-03-19.
[130] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.4); 58 Pa. Cons. Stat. § 3215; 16 Tex. Admin. Code § 4.272 (off-lease commercial recycling of fluid).
[131] 16 Tex. Admin. Code § 4.272.
[132] Mich. Admin. Code r. 324.301.
[133] Mich. Admin. Code r. 324.301.
[134] Ark. Code R. § 178.00.1-B-15 (updated in 2011); Colo. Code Regs. § 404-1:317 (updated in 2008); 225 Ill. Comp. Stat. 732/1-70 (statute passed in 2013); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6) (revised regulations proposed in 2012); N.D. Admin. Code 43-02-03-27.1 (added in 2012); Ohio Admin. Code r. 1501:9-1-08 (updated in 2012); 25 Pa. Code § 78.81 et seq. (updated in 2011); 16 Tex. Admin. Code § 3.13 (updated in 2013).
[135] 225 Ill. Comp. Stat. 732/1-70 (new intermediate casing); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6) (all new casing); 25 Pa. Code § 78.84 (generally new casing).
[136] Ohio Admin. Code r. 1501:9-1-08; 25 Pa. Code § 78.84.
[137] N.D. Admin. Code 43-02-03-27.1; 16 Tex. Admin. Code § 3.13.
[138] Ark. Code R. § 178.00.1-B-15; 225 Ill. Comp. Stat. 732/1-70; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6).
[139] Colo. Code Regs. § 404-1:317; 225 Ill. Comp. Stat. 732/1-70; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6); Ohio Admin. Code r. 1501:9-1-08; 16 Tex. Admin. Code § 3.13 (minimum separation wells).
[140] Colo. Code Regs. § 404-1:317; 225 Ill. Comp. Stat. 732/1-70; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6); Ohio Admin. Code r. 1501:9-1-08; 25 Pa. Code § 78.85; 16 Tex. Admin. Code § 3.13 (minimum separation wells).
[141] Mich. Admin. Code r. 324.410.
[142] Mich. Admin. Code r. 324.411.
[143] 225 Ill. Comp. Stat. 732/1-95.
[144] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.3).
[145] Harold R. Fitch, Chief, Office of Geological Survey, Supervisor of Wells Letter No. 2011-1 (2011).
[146] Harold R. Fitch, Chief, Office of Geological Survey, Supervisor of Wells Letter No. 2011-1 (2011).
[147] Ark. Code R. § 178.00.1-B-17; Colo. Code Regs. §§ 404-1:902, 404-1:904; N.D. Admin. Code 43-02-03-19.3; 25 Pa. Code § 78.56; 16 Tex. Admin. Code § 3.8 (non-commercial fluid recycling pits).
[148] Ark. Code R. § 178.00.1-B-17; Colo. Code Regs. § 404-1:1003; 225 Ill. Comp. Stat. 732/1-75 (if reserve pit used in unexpected conditions); N.D. Admin. Code 43-02-03-19.3; Ohio Admin. Code r. 1501:9-3-08; 25 Pa. Code § 78.56; 16 Tex. Admin. Code § 3.8 (non-commercial fluid recycling pits, if no leak detection system).
[149] N.D. Admin. Code 43-02-03-19.3.
[150] Ark. Code R. § 178.00.1-B-17.
[151] 16 Tex. Admin. Code § 3.8 (non-commercial fluid recycling pits, if no leak detection system).
[152] 225 Ill. Comp. Stat. 732/1-70 (pits allowed if unexpected conditions); High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. &

Regs. tit. 6, § 560.6). Colorado prohibits pits within an "intermediate" buffer in surface water supply areas. Colo. Code Regs. § 404-1:317B.
[153] 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6). *See also* Ohio Admin. Code r. 1501:9-3-08 ("liquid tight").
[154] 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6).
[155] 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.7).
[156] Mich. Admin. Code r. 324.102, 324.502.
[157] 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6); 58 Pa. Cons. Stat. § 3218.2.
[158] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6).
[159] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.6).
[160] Mich. Admin. Code r. 324.1002.
[161] Colo. Code Regs. § 404-1:317B; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5); 25 Pa. Code § 78.55.
[162] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5).
[163] *See* High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87445.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 750.3) (requiring a Spill Prevention Control and Countermeasure Plan for all high volume hydraulic fracturing wells).
[164] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5).
[165] 25 Pa. Code § 78.55; *see also* 25 Pa. Code § 91.34 ("Department may require a person [engaged in an activity which includes various interactions with pollutants] to submit a report…setting forth the nature of the activity and the nature of the preventative measures taken…).
[166] Colo. Code Regs. § 404-1:317B.
[167] Mich. Admin. Code r. 324.1110.
[168] *See* Ark. Code R. § 178.00.1-B-4; Colo. Code Regs. § 404-1:906; 225 Ill. Comp. Stat. 732/1-75; High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regulations/87420.html (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 560.5); N.D. Admin. Code 43-02-03-30; Ohio Rev. Code Ann. § 1509.12; 25 Pa. Code § 78.51; 16 Tex. Admin. Code § 3.20.
[169] 225 Ill. Comp. Stat. 732/1-75.
[170] Colo. Code Regs. § 404-1:906 (reporting requirement triggered when one barrel is spilled outside of berms or secondary containment or when five barrels spilled regardless of berms or secondary containment).
[171] Ark. Code R. § 178.00.1-B-26.
[172] N.D. Admin. Code 43-02-03-30.
[173] 25 Pa. Code § 78.66; 16 Tex. Admin. Code § 3.20.
[174] 58 Pa. Cons. Stat. Ann. § 3218 (Restricting private parties to a "landowner or water purveyor suffering pollution or diminution of a water supply as a result of the…operation of an oil or gas well.").
[175] 225 Ill. Comp. Stat. 732/1-83 (Defining private party as "[a]ny person who has reason to believe they have incurred pollution or diminution of a water source as a result of a high volume horizontal hydraulic fracturing treatment of a well").
[176] *See* 225 Ill. Comp. Stat. 732/1-83; 225 Ill. Comp. Stat. 732/1-105; 58 Pa. Cons. Stat. Ann. § 3218.
[177] Mich. Admin. Code r. 324.1008.
[178] Mich. Admin. Code r. 324.1008.
[179] Mich. Admin. Code r. 324.1008.
[180] Mich. Admin. Code r. 324.1006.
[181] Michigan's remediation statute, Part 201, would apply cleanup criteria to groundwater contamination. Mich. Comp. Laws § 324.20101 *et seq.*

[182] Ohio Admin. Code 1501:9-1-03.
[183] High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regs/4466.html#15481 (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 551.6).
[184] Ohio Admin. Code 1501:9-1-03.
[185] N.Y. Comp. Codes R. & Regs. tit. 6, § 551.6. New York's proposed policy would have amended the amount to instead read "an amount specified by the department." High Volume Hydraulic Fracturing Proposed Regulations, http://www.dec.ny.gov/regs/4466.html#15481 (to be codified at N.Y. Comp. Codes R. & Regs. tit. 6, § 551.6).
[186] Mich. Admin. Code r. 324.212.
[187] Mich. Admin. Code r. 324.212.
[188] Mich. Admin. Code r. 324.212.
[189] Mich. Admin. Code r. 324.212.
[190] Mich. Admin. Code r. 324.211.
[191] Colo. Code Regs. § 404-1:708.
[192] 225 Ill. Comp. Stat. Ann. 732/1-35.
[193] Ohio Rev. Code Ann. § 1509.07.
[194] N.D. Cent. Code § 38-18-07.
[195] Ark. Code Ann. § 15-72-219.
[196] 225 Ill. Comp. Stat. 732/1-85; Ohio Rev. Code Ann. § 1509.22; 58 Pa. Cons. Stat. Ann. § 3218.
[197] 58 Pa. Cons. Stat. § 3218.
[198] Ohio Rev. Code Ann. § 1509.22 (limiting the rebuttable presumption to wells using annular disposal and clarifying scope of presumption to a one-quarter-mile radius of the site of the violation).
[199] 225 Ill. Comp. Stat. 732/1-85.
[200] *See* 58 Pa. Cons. Stat. § 3218 (rebutting presumption if operator can prove that pollution existed before, refused access to predrilling survey, contamination is not within feet or time limits, or pollution from another cause); 225 Ill. Comp. Stat. 732/1-85 (rebutting presumption if contamination is either proved to be from another source or does not satisfy time and distance requirements).
[201] 225 Ill. Comp. Stat. 732/1-83; Ohio Rev. Code Ann. § 1509.22; 58 Pa. Cons. Stat. Ann. § 3218.
[202] 225 Ill. Comp. Stat. 732/1-83 (requiring the operator to replace the affected supply with an alternative source of water adequate in quantity and quality for the purposes served by the water source).

CHAPTER 5: POLICY FRAMING ANALYSIS

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5.1 INTRODUCTION

Building from the adaptive/precautionary framing in Chapter 4 (Chemical Use) this chapter provides a frame for analyzing the policy options presented in Chapter 2 (Public Participation), Chapter 3 (Water Resources) and Chapter 4 (Chemical Use). As noted in Chapter 4, when there is scientific uncertainty about the risks of an activity two common responses are to adopt an adaptive approach whereby some regulatory action is taken at the outset which can be refined as more information becomes available or a precautionary approach which seeks to control or prohibit activity which may cause harm. This chapter categorizes policy options by the approach to uncertainty they represent in order to help identify options appropriate for several plausible futures or conditions with respect to high volume hydraulic fracturing (HVHF) in Michigan. Adaptive policies are discussed first and followed by precautionary policies. The chapter concludes by organizing the policy options presented in the preceding chapters by the different adaptive and precautionary approaches. Current policy in Michigan is not included in this analysis but the proposed rules are included.

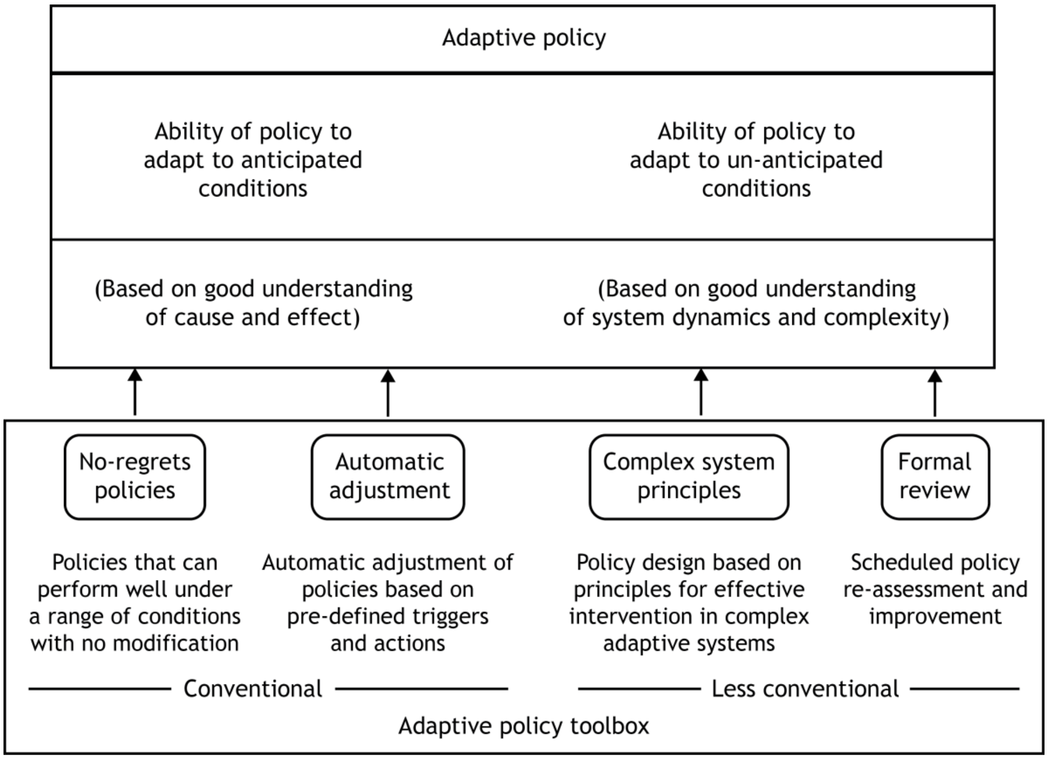
5.2 ADAPTIVE POLICIES

Based on a multi-year project examining adaptive policy making across a range of sectors – natural resources management, healthcare, transportation, engineering, information technology, and international development, the International Institute for Sustainable Development (ISSD) and the Energy and Resources Institute (TERI) offer a useful conceptual framework for applying adaptive policies. This framework was also informed by case study analyses of agriculture and water resources policy in the face of climate change.[1] In the report *Designing Policies in a World of Uncertainty, Change, and Surprise*, ISSD and TERI contributors note that “experience demonstrates that policies designed implicitly or explicitly to operate within a certain range of conditions are often faced with challenges outside of that range.”[2] In response to this policy-makers need ways to design policies that can adapt to a range of conditions.[3,4]

Figure 5.1 provides a conceptual framework for the adaptive policy approach developed by ISSD and TERI. Policies can be categorized as those which can be applied to anticipated conditions and those which can be applied to unanticipated conditions. Policies which respond to anticipated conditions can be divided into those policies which work under a range of conditions without modification and those which involve adjustments based on pre-defined thresholds. Policies which respond to unanticipated conditions can be divided into those which involve complex systems and those which involve reassessing policies on a scheduled basis.

Following the conceptual framework above, policy options from the preceding chapters will be organized into the four adaptive policy categories; no regrets, automatic adjustment, complex systems principles, and formal review. This should not be perceived as an absolute categorization but is meant to provide a useful approach for identifying policy options which might best fit different conditions or scenarios. Chapter section references are included for each option to guide the reader to more specific information on each policy option including the strengths and weaknesses.

Figure 5.1: Adaptive Policy Conceptual Framework[5]



5.2.1 Adaptive policy: no regrets

Bankes (2002) notes that no regrets policies are policies that are likely to work well no matter what anticipated conditions might prevail.[6] With respect to HVHF in Michigan, this includes policy options which deserve consideration regardless of the level of future conditions such as the price of natural gas, the level of activity in Michigan, new technological innovations, or new understandings of risks. A no regret policy does not imply no cost or administrative burden. Every policy response, including no response, can come with an associated cost – financial or administrative. Policy options from Chapter 2 (Public Participation), Chapter 3 (Water Resources) and Chapter 4 (Chemical Use) which can be categorized as potential regrets options are listed in Tables 5.1, 5.2, and 5.3, respectively, at the end of this chapter.

5.2.2. Adaptive policy: automatic adjustment

Bhadwal, Barg, and Swanson (2009) claim that automatic policy adjustments are adaptive policy mechanisms which help policies respond well in variety of plausible and clearly identified future circumstances.[7] As they are pre-established, they can speed up the process of response to conditions that are more or less anticipated and they can be used in complicated policy environments by separating the various policy issues into units wherein the understanding of the system is high (e.g., water withdrawals), allowing for fine-tuning of the system and making adjustments that help reduce risks and maintain performance.[8]

In reviewing the policy options from the preceding chapters, potential automatic adjustment policy options can be identified for all three major categories – public participation, waters resources, and chemical use. These are options which are already developed but are not activated until a particular threshold is reached or activity takes place. Examples of relevant HVHF policy options include allowing permits to be challenged when there is evidence of adverse impacts, additional regulations based on levels of water withdrawals, the formation of a user committee once a particular water withdraw zone status is established, responding to monitoring results, and adjustments to siting based on proximity to sensitive features. Options which could be placed in an automatic adjustment category are identified in Tables 5.1 – 5.3.

5.2.3. Adaptive policy: complex systems principles

A third category of adaptive policy identified through the work of ISSD and TERI are those policies which involve complex systems principles[9] – or conditions which require examining multiple factors. Based on health care policy analysis, Glouberman et al. (2003) recognized that in complex systems, which change over time and respond dynamically to outside forces, it is necessary to constantly refine policies.[10,11] Of the options presented in this report there are only a few within the Water Resources chapter which can be categorized as adaptive policies employing complex systems principles. Table 5.2 lists these options which include the possibility of developing a system for the transfer, sale or lease of water withdrawals by water users. Such a system would require a negotiated system based on market forces and other interests. The other policy options involve novel approaches for wastewater recycling both of which would require substantial review given the potential to increase surface contamination risks, water quality impacts, and additional truck traffic.

5.2.4. Adaptive policy: formal review

A fourth category of adaptive policy is formal review. It is similar to automatic adjustment, in that it acknowledges that monitoring and remedial measures are integral to complex adaptive systems[12] and that it is necessary to constantly refine interventions through a continual process of variation and selection.[13] However, Tomar and Swanson (2009) argue that it is fundamentally different from automatic adjustment in that automatic adjustment can anticipate what signposts to use and what actions might need to be triggered to keep the policy effective. Formal review is a mechanism for identifying and dealing with unanticipated circumstances and emerging issues.[14] The Water Resources and Chemical Use chapters present adaptive policy options which can be categorized as formal review options (see Tables 5.2 and 5.3). They include updating the models which are used for the Water Withdrawal Assessment Tool (WWAT) and establishing a mechanism for scheduling updates as well as reviewing and amending any list of prohibited chemicals and well integrity monitoring systems to ensure the application of best practices.

5.3 PRECAUTIONARY POLICIES

A second overall approach is precautionary policy which is based on the precautionary principle. Many definitions of the precautionary principle exist but two ideas lie at the core of the principle:[15]

1. an expression of a need by decision makers to anticipate harm before it occurs. Within this element lies an implicit reversal of the onus of proof: under the precautionary principle it is the responsibility of an activity proponent to establish that the proposed activity will not (or is very unlikely to) result in significant harm.
2. the concept of proportionality of the risk and the cost and feasibility of a proposed action.

One of the primary foundations of the precautionary principle, and globally accepted definitions, results from the work of the Rio Conference, or "Earth Summit" in 1992. Principle #15 of the Rio Declaration notes: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."[16] One well know example of the precautionary policy is the Montreal Protocol for addressing concerns about the depletion of stratospheric ozone[17] In this case, while scientific work was still underway there was sufficient consensus that action was needed and clear options and alternatives were available. While there has been increasing reference to policy based on the precautionary principle, there are also questions about application as there can be risks with regulating and not regulating certain activities.[18] The recent decisions to ban HVHF in New York[19] and Quebec[20,21] based in part on potential health and environmental impacts can be viewed as a precautionary approach.

Precautionary policy options exist across all three chapters, Public Participation, Water Resources, and Chemical Use. They range from a moratorium or complete ban on HVHF in Michigan to prohibitions, restrictions, or requirements on a range of activities. The objectives of these policies are to avoid harm, ensure additional safety precautions or monitoring, or provide full information on activities in advance.

Table 5.1: Adaptive and precautionary policy approaches for public participation

Adaptive - No regrets	
Public values	
2.2.3.2	Revise DEQ website to improve transparency
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 HVHF decision making
2.2.3.7	Appoint a multi-stakeholder advisory group to study HVHF impacts and best practices
2.2.3.8	Increase stakeholder representation on Oil and Gas Advisory Committee
State land leasing	
2.3.3.2	Increase public notice of state land auctions
2.3.3.3	Require DNR to prepare a responsiveness summary
2.3.3.4	Require public workshops prior to state land auctions
2.3.3.5	Increase public notice and comment when lessees submit an application to revise or

	reclassify a lease
Well permitting	
2.4.3.2	Increase public notice of permit applications
2.4.3.3	Require a public comment period with mandatory DEQ response
Adaptive - Automatic adjustment	
Well permitting	
2.4.3.4	Allow adversely affected parties to request a public hearing before a HVHF well permit is approved
Precautionary	
Public values	
2.2.3.5	Impose a state-wide moratorium on HVHF
2.2.3.6	Ban HVHF

Table 5.2: Adaptive and precautionary policy approaches for water resources

Adaptive - No regrets	
Modifying the WWAP	
Additional monitoring	
3.2.7.2.3	Collect baseline groundwater data (Michigan proposed rule)
3.2.7.2.5	Provide a mechanism to use private monitoring
Public engagement on new water withdrawals	
3.2.8.3.4	Require public notice on new high-capacity wells
3.2.8.4.1	Report to the Supervisor of Wells (Michigan proposed rule)
Wastewater management & water quality	
Deep well injection	
3.3.5.2.2	Increase deep well injection monitoring and reporting requirements
Adaptive - Automatic adjustment	
Modifying the WWAP	
Water withdrawal regulation thresholds	
3.2.2.3.2	Lower thresholds for regulation
3.2.2.3.3	Increase water use reporting frequency
Requirements for water withdrawal approval	
3.2.1.3.4	Adopt additional rules for proposed water withdrawals (Michigan proposed rule)
Water withdrawal fee schedules	
3.2.4.3.2	Modify water withdrawal fee schedules
Modify water withdrawal permitting	
3.2.5.3.2	Open option to obtain a large-scale water withdrawal permit
Additional monitoring	
3.2.7.2.2	Install additional monitoring wells in the presence of other water withdrawal wells (Michigan proposed rule)
3.2.7.2.4	Require site specific reviews for all HVHF water withdrawal proposals
Public engagement on new water withdrawals	
3.2.8.3.2	Organize water users committees
3.2.8.3.3	Organize water resources assessment and education committees
Adaptive - Complex systems	
Modifying the WWAP	
Transfer/sale/lease of water withdrawals	
3.2.6.3.2	Provide a mechanism to transfer, sell, lease registered/permitted water withdrawals
Wastewater management & water quality	
Wastewater recycling	
3.3.6.3.2	Provide options for wastewater recycling

3.3.6.3.3	Use alternative water sources for HVHF
Adaptive - Formal review	
Modifying the WWAP	
Improvements to the WWAT	
3.2.3.1.2	Update the scientific models of WWAT
3.2.3.1.3	Implement a mechanism for updating the models underlying WWAT
Precautionary	
Modifying the WWAP	
Water withdrawal regulation thresholds	
3.2.2.3.4	Set a total volumetric water withdrawal limit
Requirements for water withdrawal approval	
3.2.1.3.3	Disallow HVHF operation from approaching an ARI (Michigan proposed rule)
3.2.1.3.5	Disallow any HVHF operations within a cold-transitional system
3.2.1.3.6	Overestimate proposed HVHF water withdrawals
Modify water withdrawal permitting	
3.2.5.4.1	Prohibit HVHF operations from obtaining a water withdrawal permit
Transfer/sale/lease of water withdrawals	
3.2.6.4.1	Prohibit transfer or use of registered water withdrawals to HVHF operations
Wastewater management & water quality	
Deep well injection	
3.3.5.2.3	Require use of Class I hazardous industrial waste disposal wells

Table 5.3: Adaptive and precautionary policy approaches for chemical use

Adaptive - No regrets	
Information policy	
Chemical use disclosure	
4.2.4.1	Option A: Michigan's proposed rules
	Subject of disclosure: all constituents
	Means of disclosure: permit application; FracFocus
	Timing of disclosure: before HVHF and within 30 days after HVHF
	Trade secret claim review: statement of claim; must use family name or other description
4.2.4.2	Option B: Adaptive approach
	Subject of disclosure: all constituents; plain language description
	Timing of disclosure: before and within 30 days after HVHF
Water quality	
4.2.4.1	Option A: Michigan's proposed rules
	Water source tested: groundwater
	Area around well: ¼-mile radius around well
	Number of sources tested: up to 10
	Frequency of testing: once, >7 days but <6 months prior to drilling of new well or HVHF of existing well
	Test results: within 45 days; immediate notification of contaminants of concern; to state and owner
4.2.4.2	Option B: Adaptive Approach
	Water source tested: groundwater and surface water
Prescriptive policy	
Controls on surface risk	
4.3.4.1	Option A: Michigan's proposed rules
	Flowback and chemical additives: clarification that flowback is to be stored in tanks

Adaptive - Automatic adjustment		
Information policy		
Chemical use disclosure		
4.2.4.2	Option B: Adaptive approach	
		Means of disclosure: master list; state website; FracFocus
		Trade secret claim review: narrow exception for trade secrets
Well construction		
4.2.4.1	Option A: Michigan's proposed rules	
		Pressure monitoring: monitored and reported immediately to state if problem;HVHF ceases until plan of action implemented
		Mechanical integrity test: when monitoring indicates problem
4.2.4.2	Option B: Adaptive approach	
		Pressure monitoring: monitored and reported immediately to state and nearby landowners if a problem; status placed on website; HVHF ceases until plan of action implemented
		Mechanical integrity test: when monitoring indicates a problem
Water quality		
4.2.4.2	Option B: Adaptive approach	
		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; immediate notification of contaminants of concern; to state, owner, and public (through website)
Prescriptive policy		
Limitations on siting		
4.3.4.2	Option B: Adaptive approach	
		Siting: oil or gas wel site and storage tanks; distance from sensitive features changes over time based on new findings/best practices
Controls on groundwater risk		
4.3.4.2	Option B: Adaptive approach	
		Area of review analysis: within area affected by HVHF; corrective action or monitoring of conduits
Controls on surface risk		
4.3.4.2	Option B: Adaptive approach	
		Flowback and chemical additives: flowback stored in tanks; monitor well site for leaks and spills
		Secondary containment: storage tanks at well site and surface facility
Planning, response, and liability policy		
Emergency planning		
4.4.4.2	Option B: Adaptive approach	
		Emergency response plan: HVHF wells in sensitive areas; adapt plans over time
Cleanup		
4.4.4.2	Option B: Adaptive approach	
		Notification: all losses or spills; larger spills reported immediately; to state and public
		Standard: remediation and long-term monitoring
		Bonds and insurance: eliminate blanket bonds
Liability		
4.4.4.2	Option B: Adaptive approach	
		Type of contamination: spills of chemical additives and flowback into groundwater
		Presumption: for liability if do not monitor environment around well
		Remedy: remediation and long-term monitoring

Adaptive - Formal review
Prescriptive policy
Restrictions on chemical use
4.3.4.2 Option B: Adaptive approach
List of prohibited chemicals, amended over time
Controls on groundwater risk
4.3.4.2 Option B: Adaptive approach
Construction requirements: reviewed every 3 years; change over time based on new findings/best practices
Precautionary
Information policy
Chemical use disclosure
4.2.4.3 Option C: Precautionary approach
Subject of disclosure: all constituents; plain language 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 construction
4.2.4.3 Option C: Precautionary approach
Pressure monitoring: monitored and reported immediately to state and nearby landowners if problem; HVHF ceases until operator demonstrates integrity
Mechanical integrity test: prior to approval of HVHF; when monitoring indicates a problem
Water quality
4.2.4.3 Option C: Precautionary approach
Water source: groundwater and surface water with a specific focus on drinking water and ecologically sensitive sources
Number of sources tested: based on characteristics of aquifer/watershed with a specific focus on drinking water and ecologically sensitive sources
Frequency of testing: baseline test prior to approval of well; long-term regular monitoring
Test results: prior to approval of well and within 10 days; immediate notification of contaminants of concern; to state and owner
Prescriptive policy
Restrictions on chemical use
4.3.4.3 Option C: Precautionary approach
Approval of all chemicals only if reduced toxicity
Limitations on siting
4.3.4.3 Option C: Precautionary approach
Siting: all related facilities; all potentially affected water resources; greater setback and protected areas
Controls on groundwater risk
4.3.4.3 Option C: Precautionary approach
Construction requirements: strict requirements for several levels of safety
Area of review analysis: within area affected by HVHF; relocate well unless no risk from conduits
Controls on surface risk
4.3.4.3 Option C: Precautionary approach
Flowback and chemical additives: closed loop system for chemical additives, flowback; additive handling requirements
Secondary containment: entire well sites and surface facility

Planning, response, and liability policy
Emergency planning
4.4.4.3 Option C: Precautionary approach
Emergency response plan: all HVHF wells
Cleanup
4.4.4.3 Option C: Precautionary approach
Notification: immediate reporting of all losses or spills to state and public
Standard: restoration of environment
Bonds and insurance: increase individual well bond to $250,000; liability insurance
Liability
4.4.4.3 Option C: Precautionary approach
Type of contamination: all spills of chemical additives and flowback
Presumption: strict, joint and several liability
Remedy: restoration of the environment

5.4 SUMMARY

This chapter has provided a framing for the policy options presented in the preceding chapters. Two primary frames were employed – an adaptive policy frame and a precautionary policy frame. Within adaptive policy, four different categories were used to organize the policy option: no regrets, automatic adjustment, complex systems principles, and formal review. Each category had unique conditions under which the policy option might work best. For example, no regrets could be applied in any future or scenario whereas automatic adjustments only engage once specific criteria are met. Complex systems principles fit policies which must consider multiple factors and formal review policies outline mechanisms and timetables for updating processes. For precautionary policies, there are different opinions for when they are best applied. For some, they should be applied early to prevent any harm. For others there must be some consideration of proportionality of the risk and the cost and feasibility of a proposed policy response.

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CHAPTER 6: BROADER CONTEXT

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6.1 OVERVIEW

During the public comment period following the release of the technical reports numerous comments were received regarding topics extending beyond the geographic scope of Michigan. Similar topics were also identified in the technical reports themselves. While not central to the focus of the (Integrated Assessment) IA, the Integration Team and Report Team determined it would be useful to present a concise summary of key aspects of the these topics so that readers of the IA report could understand the broader context and national discourse of issues related to expanded natural gas production and use. The objective of this chapter is not to advocate a particular perspective but to present the results of key reports and analyses on these topics: 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.

6.2 CLIMATE CHANGE: WHAT ARE THE EFFECTS OF NATURAL GAS PRODUCTION AND FUGITIVE METHANE EMISSIONS?

The potential impact of shale gas development on climate is a subject of significant concern and debate.[1,2,3] While the combustion of natural gas emits less carbon dioxide (CO_2) per unit of energy generated than coal, the overall effect of a shift toward natural gas is not as clear when the full life cycle (exploration through end use) is considered. This is, in part, because fugitive emissions of methane reduce the net climate benefits of using lower-carbon natural gas in electricity generation or transportation. Methane is a primary component of natural gas[i] and potent, short-lived greenhouse gas with a global warming potential[ii] 28-34 times greater than CO_2 over a 100-year timeframe, and 84-86 times greater over a 20-year time horizon.[4] Given that methane is a potent greenhouse gas (GHG), in addition to its being a tropospheric ozone precursor, the role of the production and use of shale gas in contributing to methane emissions is worthy of consideration.

[i] Natural gas is a hydrocarbon gas mixture consisting primarily of methane (70-90%), but it can also include ethane, propane, butane, and pentane, as well as carbon dioxide, nitrogen, and hydrogen sulfide.
[ii] Global Warming Potential (GWP) refers to the total energy a compound absorbs over a period of time, typically 100-years, compared to CO_2 (i.e., a GWP of 10 means that it is 10 times more potent than CO_2 at the given timeframe). While methane's perturbation lifetime is only 12 years, its GWP takes into account indirect impacts from changes to ozone and stratospheric water vapor (IPCC 2013).

6.2.1 Relative life cycle GHG emissions

Total GHG emissions from the production and use of unconventional gas compared to conventional gas and other fuel sources such as coal have been the subject of considerable recent research. Studies to date have come to conflicting conclusions, due largely to different data, assumptions, and methodologies[5,6]; however, some general trends are notable. The first trend is that most studies indicate that GHG emissions from the shale gas life cycle through energy generation are likely smaller than those from the coal life cycle. Estimates from nine studies, employing various assumptions and data, suggest that emissions from natural gas (including shale gas specifically) are likely between 20% to 53% less than emissions produced from coal.[7,8,9,10,11,12,13,14] The most notable exception is a study by Howarth et al. that estimated that GHG emissions from shale gas could be anywhere from 20% to 200% greater than coal in the 20-year timeframe and comparable in the 100-year timeframe.[15] Among other differences, the Howarth et al. study utilized significantly higher methane leakage rates, a heat generation basis, and shorter GWP timeframe, and it is the only one to conclude that emissions associated with shale gas are greater than those associated with coal. Many of the other studies utilized U.S. Environmental Protection Agency (EPA) emissions estimates for at least some of their emissions data, but as discussed later, evidence suggests these estimates may be too low.[16,17,18,19]

Researchers have also explored the relative GHG emissions from unconventional and conventional gas production and arrived at different conclusions, again reflecting different underlying assumptions, data, and scopes. On the high end, Howarth et al. estimated that the GHG footprint of shale gas is as much as 19% greater than that of conventional gas on the 100-year time horizon.[20] Other studies have estimated that unconventional GHG emissions are between 2% and 11% greater than conventional gas emissions through the electricity generation stage.[21,22,23,24,25] Burnham et al. estimated that total shale gas emissions are 6% less than conventional gas emissions, but an overlap in value ranges leads to uncertainty about whether shale gas emissions are actually lower.[26]

There are a number of factors underlying the differences among studies' estimates, but the lack of consistency in assumptions and data is likely a principle contributor to the variety of differing conclusions. Key differences and uncertainties, as identified in the literature, are summarized in Box 6.1. If these assumptions or estimates are incorrect (as studies are suggesting the EPA's emission factors are), then estimates of GHG emissions may also be incorrect.

Studies attempting to reconcile these underlying differences suggest that unconventional and conventional gas emissions are comparable. One review study using Monte Carlo uncertainty analysis to compare normalized "best estimates" from six studies comparing shale and conventional gas concluded upstream GHG emissions were similar.[27] Additionally, harmonized lifecycle GHG emissions from eight studies indicated that median estimates of GHG emissions from shale gas-generated electricity are similar to those for conventional natural gas, with both approximately half that of coal.[28] It is worth noting, however, that even if the GHG intensities of conventional and unconventional gas are similar, the extraction and use of expanded natural gas reserves due to advances in hydraulic fracturing technology are potentially significant for climate change.

Box 6.1: Differences and uncertainties in GHG emissions estimates

Global warming potential

The IPCC's 100-year GWP time is standard for GHG accounting. Some, such as Howarth et al.,[29] have also used alternative estimates and shorter timescales arguing that a 20-year timeframe is more appropriate given the climate system's responsiveness to changes in potent, short-lived emissions.[30] According to the IPCC, "there is no scientific argument for selecting 100 years compared with other choices," and the selection is a policy choice about how short- and long-term costs and benefits are weighted.[31]

LCA boundaries & scope

LCA's must have equivalent systems boundaries to be directly comparable. Some studies have considered only stages upstream of electricity generation, others included generation (with some excluding downstream transmission and distribution), and still others considered emissions from upstream and combustion without specifying end-use and efficiency. Additionally, studies focused on a limited geographic scope may reflect unique conditions not applicable elsewhere. Studies have also focused on shale gas exclusively or unconventional gas more generally.

Data sources, parameters & assumptions

Rather than conducting direct measurements, many studies rely on EPA and industry emissions data, which may be incomplete as a result of limited sampling, subject to bias, or outdated data.

Moreover, there are uncertainties at points throughout the gas production process. During completion, the emission of natural gas from flowback water accounts for most of the emissions, but the amount of methane released is uncertain, and studies have utilized different flowback emission factors.[32,33,34,35] A 2014 top-down study observed high emissions during drilling, a pre-production stage previously thought not to contribute significant emissions.[36] During the production stage, workovers, maintenance, and liquids unloading (the periodic removal from a well of liquids and other debris that impede gas flow) are the primary sources of emissions, and studies have utilized different assumptions regarding the frequency at which these occur.[37] Liquids unloading, in particular, was recently documented as relevant to shale gas production[38] and identified as a factor to which emissions estimates are most sensitive.[39]

Emissions are typically reported per unit of natural gas produced. For that reason, the total lifetime production of a well is important in determining total methane emissions. Estimated ultimate recovery (EUR) has been identified as one of the most influential parameters on GHG estimates.[40,41,42] Uncertainty in EURs reflects the lack of long-term historical production data[43] and variation between wells and basins.[44]

Evolving technology

Due to advancement in technology, practices and emissions controls, different data and assumptions may not reflect current practices and conditions.

6.2.2 EPA emissions inventories & leakage rates

Of the many uncertainties, the lack of reliable estimates of total methane emissions, in particular, has received significant recent attention. The EPA publishes official estimates of methane emissions from natural gas systems annually in its *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.[45] The EPA does update its methodology and data as new information becomes available, as it did in 2011 when it revised the way fugitive methane emissions from natural gas systems were estimated. Over the last decade, official estimates of methane emissions from natural gas production operations have ranged from <0.2% to 1.5% of gross national gas production.[46,47,48]

While one study utilizing direct measurements at gas production sites estimated nationwide methane emissions comparable to EPA's estimates,[49] top-down atmospheric studies have consistently suggested that the EPA significantly underestimates methane emissions.[50,51] In comparison to the EPA's estimated total leakage rate for natural gas systems from wells to end-users of 1.4%,[52] regional atmospheric studies have found, for instance, methane emissions corresponding to a leakage rate between 3% to 17% of total natural gas production.[53,54] A national modeling study[55] and recent synthesis[56] find smaller excess methane emissions, but still suggest that national methane emissions are 1.5 times greater than EPA estimates (although that higher estimate still yields lower GHG emissions than coal for electricity generation).[57] In reconciling these discrepancies, studies[58,59] have suggested that high regional estimates, and a small number of "superemitter" sources, are likely not representative of the norm across the U.S.

In theory, both bottom up approaches (process-based modeling, where emissions from each process involved in production is estimated separately) and top-down approaches (atmospheric observations of methane concentration levels over a spatially distributed area) to collecting emissions data should yield comparable emissions factors, but that has not been the case. The bottom-up approach can be quite thorough, but when it is extrapolated to larger scales, uncertainty arises from large variations in emissions over time and region, limited sample sizes,[60] and potential sampling bias from self-selected cooperating facilities.[61] The top-down approach is most limited in its ability to attribute emissions to multiple potential sources, but also can suffer from too few observations and weaknesses in modeling.[62] Both approaches are further challenged by the rapid evolution of gas technologies, production practices, and emissions controls, and may not reflect current conditions.[63]

Despite the lack of consensus on emissions, there has been little, if any, debate in the existing literature that methane emissions at all stages of production can be reduced. By using a range of existing technology and best practices, methane emissions from all forms of natural gas at all stages of production through distribution can be mitigated.[64] New EPA rules required green completions or flaring at all new wells starting in 2013, and green completions at all new wells starting in 2015.[65] The rules are credited for a 78% reduction in methane emissions from completion of hydraulically fractured wells from 2011 to 2013.[66] The rules do not address emissions from liquids unloading or natural gas pipelines; however, methods exist to reduce emissions at those stages.[67]

Moreover, there is general agreement that end-use combustion contributes more than 75% of lifecycle natural gas GHG emissions. Consequently, improvements in the efficiency of heat, electricity, and transportation uses of gas are also important emissions reduction opportunities to consider.[68]

6.2.3 Future emissions

The effect of unconventional gas development on future GHG emissions depends also on broader systems changes. There are multiple productive uses for an increased gas supply beyond power generation, such as transportation, industrial use, and export. The full impact of an energy shift must consider these system-levels issues, requiring a linking of LCA to economic, policy, and technology models.[69] Newell and Raimi analyze environmental and economic modeling projections and estimate that lower natural gas prices from increased supply would increase overall energy consumption by 3% but reduce greenhouse gas emissions ~0.5% (subject to upstream emission estimates) by encouraging fuel-switching from coal to natural gas for electricity generation. Absent policy interventions, they conclude increased shale gas development will not substantially change the course of global GHG concentrations.[70] At a more simplistic but still significant level, the climate change benefits that increased use of gas may provide are dependent upon gas actually displacing coal (that is, the coal remaining in the ground) rather than merely adding to total fossil fuel use.

In sum, the diversity of data and conclusions from the small but growing body of literature on shale gas highlights the need for additional research on GHG emissions throughout the gas life cycle. The debates over timeframes and estimate/observation methodologies emphasize the importance of establishing consistent study protocols and standards. Additionally, consideration and re-evaluation of methane emissions from oil or coal production are also necessary in order to make accurate comparisons between fossil fuels. While much more research is needed on the contribution that unconventional gas production, including hydraulic fracturing, will make in relation to GHG emissions, and how these emissions shall compare to those from coal and conventional natural gas, it is clear that there are opportunities to reduce GHG emissions now.

6.3 RENEWABLE ENERGY: WILL NATURAL GAS BE A BRIDGE TO A CLEANER ENERGY FUTURE?

Another key issue for those concerned with global climate change, as well as current and future energy systems and the domestic economy, is that of the connection between natural gas and renewable energy technologies. Increased domestic interest and investment in shale gas production have resulted in some analysts questioning whether this growth could negatively impact the development, and use, of low- or zero-carbon technologies.

Some stakeholders, including the current U.S. Energy Secretary Dr. Ernest Moniz,[71] see shale gas, and more broadly natural gas, as a ‘bridge fuel’—bridging the gap, and facilitating the transition, between the current fossil-fuel dependent economy and a renewable-energy based future. While the relative climate change impacts of the different fossil fuel sources remain under debate, as explained previously, current research suggests that natural gas likely has less of a climate impact than coal (provided that it is used for electricity generation, that methane leakages during production and extraction are kept to a minimum, and that a 100-year time frame is followed for evaluating GWP). However, the growth of shale gas as an energy source has consequences beyond coal. Significantly, it has the potential to affect investment in research, development, and deployment of low- or zero-carbon technologies.[72]

6.3.1 Natural gas as a complement

Proponents of natural gas, including J. Podesta of the Center for American Progress, argue that natural gas should be viewed as being complementary to renewable energy technologies.[73] In their view, the intermittent output nature of some low-carbon energy sources, such as wind or solar, means that fossil fuels shall be an essential component of the energy mix going forward. Unlike coal or other fossil fuels, natural gas is perhaps the only fossil fuel energy source that is well suited to fill in these gaps in renewable energy availability.[74,75,76,77]

6.3.2 Natural gas as competition

If the goal is to reach near-zero greenhouse gas emissions as quickly as possible, or even to cut emissions substantially, then low-/zero-carbon technologies must rapidly become competitive within the marketplace, as the current business-as-usual trajectory leads to an increase in emissions by 2050.[78,79] This has led many to be concerned that a focus on natural gas as a bridge fuel could delay important research, development, and deployment of low-carbon technologies, which "may set us back more than the climate benefits achieved from a marginal reduction in U.S. coal consumption."[80] Barring a technological breakthrough, or other unforeseen developments that would make low carbon technologies cost-competitive, there is a growing sense in the scientific literature that market forces alone are not likely to lead to natural gas becoming an effective bridge fuel or renewable technologies becoming a significant part of the national energy mix.[81] Without a federal regulatory structure in place to promote accelerated development and deployment of low-carbon energy technologies, an affordable and abundant gas supply is projected to increase gas use and displace both nuclear and renewable sources of energy,[82] thus outcompeting the very technologies to which bridge-fuel advocates want to transition.

6.3.3 Policy context

One of the primary factors in determining whether natural gas will serve as a bridge-fuel is the domestic regulatory landscape, specifically, interventions designed to control carbon emissions or drive growth in low-carbon technologies. Even though the future is unknown, it is possible to look at future scenarios that could plausibly unfold, given current trends and forecasts. In an analysis of 23 such scenarios provided by a range of academic researchers, along with government and industry analysts, Shearer et al. concluded that in fact, without "strong limits on GHG emissions or policies that explicitly encourage renewable electricity, abundant natural gas may actually slow the process of decarbonization…"[83] This finding echoes those of Paltsev et al. and Brown et al., who in separate scenario analyses likewise found that without any sort of "climate policy," the proportion of electricity generation from natural gas would increase, while nuclear and renewable sources would either be displaced or contribute only slightly more than at present.[84,85]

The three primary policy interventions discussed as possible climate policies include a price-based approach (such as a carbon tax or price per unit emission), a quantity-based approach (such as a tradable emissions permit system or non-tradable emissions quotas), or a federal renewable mandate. Other potential interventions, such as subsidies, state level renewable mandates, or production tax credits, were not included in the analysis. Both a price-based and a quantity-based approach are projected to have two main effects in the near- to intermediate-term: lowering overall energy consumption and favoring natural gas over other fossil fuels for electricity generation.[86,87] However, it remains unclear with these interventions how long it might take before low-carbon technologies are favored, or if other incremental improvements (such as efficiency upgrades) might further delay the adoption of low-carbon technologies. Indeed, the analysis by Shearer et al. consistently found that with an abundant supply of gas, both coal and renewable energy would be used less, and both price- and quantity-based interventions would only dampen this trend but not change it.[88]

The third climate policy, a federal renewable mandate, was the only policy option that ensured a similar utilization of natural gas and renewables in Shearer's analysis, since the mandated renewable electricity use would decrease market competition between natural gas and renewables.[89]

6.3.4 Key uncertainties

Whether increased natural gas production will ease or hinder a transition to a low-carbon domestic energy system is not clear. The overall energy portfolio in the U.S. is affected by a number of factors that remain uncertain, including future energy and climate policies, the availability and costs of low-carbon energy and carbon-storage technology, and broad macroeconomic factors impacting natural gas markets and prices. Each, independently or in partnership with each other, could heavily influence the viability of natural gas as a bridge fuel in the short- to medium term.

6.4 MANUFACTURING: WILL NATURAL GAS DEVELOPMENT REVITALIZE DOMESTIC MANUFACTURING?

The economic implications of shale gas production have also received significant attention. Among other considerations, many industry experts and analysts have been projecting a so-called manufacturing renaissance in the U.S. [90,91, 92,93,94,95, 96,97,98,99,100,101] Analysts from organizations such as IHS, PricewaterhouseCoopers (PwC), and Resources for the Future (RFF) predict significant increases in employment, household income, tax revenue, and gross domestic product (GDP) value added, in addition to increased demand in consumption and government spending.[102,103,104,105] This projected national level economic growth is the result of a boom in domestic manufacturing arising from the availability of abundant and affordable natural gas.[106,107,108,109,110,111,112] Although these potential benefits have received fairly widespread attention, there is a concern among some that estimates may be overstated due to methodological issues, unrealistic assumptions, or the omission of potentially significant considerations.[113,114,115,116] Others have pointed to some predicted trends which have simply failed to materialize.[117]

6.4.1 Industry trends

A number of industry groups and analysts have predicted that expanded shale gas production will make significant contributions the broader economy over the next decade. For instance, the consulting firm IHS used an input-output model to estimate the full value chain for unconventional gas and oil.[iii] They concluded that it supported 2.1 million jobs nationally, created nearly $75 billion in tax revenue, and contributed $283 billion to the U.S. GDP in 2012 alone. IHS and PwC also projected that by 202, unconventional fuels could contribute between 1 and 3.9 million additional jobs, $532.8 billion in GDP value added, and an increase of over $3,500 in average household disposable income.[118,119]

Analysts expect this growth to occur along multiple portions of the value chain. In addition to a significant growth upstream associated with exploration, drilling, new construction, and transportation infrastructure,[120,121] several downstream manufacturing industries are expected to benefit. Specifically, industries reliant upon natural gas for use as a feedstock (chemical manufacturing) or as a fuel (metals and long-haul transportation) are expected to see significant cost-savings.[122,123,124,125]

Natural gas liquids, which can be extracted directly or formed as a by-product during processing of dry natural gas, are valued as raw materials by the petrochemical industry.[126] These liquids, which include hydrocarbons such as methane, ethane, propane, and butane, can then be processed and refined into derivative compounds, and further downstream into a variety of intermediate and end products.[127]

Globally, many chemical manufacturers use naphtha, refined from crude oil, as a primary feedstock in chemical manufacturing. [128] Compared with the more expensive naphtha, and the rising production costs in the Middle East, the United States is emerging as a cost-advantaged producer of ethylene, which is the main product created from ethane and is one of the primary building blocks in the chemical value chain.[129] As ethylene is one of the primary building blocks in the chemical value chain, this trend has the potential to positively impact the domestic manufacturing industry as a whole.[130]

To take advantage of this, 148 chemical industry related projects (including new factories, expansions, and process updates to increase capacity), valued at over $100 billion, had been announced as of February 2014.[131] Most of these new plants are planned for the Gulf Coast region, where infrastructure already exists.[132] This level of new capital investment is nearly triple IHS' 2013 prediction of an estimated $31 billion of investment by 2016.[133] Whether current trends continue remains to be seen, but if they do, it is likely that total investments will exceed

[iii] Although this report concerns shale gas specifically, the IHS report cited here does not separate unconventional gas from oil, as it would be difficult to differentiate the economic impacts of oil and gas production. Oil production often produces gas that can be marketed separately, and dry gas production can yield natural gas liquids as well.

IHS' longer-term prediction of over $129 billion of major investments and nearly 89 million tons of capacity by 2025.[134]

Another industry that could see benefits from abundant and affordable domestic natural gas is metal manufacturing, though the magnitude of such benefits remains unclear. This industry is expected to benefit through two mechanisms: decreased energy costs and increased demand.[135] Many U.S. facilities have traditionally used coal as a fuel in processing iron ore, but some are beginning to switch to natural gas to take advantage of its lower cost.[136,137] Demand is experiencing an uptick as well, as the shale gas production process requires steel products.[138,139] While some are optimistic that this is the start of a longer-term trend that could lead to the creation of one million new domestic manufacturing jobs,[140] others urge caution and note that the benefits may not be as substantial. They assert that the demand increase is likely to be short-run in nature,[141] and that the cost savings from switching to natural gas may represent less than 2% of the per-ton cost of steel production ($8-10/ton in savings compared to an overall production cost of approx. $600/ton).[142]

As noted in the University of Michigan Energy Institute's report on domestic shale gas,[143] so long as the price differential between natural gas and diesel is large enough, parts of the transportation sector could stand to benefit. In fact, a natural gas trade association projected a 20 percent growth rate in natural gas powered truck sales for 2014, based in part on the lower fuel costs relative to diesel.[144] However, the Energy Institute's report also notes that the use of natural gas as a transportation fuel does face a number of obstacles,[145,146,147,148] such as a limited nationwide fueling infrastructure, fuel storage issues, relatively high up-front costs, some safety concerns,[149,150,151,152,153,154,155] and price challenges from motor gasoline. Whether and the extent to which this industry benefits depends heavily on how the price of domestic natural gas evolves in relation to motor gasoline and diesel. If natural gas prices increase as a result of greater demand (either from exports–see section 6.5 Exports below for more–or from expanded domestic accessibility[156]), or if motor gasoline prices decline substantially (as was beginning to happen as of the end of 2014[157]), then the competitiveness of natural gas as a transportation fuel could be significantly affected.

While most of the discussion around natural gas usage in the transportation sector has focused on the trucking industry, and to a lesser extent, passenger vehicles, PwC notes that railroads and airlines may also benefit in the short and long term. Railroads are already hauling equipment and chemicals needed during the extraction process, and shale gas and oil after extraction. In the airline industry the combination of high jet fuel prices and crude oil price volatility has motivated Shell (RDSC) and Qatar Petroleum to look for cheaper fuel alternatives, such as those derived from natural gas.[158]

6.4.2 Other perspectives

An analysis published in mid-2014 by Goldman Sachs found that reinvestment rates in energy intensive manufacturing lags similar reinvestment in the Middle East and Asia by a ratio of 15-to-1.[159] It also found that the infrastructure to ensure the benefits of abundant energy supplies can be fully reaped is lacking.[160] By their calculations, if these trends continue, North America would, over the next decade, forego more than 2 million new jobs, 1.0% of additional GDP growth, and at least a 5% incremental reduction in GHG emissions.[161] While these numbers incorporate considerations beyond only manufacturing, this sector is a major component.

Despite the detailed commentary and data published by business and industry groups, to date there have been only a handful of peer-reviewed studies or evaluations published on the topic of a projected manufacturing renaissance and economic growth from shale gas. These publications, in sum, paint a more nuanced picture of the manufacturing sector and natural gas. Researchers have, for example, pointed out several concerns. These include assumptions and limitations associated with input-output analyses, negative effects on other sectors, and use of appropriate counterfactuals.

Input-output analysis is a well-established method, but like all models, it has limitations and its predictions depend on underlying assumptions and data. Some researchers have questioned the accuracy of multipliers used to capture the effects on other industries,[162,163] assumptions about whether inputs are sourced and expenditures made within the same region as development,[164,165] and estimates of future drilling activity,[166,167,168] all of which could affect projections. Additionally, a recognized best-practice in economics when analyzing the effect of an intervention or change (in an input-output model or otherwise) is to compare it to the counterfactual—what would happen without the intervention. Comparing projections to conditions when a policy or change started, rather than a counterfactual, does not control for underlying trends or other factors that could contribute to the projected outcomes.[169,170] Not making adequate use of counterfactuals could lead to significantly different conclusions and projections.

In addition to potential indirect economic growth stemming from a boost to domestic manufacturing, shale gas extraction may have a number of indirect negative consequences. A disadvantage of the input-output model used in many industry assessments is that it does not necessarily capture losses in other sectors, and, therefore, presents gross, not net, economic impacts.[171] Shale gas extraction could, for example, displace coal mining in some regions, with experts predicting an increase in natural gas related jobs to come at the expense of fewer jobs in coal production and coal-dependent industries.[172] Tourism as well could be negatively impacted from fears of pollution.[173,174]

An economic phenomenon known as “Dutch Disease” concerning the relationship between increasing exploitation of natural resources and a corresponding decline in the manufacturing sector has not been fully examined. The underlying theory in the context of natural gas extraction in the U.S. is that increased local wages and land costs resulting from gas production may cause a *decline* in local firms that manufacture tradable goods. A recently published study examining oil and gas booms did find evidence that industries that are unlinked to oil and gas and that are likely to trade outside local markets contracted during resource booms; however, most industries were positively affected, because they either supply to the oil and gas sector or benefit from increases in local demand.[175]

Furthermore, some researchers have questioned projected employment effects. For instance, researchers at the Ohio State University estimate that from 2004 to 2010, in Pennsylvania—home of the Marcellus Shale region—shale drilling activities created approximately 20,000 jobs.[176] This corresponds closely to other estimates from 2009,[177] but is far less than the 140,000 jobs associated with natural gas estimated for the same year by an industry-funded study.[178] While this example is admittedly on a different scale and is more narrowly focused than the national employment projections, it highlights a trend that certain researchers point to – that shale gas production may be associated with significant income effects, but only modest employment effects.[179] Still others note that even income effects may be less than input-output models suggest.[180]

In all, shale gas has the potential to bring significant benefits to the U.S. economy. The manufacturing sector, in particular, appears likely to benefit substantially through investment in shale gas development activities. Yet, while business and industry analysts appear to be optimistic in their projections, others have adopted a more cautious perspective to the economic potential of expanded shale gas production within the U.S, citing the need for a closer examination of various key factors before drawing strong conclusions.

6.5 EXPORTS: WHAT ARE THE IMPLICATIONS OF NATURAL GAS EXPORTS?

In large part as a result of technological advances in drilling, the country now faces an abundance of natural gas, which has driven prices down to levels that give the U.S. a cost-advantaged status globally. With market conditions thus shifting from favoring U.S. natural gas imports[181,182,183] towards favoring exports, policymakers and others are discussing the possibility of expanding permitting of exports beyond North America.[184]

The U.S. Department of Energy's Office of Fossil Energy and the Federal Energy Regulatory Commission (FERC) are the primary authorizing agencies for any gas exporting processes.[185] Federal law currently prohibits any imports or exports of natural gas without authorization from FERC, which also has authority over import/export terminals.[186] At the end of March 2014, there were five LNG terminals approved or under construction in the U.S., and eight throughout North America[187]; 37 applications were pending.[188] Although FERC and the Office of Fossil Energy are responsible for regulating the export of natural gas, Congress is currently debating whether, and how, to allow exports of natural gas.[189,190,191,192,193,194,195,196]

6.5.1 Projected costs and benefits

When considering whether or not to allow expanded global exports, one may naturally wonder whether the costs and benefits from such a move would be expected to be net positive or negative. In one sense, this question gets at the much larger question of the net impacts from shale gas production in general: since expanded exports would likely lead to increased domestic production in response to the increase in demand, the net impacts may largely be an amplification of the current production impacts (e.g. ecological, economic, social, etc.). To date, there have been a number of analyses conducted by various public and private institutions regarding the potential impacts from expanded exports. It is difficult, however, to directly compare these studies, since they look at different issues, use various modeling methodologies, and are based on widely different assumptions.[197] The following summarizes findings from a number of recent analyses.

6.5.1.1 Gas prices

How the price of natural gas may change is considered particularly important, even more so than concerns around the amount of natural gas available. As Deloitte points out in their report: “if price is not significantly affected, then scarcity and shortage of supply are not significant issues.”[198] Although a significant increase in exports would likely raise domestic prices, the magnitude of any increase is uncertain.[199] Producers generally contend that due to an ample supply to meet domestic demand, increasing exports would not greatly raise current prices.[200] Such statements have done little to alleviate consumer fears of being negatively impacted by price increases, however.[201]

Of eight separate studies evaluated by ICF International, all eight projected that expanded exports would lead to an increase in domestic natural gas prices, ranging from as little as $0.03/MMBtu to as much as $4/MMBtu.[202] After accounting for differences among the various scenarios through normalizing to $/MMBtu per 1 bcfd, this range became $0.03 - $0.33/MMBtu per 1 bcfd.[203] While there is a consensus among analysts that exports would lead to a price increase, the magnitude of such an increase is unclear. Nonetheless, some of the analyses point out that the global gas market would limit how much domestic natural gas prices can rise, since importers would simply not purchase U.S. exports if U.S. wellhead prices rise above the cost of competing supplies.[204,205]

6.5.1.2 Electricity

As natural gas is used as a fuel source in domestic electricity generation, changes in the price of gas could lead to changes in both the price of electricity as well as to the domestic energy mix itself. An analysis from Deloitte suggested that electricity price increases would be limited to around 1.2% in exporting regions, and would be much less elsewhere, such as the Midwest.[206] A study conducted by economists at Purdue University, however, projected electricity price increases of 1.1 – 7.2% compared to the reference case.[207] Additionally, the Purdue study projected that by 2035, exports would cause the following shifts in the domestic energy mix: a decrease in natural gas from 25% to 27%, increase in coal from 21% to 23%, increase in oil from 36% to 37%, and small increases in nuclear and renewables.[208]

6.5.1.3 Industry impacts

There are mixed findings around the potential impacts to U.S.-based industry. The Purdue study found that exports would lead to all domestic energy intensive sectors experiencing a loss of labor and capital income, with increasing energy costs, while foreign industries and consumers would experience reduced energy costs.[209] According to the authors, U.S. industry would be rendered less competitive against foreign industry,[210] thus potentially threatening the manufacturing boost discussed elsewhere in this report.

A study conducted for the Department of Energy by NERA likewise found that the electricity sector, energy-intensive sector, and natural gas-dependent goods and services producers would all be impacted by price rises, but that natural gas suppliers would benefit.[211] They also concluded that manufacturers would switch to cheaper fuels or use natural gas more efficiently as natural gas prices rise and production overall is reduced.[212] The Deloitte report, however, found that the price impact from exports would be unlikely to cause U.S. industry to be uncompetitive in global markets.[213]

6.5.1.4 Employment

The analyses also vary in their estimates of potential impacts to domestic employment. While the NERA and Deloitte studies found that exports would be unlikely to affect the overall employment level in the U.S. positively or negatively,[214,215] the ICF report projected employment increases across all export scenarios.[216] Specifically, they found the effect on U.S. employment through 2035 to be an average net job increase of 73,100 to 454,300 (including all economic multiplier effects).[217] They further found manufacturing would net between 7,800 and 76,800 jobs, including 1,700-11,400 net job gains in specific industries such as refining and chemicals.[218] On the other hand, an analysis by the Brookings Institution found that these sort of employment gains may be overstated, as a result of giving too much weight to positions that are likely to be temporary, which may take years to materialize, and which may be largely offset by employment losses in other areas.[219]

6.5.1.5 GDP

In term of impact to U.S. GDP, the sole academic study, from Purdue University, found that counter to the standard idea that more open trade results in a net gain for society, increasing natural gas exports would actually result in a slight decline in GDP.[220] The authors attribute this to the losses in electricity and energy intensive sectors of the economy outweighing gains from export.[221]

The NERA and ICF studies meanwhile, found that exports would lead to positive benefits to U.S. GDP.[222,223] The NERA report found that the long-run boost to GDP would be relatively smaller compared to the short-run boost.[224] The ICF analysis found that positive GDP benefits would increase as the volume of exports rises, supporting and going further than the NERA findings.[225] The authors of the Purdue report point out, however, that the NERA analysis found a net GDP increase of $10 billion (2010$) by 2030 – which they assert could be seen as being quite small in a $15 trillion economy, equating it to just 6 hours of U.S. economic activity.[226,227]

6.5.1.6 Other considerations

Although most of the analyses conducted to date have focused almost exclusively on economic consequences, there may be other, less easily quantifiable but nonetheless significant consequences. The Brookings Institution analysis, for instance, notes that expanded exports could influence geopolitics and give the U.S. new leverage in international trade negotiations, perhaps ensuring U.S. access to important markets, such as Chinese rare earth metals.[228]

In addition to the factors considered above, the Purdue study found that exports could have several other impacts. First, they could lead to a dramatic reduction or elimination of compressed natural gas (CNG) use in transportation by 2035.[229] Next, they note that there could be income distribution consequences resulting from exports, as losses were projected for wage and capital income in energy intensive industries, while the gains were projected to be almost exclusively wealth transfers to owners of natural gas resources.[230] The Brookings Institution likewise found that allowing exports would likely raise domestic natural gas prices with disproportionate consequences for low-income consumers.[231]

The Purdue authors also found that increasing exports would lead to increasing GHG and other (such as particulate) emissions.[232,233] Interestingly, they found that in the early years of their simulation, GHG emissions from electricity would be 2-12% higher, but only 1-4% higher by 2035 – a trend they attribute to the emergence of less expensive renewable energy technology after 2020 and to some increase in nuclear energy.[234] They acknowledge that GHG emissions might fall in other regions as fossil fuels are replaced with cleaner natural gas, but they anticipate 'emissions transaction costs' from liquefying, transporting, and de-liquefying the gas, which would result still in a net GHG increase.[235]

Finally, others expect that expanding exports, and the increase in demand that would accompany such a move, would require greater U.S. shale gas production, potentially amplifying any and all associated impacts (e.g., environmental, social, health, etc.).[236,237]

6.5.1.7 Net effects

With the notable exception of the Purdue University study,[238] all of the analyses projected that the U.S. would gain net economic benefits from allowing greater LNG exports.[239,240,241] Although the NERA report noted that exports would only be feasible under scenarios with high international demand and/or low U.S. costs of production, they also found that the benefits from export expansion would more than outweigh the losses from reduced capital and wage income to U.S. consumers.[242]

6.5.2 Conclusions

There are considerable uncertainties surrounding the consequences – positive and negative – of expanding natural gas exports. In particular, potential impacts on domestic prices and market volatility, domestic employment, industry growth, environmental issues, and global trade and geopolitics are all part of the equation. While there is to date only a small body of literature that examines these uncertainties, the analyses that do exist suggest that under certain conditions, the benefits of allowing exports may outweigh the costs, though this net balance, nor its magnitude, is by any means clear, and depends in part on the net impacts of domestic shale gas production in general.

6.6 HUMAN HEALTH RISKS: HOW DO WE KNOW IF SHALE GAS DEVELOPMENT IS "SAFE"?

Amongst the general public within the U.S., there is a strong desire to know whether or not shale gas development, including hydraulic fracturing, is 'safe', as well as to understand what human health risks may be specifically associated with the practices. Such questions are reasonable; however, they are inherently complicated, and cannot be answered definitively at this time.

Some commentators within industry and various regulatory agencies would point to the more than 60 years of hydraulic fracturing activity in the U.S. to argue that the practice does not adversely impact human health.[243] However, this view is contested. Researchers and practitioners within the fields of medicine and public health do not necessarily see a lack of data as evidence of an absence of acute or chronic human health risks. Just like any other fossil fuel, the development of shale gas poses inherent potential environmental public health risks. It is the extent of the risks and their effect on health outcomes that are relevant to the safety question, and they remain unknown.[244,245]

Despite ongoing efforts, the body of peer-reviewed environmental health research on shale gas development and hydraulic fracturing is limited.[246,247] For example, the Institute of Medicine noted, "public health is lacking critical information about environmental health impacts of these [shale gas extraction] technologies and is limited in its ability to address concerns."[248] Notably, there have been no comprehensive studies of the public health effects of shale gas development, and significant uncertainties, data gaps, and research limitations persist.[249,250,251,252] Key uncertainties include the types and magnitudes of human exposures to hazards, identities and concentrations of chemicals used, synergistic effects of multiple stressors, and long-term cumulative effects. The lack of baseline and monitoring data, as well as the length of time it takes for certain health outcomes to manifest and the multi-causal nature of some potential outcomes, pose further challenges to assessing associations between hazards and health outcomes.[253,254,255,256,257]

These substantial uncertainties and data gaps have prompted numerous researchers and organizations[258,259,260,261,262,263,264] to call urgently for additional human health research to be undertaken on the topic. Data generated in such studies are critical to our understanding of the human health impacts associated with hydraulic fracturing, and shale gas development more broadly.

6.6.1 Types of health assessments

There are several methods beyond the scope of this Integrated Assessment that could be employed to develop a comprehensive assessment of the human health-related effects of hydraulic fracturing and unconventional gas development (see Table 6.1). Each of these methods requires a substantial commitment of resources to arrive at useful and actionable conclusions. For instance, the evaluation of the human health effects of just one chemical in a traditional risk assessment requires extensive laboratory studies, research into population exposure data, computer modeling, and other time and labor intensive activities. With hydraulic fracturing, there are many variables and confounders. Additionally, there is not merely one standard approach to the process, which can make use of numerous chemicals and methods in a range of settings (see the Public Health Technical Report[265] and Chapter 4 Chemical Use, this report). As such, determining the potential types of assessments required and evaluating the potential health impacts is a complex and resource-intensive process.

Table 6.1: Types of studies for examining different factors influencing human health[266]

Type of assessment	Type of determinants of health considered
Environmental Impact Assessment	Physical environment (e.g., clean water, air, soil, etc.)
Social Impact Assessment	Social (e.g., access to education and other resources, public safety, literacy, etc.)
Economic Impact Assessment	Economic (e.g., income inequality or public expenditures on social goods and services), cost-benefit, and other types of economic analysis
Traditional Health Risk Assessment	Typically a single hazard (chemical/biological/physical substance) and its probability for causing disease (e.g., cancer, asthma) in a select human population
Health Impact Assessment	All determinants (environmental, social, economic, and any others) with a focus on population wide health impacts

For the question of human health as it relates to hydraulic fracturing, the two most relevant study methodologies (of those shown in Table 6.1) would be traditional health risk assessment and health impact assessment (HIA). Traditional risk assessment combines hazard identification, exposure assessment, and dose-response assessment to characterize risk and eventually make management decisions.[267] While it can be thorough and effective at illuminating quantitative information concerning the risks associated with a certain substance, it is limited in that it does not incorporate perceived risks, nor does it compare risks between multiple policies, or include an analysis of the economic/social implications of a policy under consideration.[268]

Unlike a traditional risk assessment, HIAs use a variety of data sources - including input from stakeholders - and analytic methods to determine the potential effects of a particular operational practice, regulatory policy, or other action plan on the health of a given population.[269] HIAs are not intended to evaluate whether a project or plan should or should not be implemented, but rather they serve to inform decision makers as to how to make a proposed action plan or regulatory policy more likely to promote health and avoid negative health outcomes.[270] Typically, the main end product of an HIA is the identification of primary health determinants and affected outcomes, the direction of any changes (positive or negative), and the severity of any potential impacts.[271] HIAs are typically more qualitative in nature than traditional risk assessments, but they can, and frequently do, include a significant quantitative component that resembles a risk assessment, wherein multiple determinants and outcomes are identified and analyzed.[272,273] There is no standard methodology for HIAs, but most share a common 5-6 step procedure, as set out in Table 6.2.[274,275]

Table 6.2: Typical Process of an HIA

Step 1	Screening: determine whether HIA should be conducted (is it feasible and does it add value?)
Step 2	**Scoping**: determine the boundaries, develop the framework, identify the concerns to address, along with possible causal pathways, methodologies, and the population(s) of interest
Step 3	**Assessment of impacts**: the main stage that clarifies a baseline of the population as well as the nature and magnitude of health impacts likely to result; assess the distribution of health impacts if at all possible
Step 4	**Recommendations**: (if appropriate) develop health-based recommendations, an action plan for implementation, and key performance indicators for monitoring
Step 5	**Reporting to decision makers**: create a report with the results, including possible improvement actions; present to decision makers, the public, and all other participating or interested stakeholders
Step 6	**Monitoring and evaluation**: evaluate the HIA process and any lessons learned, determine if it actually added value, monitor the status of the recommendations, and evaluate the outcomes (if appropriate)

Adapted from Assessment of Population Health Risks of Policies[276] (p. 28-29)

HIAs are growing in usage in the U.S., and they are used routinely by international development organizations, as well as governments ranging from the UK and Canada to countries in Africa and Asia, and even industry.[277,278] There are, however, limitations associated with the approach. There have been remarkably few attempts to review the accuracy of predictions made about health within HIAs, not to mention or the impacts that HIAs have had on the policy making process.[279]

6.6.2 Current and future assessments

Despite the lack of comprehensive assessments, there have been efforts to assess human health risks focused on smaller scales, such as specific exposure routes or a limited geographic area. For instance, Adgate et al.[280] note that published health risk assessments have focused on risks from air exposure.[281,282] In terms of HIAs, a draft assessment was prepared by the Colorado School of Public Health for the Battlement Mesa community in Colorado.[283] More recently, the School of Public Health at the University of Maryland prepared a "rapid" HIA of potential public health impacts of natural gas development and production in the Marcellus Shale in Western Maryland.[284]

While these studies have been helpful in illuminating smaller, specific areas, there is still a dearth of comprehensive studies on the public health effects of shale gas development and hydraulic fracturing. Interest in such a study is growing, as calls for a comprehensive health impacts assessment are increasing, from organizations ranging from the Institutes of Medicine[264] to the Health Effects Institute.[285] This latter Boston-based organization has already convened a special committee of experts to "develop a strategic plan to guide future research on the potential health and environmental impacts of unconventional oil and gas development in the Appalachian Basin."[286] Until such a comprehensive study is completed, however, the scientific and public health communities cannot conclusively answer whether or not shale gas development through hydraulic fracturing is 'safe' for public health.

6.7 CONCLUSION

In response to public comments received during that IA and broader context topics identified in the technical reports, this chapter has provided an overview of the literature on several key issues related to expanded shale gas production and use but not necessary specific to Michigan. While not exhaustive, these issues (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) 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 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 the opportunities which do exist now to reduce GHG emissions through existing technology and best practices, the influence of federal renewable mandates for transitioning to low- or zero-carbon technologies, and the potential economic benefits from expanded manufacturing and all allowing natural gas exports. These should not be read as definitive conclusions but a snapshot of current understandings of these topics. One comprehensive review of the available scientific peer-reviewed literature on the impacts of shale gas development estimated that only 73% has been published since January 1, 2013.[287] As has been noted above, much still needs to be examined regarding expanded shale gas development and there is significant work currently taking place which will hopefully better inform decision making moving forward.

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CHAPTER 7: LIMITATIONS AND KNOWLEDGE GAPS

7.1 LIMITATIONS

While this integrated assessment has attempted to provide a comprehensive review of the current status and trends of high volume hydraulic fracturing (HVHF) in Michigan (the technical reports) and an analysis of policy options (this report) there are certain limitations which must be recognized. First, the assessment does not provide a quantitative assessment (human health or environmental) of the risks associated with HVHF. This was not the intent of the assessment but it is a question we have often received regarding the scope of the project. As was noted in Chapter 6, completing such assessments is currently a key point of discussion related to HVHF despite the challenges of uncertainty and limited available data – particularly baseline data. Completing a quantitative risk assessment would also require significantly more time and funding.

Second, the assessment does not provide economic analysis or a cost-benefit analysis of the policy options presented in the preceding chapters. 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.

7.2 KNOWLEDGE GAPS

In addition to the status and trends information provided in the technical reports, additional areas of investigation and knowledge gaps were identified. Those are listed below following the thematic areas of the technical reports. Several other emerging research questions identified in a recent publication of the *Annual Review of Environment and Resources*[1] are also referenced.

Technology

- A comparative analysis of water-based and water-free fracturing methods.
- Assessing the effectiveness and impacts of refracturing or other restimulation efforts.[2]
- Investigating if horizontal drilling and HVHF lead to higher stresses that require engineering safeguards to be reevaluated, particularly the mechanical properties of steel and cement.[3]
- A comparison of recent well integrity statistics to past statistics.[4]
- Evaluating the legacy effects of older wells (older than 25-50 years) for greenhouse gas emissions and potential groundwater contamination.[5]

Geology/hydrogeology

- Evaluating the impact of HVHF chemicals on the release and transport of toxic metals and naturally occurring radionuclides.
- Establishing standard measurement techniques (e.g. microseismic) for evaluating the extent and direction of major fracture networks during HVHF.

- Conducting modeling studies to assess subsurface flow, fluid residence times, and leakage risk up existing wells.
- Reevaluating current regulatory definition of 'produced water". Analyze the flowback water chemistry and compare it with that of the produced brine from older wells nearby.
- Evaluating the adsorption of fracking chemicals.

Environment/ecology

- Establishing a decision-matrix that guides decision making on establishing HVHF operations in "sensitive/susceptible" ecosystems.
- Establishing baseline (reference condition) ecosystem monitoring in susceptible areas that continues through post-operation periods to establish whether or not detrimental impacts occur.
- Assessing the cumulative impacts of multiple HVHF operations within a watershed for downstream surface waters and groundwater.
- Establishing to what degree other likely stressors in watershed, unrelated to HVHF operations, impact aquatic communities.
- Identifying areas for improved quality control / best practices in HVHF operations, especially near riparian zones, surface waters and shallow aquifers.
- Establishing a publically available database for HVHF studies and data. It is important that close attention be paid to the findings published in the "peer-reviewed" scientific literature in the coming months to years to improve decision making.
- Evaluating how potential HVHF impacts compare to the environmental impacts of energy-related activities, such as coal mining, that it may be replacing.

Public health

- Empirical data is needed in Michigan concerning a number of public health indicators, such as air and water quality, exposure assessments in workers, and health of fish and wildlife. Such data is needed to help establish baseline measurements, make judgments against acceptable thresholds, and compare to other HVHF regions. There are some important datasets available (e.g., well locations), and to broadly assess potential for risk these could be overlaid with datasets such as location of homes, agricultural fields, hospitals, and schools.

Law/policy

- Examining private landowner leases signed in Michigan and the ways in which they create a private standard addressing contamination and HVHF.
- Surveying local units of government and residents to determine the issues of greatest concern.[6]

Economics

- Examining the occupational risks of exposure to the chemicals currently used in HVHF in order to develop guidelines for minimizing worker occupational illness and injury.
- Estimating the level of direct industry employment that is imported from out-of-state.

- Estimating the necessary bonding requirements on industry to mitigate liabilities to the State. This will require a risk assessment to determine whether insurance levels sufficiently cover potential remedial costs.
- Tracking employment changes in high natural gas utilization industries and compare the movement of jobs with the price of natural gas.
- Examining the question of HVHF and property values in Michigan.

Public perceptions

- Evaluating whether appropriate tax structures are in place to support rapid population growth in small communities.
- Assessing mineral rights owners' awareness of standard leasing procedures and help connect them to resources like the Michigan State University Cooperative Extension, which provides information about best practices.
- Conducting an in-depth study of local perceptions in communities where natural gas extraction through HVHF is likely to continue and expand.

Finally, other useful resources for information on shale gas development include:

- The Physicians, Scientists, and Engineers (PSE) study citation database.[7] The citation database provides bibliographic information, abstracts, and links to many of the vetted scientific papers house in the PSE Health Energy Library. This comprehensive database directly pertains to shale gas and tight oil development. The literature is organized into twelve different categories, including air quality, water quality, climate, public health, and regulations.[8]
- The Center for Sustainable Shale Development (CSSD). This is a non-profit organization whose mission is to support continuous improvement and innovative practices through performance standards and third-party certification. Focused on shale development in the Appalachian Basin, the Center provides a forum for a diverse group of stakeholders to share expertise with the common objective of developing solutions and serving as a center of excellence for shale gas development.[9]
- The Shale Gas Project of Resources for the Future (RFF). Includes reports on managing risks and the economics of shale gas development.[10]
- Resources from the American Petroleum Institute (API) on hydraulic fracturing. These include guidelines for community engagement and other best practice resources.[11]
- The Center for Local, State and Urban Policy (CLOSUP) at the University of Michigan's Ford School of Public Policy. CLOSUP's Energy & Environmental Policy Initiative Fracking Project provides reports on public opinion surveys and shale gas governance issues.[12]

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[6] Much work has already been done on this topic by the Center for Local, State, and Urban Policy, see: http://closup.umich.edu/fracking/ [accessed December 2, 2014].
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APPENDIX A: GLOSSARY OF TERMS

Note: Most definitions come from the following source - *Modern Shale Gas Development in the United States: A Primer*.[1] Other definitions are indicated with separate endnote references.

ADVERSE RESOURCE IMPACT. An adverse resource impact is defined as impairing the lake or stream's ability to support its characteristic fish population.[2]

AIR QUALITY. A measure of the amount of pollutants emitted into the atmosphere and the dispersion potential of an area to dilute those pollutants.

AQUIFER. A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.

BASIN. A closed geologic structure in which the beds dip toward a central location; the youngest rocks are at the center of a basin and are partly or completely ringed by progressively older rocks.

BIOGENIC GAS. Natural gas produced by living organisms or biological processes.

BRINE. Nonpotable water resulting, obtained, or produced from the exploration, drilling, or production of oil or gas, or both.[3]

CASING. Steel piping positioned in a wellbore and cemented in place to prevent the soil or rock from caving in. It also serves to isolate fluids, such as water, gas, and oil, from the surrounding geologic formations.

CHEMICAL ABSTRACTS SERVICE (CAS) NUMBER. The unique identification number assigned to a chemical by the division of the American Chemical Society that is the globally recognized authority for information on chemical substances.[4]

COAL BED METHANE/NATURAL GAS (CBM/CBNG). A clean-burning natural gas found deep inside and around coal seams. The gas has an affinity to coal and is held in place by pressure from groundwater. CBNG is produced by drilling a wellbore into the coal seam(s), pumping out large volumes of groundwater to reduce the hydrostatic pressure, allowing the gas to dissociate from the coal and flow to the surface.

COMPLETION. The activities and methods to prepare a well for production and following drilling. Includes installation of equipment for production from a gas well.

CONVENTIONAL 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.[5]

CORRIDOR. A strip of land through which one or more existing or potential utilities may be colocated.

DISPOSAL WELL. A well which injects produced water into an underground formation for disposal.

DIRECTIONAL DRILLING. The technique of drilling at an angle from a surface location to reach a target formation not located directly underneath the well pad.

DRILL RIG. The mast, draw works, and attendant surface equipment of a drilling or workover unit.

EMISSION. Air pollution discharge into the atmosphere, usually specified by mass per unit time.

ENDANGERED SPECIES. Those species of plants or animals classified by the Secretary of the Interior or the Secretary of Commerce as endangered pursuant to Section 4 of the Endangered Species Act of 1973, as amended. See also **Threatened and Endangered Species**.

EXPLORATION. The process of identifying a potential subsurface geologic target formation and the active drilling of a borehole designed to assess the natural gas or oil.

FLOW LINE. A small diameter pipeline that generally connects a well to the initial processing facility.

FLOWBACK FLUID. “Flowback fluid” means hydraulic fracturing fluid and brine recovered from a well after completion of a hydraulic fracturing operation and before the conclusion of test production under R 324.606.[6]

FORMATION (GEOLOGIC). A rock body distinguishable from other rock bodies and useful for mapping or description. Formations may be combined into groups or subdivided into members.

FRACTURING FLUIDS. A mixture of water and additives used to hydraulically induce cracks in the target formation.

GROUNDWATER. Subsurface water that is in the zone of saturation; source of water for wells, seepage, and springs. The top surface of the groundwater is the “water table.”

HABITAT. The area in which a particular species lives. In wildlife management, the major elements of a habitat are considered to be food, water, cover, breeding space, and living space.

HIGH VOLUME HYDRAULIC FRACTURING. High volume hydraulic fracturing well completion is defined by State of Michigan regulations as a "well completion operation that is intended to use a total of more than 100,000 gallons of hydraulic fracturing fluid."[7,8]

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 horizontally through the target formation.

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.

HYDROSTATIC PRESSURE. The pressure exerted by a fluid at rest due to its inherent physical properties and the amount of pressure being exerted on it from outside forces.

INJECTION WELL. A well used to inject fluids into an underground formation either for enhanced recovery or disposal.

LEASE. A legal document that conveys to an operator the right to drill for oil and gas. Also, the tract of land, on which a lease has been obtained, where producing wells and production equipment are located. In Michigan, state land leases do not convey a right to drill. It conveys the exclusive right to pursue development of the oil and gas resource, after obtaining all necessary permissions, if the lessee chooses to do so.[9]

NORM (Naturally Occurring Radioactive Material). Low-level, radioactive material that naturally exists in native materials.

ORIGINAL GAS IN PLACE. The entire volume of gas contained in the reservoir, regardless of the ability to produce it.

PARTICULATE MATTER (PM). A small particle of solid or liquid matter (e.g., soot, dust, and mist).PM10 refers to particulate matter having a size diameter of less than 10 millionths of a meter (micrometer) and PM2.5 being less than 2.5 micro-meters in diameter.

PERMEABILITY. A rock's capacity to transmit a fluid; dependent upon the size and shape of pores and interconnecting pore throats. A rock may have significant porosity (many microscopic pores) but have low permeability if the pores are not interconnected. Permeability may also exist or be enhanced through fractures that connect the pores.

PRIMACY. A right that can be granted to state by the federal government that allows state agencies to implement programs with federal oversight. Usually, the states develop their own set of regulations. By statute, states may adopt their own standards, however, these must be at least as protective as the federal standards they replace, and may be even more protective in order to address local conditions. Once these state programs are approved by the relevant federal agency (usually the EPA), the state then has primacy jurisdiction.

PRODUCED WATER. Water produced from oil and gas wells.

PROPPING AGENTS/PROPPANT. Silica sand or other particles pumped into a formation during a hydraulic fracturing operation to keep fractures open and maintain permeability.

PROVED RESERVES That portion of recoverable resources that is demonstrated by actual production or conclusive formation tests to be technically, economically, and legally producible under existing economic and operating conditions.

RECLAMATION. Rehabilitation of a disturbed area to make it acceptable for designated uses. This normally involves regrading, replacement of topsoil, re-vegetation, and other work necessary to restore it.

SETBACK. The distance that must be maintained between a well or other specified equipment and any protected structure or feature.

SHALE GAS. Natural gas produced from low permeability shale formations.

SLICKWATER. A water based fluid mixed with friction reducing agents, commonly potassium chloride.

SOLID WASTE. Any solid, semi-solid, liquid, or contained gaseous material that is intended for disposal.

SPLIT ESTATE. Condition that exists when the surface rights and mineral rights of a given area are owned by different persons or entities; also referred to as “severed estate”.

STIMULATION. Any of several processes used to enhance near wellbore permeability and reservoir permeability.

STIPULATION. A condition or requirement attached to a lease or contract, usually dealing with protection of the environment, or recovery of a mineral.

SULFUR DIOXIDE (SO2). A colorless gas formed when sulfur oxidizes, often as a result of burning trace amounts of sulfur in fossil fuels.

TECHNICALLY RECOVERABLE RESOURCES The total amount of resource, discovered and undiscovered, that is thought to be recoverable with available technology, regardless of economics.

THERMOGENIC GAS. Natural gas that is formed by the combined forces of high pressure and temperature (both from deep burial within the earth’s crust), resulting in chemical reactions of the organic matter in the source rock matrix.

THREATENED AND ENDANGERED SPECIES. Plant or animal species that have been designated as being in danger of extinction. See also **Endangered Species.**

TIGHT GAS. Natural gas trapped in a hardrock, sandstone or limestone formation that is relatively impermeable.

TOTAL DISSOLVED SOLIDS (TDS). The dry weight of dissolved material, organic and inorganic, contained in water and usually expressed in parts per million.

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. 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.[10]

UNDERGROUND INJECTION CONTROL PROGRAM (UIC). A program administered by the Environmental Protection Agency, primacy state, or Indian tribe under the Safe Drinking Water Act to ensure that subsurface emplacement of fluids does not endanger underground sources of drinking water.

UNDERGROUND SOURCE OF DRINKING WATER (USDW). 40 CFR Section 144.3 An aquifer or its portion:

(a) (1) Which supplies any public water system; or

(2) Which contains a sufficient quantity of groundwater to supply a public water system; and

(i) Currently supplies drinking water for human consumption; or

(ii) Contains fewer than 10,000 mg/l total dissolved solids; and

(b) Which is not an exempted aquifer.

WATER QUALITY. The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use.

WATERSHED. All lands which are enclosed by a continuous hydrologic drainage divide and lay upslope from a specified point on a stream.

WELL COMPLETION. See **Completion**.

WORKOVER. To perform one or more remedial operations on a producing or injection well to increase production. Deepening, plugging back, pulling, and resetting the liner are examples of workover operations.

[1] Ground Water Protection Council (Oklahoma City, OK); ALL Consulting (Tulsa, OK).Modern Shale Gas Development in the United States: A Primer. [place unknown]: U.S. Department of Energy Office of Fossil Energy and National Energy Technology Laboratory; 2009 [accessed 2014 Sep 30]. Contract No.: DE-FG26-04NT15455. http://www.eogresources.com/responsibility/doeModernShaleGasDevelopment.pdf.

[2] Michigan Department of Environmental Quality. New Water Withdrawal Law for Michigan! [Lansing (MI)]: Michigan Department of Environmental Quality; 2006 [accessed 2015 Feb 12]. https://www.michigan.gov/documents/deq/deq-wd-withdrawallaw-summary_260216_7.pdf.

[3] Mich. Admin. Code r.324.102(f).

[4] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules, http://www.michigan.gov/deq/0,4561,7-135-3306_57064---,00.html (proposed January 14, 2015) (to be codified at Mich. Admin. Code r.324.1402).

[5] Canadian Association of Petroleum Producers. Conventional & Unconventional. Calgary (AB):Canadian Association of Petroleum Producers; 2014 [accessed 2014 September 26]. http://www.capp.ca/CANADAINDUSTRY/NATURALGAS/CONVENTIONAL-UNCONVENTIONAL/Pages/default.aspx.

[6] Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules, http://www.michigan.gov/lara/0,4601,7-154-35738---,00.html (proposed January 14, 2015) (to be codified at Mich. Admin. Code r.324.1402).

[7] Michigan Department of Environmental Quality, Supervisor of Wells Instruction 1-2011 (2011), *available at* http://www.michigan.gov/documents/deq/SI_1-2011_353936_7.pdf (effective June 22, 2011). Michigan.

[8] The proposed rules provide the following definition of high volume hydraulic fracturing: “High volume hydraulic fracturing" means a hydraulic fracturing well completion operation that is intended to use a total volume of more than 100,000 gallons of primary carrier fluid. If the primary carrier fluid consists of a base fluid with 2 or more components, the volume shall be calculated by adding the volumes of the components. If 1 or more of the components is a gas at prevailing temperatures and pressures, the volume of that component or components shall be calculated in the liquid phase.” Office of Oil, Gas, and Minerals, Oil and Gas Operations, Proposed Rules, http://www.michigan.gov/deq/0,4561,7-135-3306_57064---,00.html (proposed January 14, 2015) (to be codified at Mich. Admin. Code r.324.1402).

[9] Michigan Dept. of Natural Res., Sample Oil and Gas Lease (revised Apr. 3, 2012), *available at* https://www.michigan.gov/documents/dnr/OilAndGasLeasePR4305_183829_7.pdf.

[10] Canadian Association of Petroleum Producers. Conventional & Unconventional. Calgary (AB):Canadian Association of Petroleum Producers; 2014 [accessed 2014 September 26]. http://www.capp.ca/CANADAINDUSTRY/NATURALGAS/CONVENTIONAL-UNCONVENTIONAL/Pages/default.aspx.

APPENDIX B: ADDITIONAL ISSUES

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B1. OVERVIEW

Drawing again from the range of public comments received during this project, this appendix provides a scan of topics relevant to natural gas (shale gas) development in Michigan but not necessarily specific to high volume hydraulic fracturing (HVHF). This includes a range of environmental impacts, air quality concerns, landowner and local community impacts, as well as agency capacity and financing issues. For these issues, approaches from other states and findings from key reports are provided, but an in-depth options analysis, as was done with the chapters on public engagement, water resources, and chemical use, is not provided. It is important to stress that the example approaches highlighted are not comprehensive. Additionally, the approaches presented are intended only to highlight possibilities, and inclusion does not indicate a recommendation.

Topics for the following sections (environmental impacts, air quality concerns, landowner and local community impacts, and agency capacity and financing) were identified based on key concerns about and potential impacts from hydraulic fracturing identified in the public comments, as well as the integrated assessment technical reports, media releases, and scientific literature. Unlike the topics addressed in the analysis of policy options in Chapters 2 – 4 of the full report, the topics here are not specific to HVHF. Rather, they are relevant to unconventional shale gas development more generally and include other steps in the gas development process. Once the primary impacts and concerns were identified, resources were consulted in order to develop a list of approaches to address these concerns. These approaches include existing and proposed state oil and gas regulations from other states, policy analyses and interpretations from legal scholars and non-profit organizations, and articles published in academic journals. Industry groups such as the American Petroleum Institute have also developed resources and guidelines for hydraulic fracturing.[1]

B2. ENVIRONMENTAL IMPACTS

The entire shale gas development life cycle has the potential to adversely impact ecosystems in numerous ways. In addition to the potential for environmental impacts from chemical usage, water withdrawals and contamination, waste management, and emissions to air and soil described elsewhere in this report, shale gas development can have other adverse impacts, such as habitat fragmentation or the introduction of invasive species. Although little of the current literature surveyed mentions habitat disruptions as a prominent part of the discussion around environmental impacts of hydraulic fracturing, there can indeed be impacts to local flora and fauna.[2,3] As part of the site preparation stage–when land is cleared and infrastructure constructed–there is a consensus among a wide variety of experts surveyed by Resources for the Future as part of the Managing the Risks of Shale Gas project (which included academic, industry, government, and NGO experts), as well as support in the academic literature, that habitat fragmentation is a possibility and concern.[4,5] Other environmental impacts are possible as equipment and water are brought in from distant locations. Invasive species, which can disrupt normal ecosystem functioning, are of particular concern.[6] Finally, increased levels of light and noise from operations can cause disturbances–especially around reproduction, rest, and feeding–for flora and fauna, potentially leading to disruptions within ecosystems.[7]

Currently in Michigan, state regulations require the Department of Natural Resources (DNR) and Department of Environmental Quality (DEQ) to evaluate potentially sensitive areas for impacts to wildlife, water, and other areas of concern before issuing gas development permits.[8] Additionally, the state's permitting process (which includes both the DNR for well-site permits for state-owned surface land and the DEQ for drilling permits[9]) sets out a number of specific site requirements, such as, although not limited to: setback distances, the use of silt curtains, covering pervious ground in plastic, and using native species to reclaim the site after operations have completed.[10] Table B.1 offers a range of policy approaches addressing environmental impacts. For each topic, a description of current practice in Michigan is included first.

Table B.1: Environmental impacts – additional policy approaches

Issue	Example policy approaches	Source
Habitat loss and fragmentation	*Michigan: The state sets forth a number of requirements for hydraulic fracturing operations to reduce their potential impacts, including constructing the well-pad at least 1,320 feet from the nearest stream (for state leases) and the use of an 'optimal' location for private properties.[11]*	
	Require a minimum 300 foot aquatic habitat setback, with the distance measured from the edge of any land disturbance (not from the location of a particular wellbore) to the edge of a particular habitat	Best Management Practices / Recommendations[12]
	Minimize well pad size, cluster multiple well pads, and drill multiple wells from each pad to minimize the overall extent of disturbance and reduce fragmentation and associated edge effects	Best Management Practices / Recommendations[13,14]
	Co-locate linear infrastructure as practicable with current roads, pipelines, and power lines to avoid new disturbances; when possible, existing roads should be used.	Best Management Practices / Recommendations[15]
	Surveying and data collection to choose the least environmentally sensitive site from which the target formation may be effectively accessed – to reduce land use conflicts and/or absolute magnitude of ecological impact	Best Management Practices / Recommendations[16]

	State agencies must consult with the relevant state oil and gas commission, the surface owner, and the operator on a location assessment when the proposed location will be within areas of known occurrence or habitat of a federally threatened or endangered species; also if the operator requests an increase in well density to more than 1 well per 40 acres	Current rules and regulations in Colorado[17]
	A written E&S (environment and safety) plan required if disturbing 5,000 ft^2 or more in total, or if activity has the potential to discharge to high quality water	Current regulation in Pennsylvania[18]
	Establish 'sensitive habitat areas' – gas projects proposed within such zones must first receive approval from the appropriate state agency (such as Parks & Wildlife, Department of Natural Resources, etc.)	Current regulation in Colorado[19]
	In high value/high risk watersheds, impose a cap (for instance, 2%) on cumulative surface development (including all well pads, access roads, public roads, etc.)	Best Management Practices / Recommendations[20]
Flora and fauna	*Michigan: The state prohibits the intentional depositing of non-native invasive species, and it requires well-site owners to reclaim the site using native species of vegetation after site operations have ended.*	
	Applicants for drilling permits must submit a plan with every well application for preventing the introduction of invasive species and controlling any invasive that is introduced. Plans should include: • Flora/fauna inventory surveys • Procedures for avoiding transfers of species • Interim reclamation following construction/drilling • Annual monitoring/treatment of new invasive species as long as well is active • Post activity restoration to pre-treatment community structure and composition	Best Management Practices / Recommendations[21]
	Establish habitat- and land area-specific requirements for operators, such as: • Treating water pits that could breed mosquitos with Bti to prevent the spread of West Nile Virus to wildlife • Installing and using bear-proof dumpsters in black bear habitat • Disinfecting water suction hoses and water transportation tanks in designated Cutthroat Trout habitat	Current rules and regulations in Colorado[22]
	Master Leasing Plans (MLPs), issued by the Bureau of Land Management – focused primarily on the American west, MLPs identify large blocks of unleased federal	Current Bureau of Land Management rule (Master Leasing Plans)[23]

	lands with high mineral potential and high recreational/wildlife value. They place some lands off-limits to leasing while requiring that others be developed in phases, with tighter pollution controls or lower densities of roads and well pads.	
Soil	*Michigan: The state requires those applying for DEQ drilling permits to also file a soil erosion and sedimentation control plan, which describes when erosion control structures are needed, and requires applicants identify any such structures that they will use.*	
	For activities that involve "earth disturbance" (including gas drilling), require developers to implement and maintain a series of best management practices for minimizing accelerated erosion and sedimentation	Current regulation in Pennsylvania[24]
	Michigan: Michigan has several requirements related to soil protection for shale gas operations, such as avoiding hillsides, using silt curtains, and covering pervious grounds in plastic to contain any spillage.	
	Lay reusable mats over well pad site and planned access routes (rather than laying gravel) - reduces risk of erosion damage, reduces risk of soil and surface water contamination, and also speeds the reclamation process once well is put on production	Best Management Practices / Recommendations[25]
Miscellaneous	Reuse of drilling fluids and muds ("closed-loop drilling") - reduces solid waste, and could reduce truck traffic, and therefore air emissions, noise, and road damage	Best Management Practices / Recommendations[26]
	Comprehensive Development Plans (CDPs) – refer to *B4. Landowner and community impacts*	

B3. AIR QUALITY

Most stages of the shale gas exploration and production process, along with the supporting logistics and infrastructure have the potential to impact air quality. Pollutants that have been connected with shale gas operations in Michigan and in other states include nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), volatile organic compounds (VOCs), methane, diesel, hydrogen sulfide, and crystalline silica.[27] Indeed, these pollutants are "known to have a range of adverse effects on human health," as well as negative impacts to ecosystems.[28] While workers at well sites likely have the greatest potential for exposure to the widest variety of air pollutants, impaired air quality at the local and regional levels is possible.[29] Broadly speaking, there are two main sources of air emissions: on-site activities and transportation. On-site activities that can produce emissions include the use of motors and engines, shale gas leaks, and compounds mixed in with the fracturing fluid, among others. On the transportation side, the creation and use of access roads can lead to increased levels of dust and dirt being sent airborne, and the use of fossil fuel powered trucks to transport materials to and from drill sites also has the potential to generate air emissions.

The federal government and the State of Michigan both have regulations that govern various types of airborne emissions from on-site and off-site sources. For instance, on the federal level, the EPA has published rules under the Clean Air Act, which are meant to control VOC and methane emissions.[30] To comply with these new rules, operators are currently allowed to either flare on-site VOCs and methane or capture them using green completions, but beginning January 1, 2015, all operators must use green completions.[31] Green completions refer to the process of capturing gasses and hydrocarbon liquids that would otherwise be vented or flared into the atmosphere. These captured gasses can then be used commercially or otherwise, thereby reducing atmospheric emissions and providing additional economic opportunities.[32] While Michigan does not mandate any technology or process for VOC emissions control, some operators in the state nonetheless already employ techniques similar to green completions, in order to prevent lost gas and lost revenue.

The State of Michigan has several regulations that are applicable to shale gas development and associated impacts to air quality. Operators are required to burn, process, or dispose of gas from operations if it is not going to be utilized.[33] Generally, operators choose to burn the gas through flaring,[34] though the EPA's new rule will likely change this. Flowback liquids are also prohibited in Michigan from being stored in open pits,[35] preventing emissions through evaporation. Michigan's oil and gas rules also prohibit creation of a "nuisance odor,"[36] defined as "... an emission of any gas, vapor, fume, or mist, or combination thereof, from a well or its associated surface facilities, in whatever quantities, that causes, either alone or in reaction with other air contaminants, injurious effects to human health or safety; unreasonable injurious effects to animal life, plant life of significant value, or property; or unreasonable interference with the comfortable enjoyment of life or property."[37] The rules also require an operator to report a condition that may cause a nuisance odor.[38] Additionally, Michigan regulations prohibit gas operations to begin or to continue at a location where "it is likely that a substance may escape in a quantity sufficient to pollute the air…"[39] There are also multiple Michigan regulations that specifically target hydrogen sulfide (H_2S).[40]

Gas operations in Michigan may also be subject to air quality permitting requirements. An Air Quality Permit to Install is required for oil and gas facilities if total potential emissions of criteria pollutants or VOCs exceed specified thresholds.[41] There are exemptions for certain pieces of oil and gas equipment if they meet prescribed criteria[42]; however, the overall thresholds generally apply.[43] An Air Quality Renewable Operating Permit is required for any facility that has the potential to emit 100 tons per year of lead, sulfur dioxide, nitrogen oxides, carbon monoxide, PM-10, PM-2.5, ozone, or volatile organic compounds; or that exceeds prescribed levels of greenhouse gas emissions or one or more hazardous air pollutants.[44]

Table B.2 offers a selected list of strategies for addressing air quality concerns. These strategies include proposed and current legislation and performance standards.

Table B.2: Air quality impacts – additional policy approaches

Issue	Strategy	Example policy approaches	Source
On-site emissions	Monitoring	*Michigan: Routine ongoing air sampling for oil and gas facilities not required; however, DEQ staff conduct on-site monitoring on a case-specific basis whether a specific air quality permit is or is not required.*	
		Require gas developers to reduce or eliminate “air emissions” during drilling and production, as well as to monitor and report air quality for pollutants regulated under the federal Clean Air Act or Arkansas law if: 1. Drill pad is within 1,000 feet of a habitable dwelling 2. Arkansas Department of Environmental Quality determines there is a reasonable risk of air pollution from multiple wells being located in the same area	Arkansas House Bill 1395[45]
		Department of Environmental Quality required to provide air monitoring to residents who complain about air quality within 10 days.	Arkansas House Bill 1395[46]
		Operators required to test and monitor for fugitive emissions (specifically methane and VOCs) - which generally come from leaking valves or connectors - quarterly, and are required to develop and implement a leak detection and repair program.	Ohio EPA rules[47]
	Technology	*Michigan: Michigan currently restricts flares in residential areas,[48] and prohibits flaring of gas from Salina-Niagara wells,[49] but otherwise does not require specific technological interventions to manage air emissions.*	
		Convert drilling rig engines at the well pad that are powered by diesel to another fuel source, such as dual-fuel, electricity, or natural gas.	Center for Sustainable Shale Development performance standards[50]
		Activities or materials (such as produced water tanks, etc.) that produce above 5 tons/year of VOCs and that are within 1,320 feet of a building must use an emissions control device and obtain a special permit from the Department of Public Health and Environment.	Current Colorado rules and regulations[51]
		All gas must be captured and put to a beneficial use (e.g., directed into a pipeline or used for onsite energy generation) unless it	Current Illinois law (Illinois Hydraulic Fracturing Regulatory

		can be demonstrated that it would be technically or economically infeasible to do so.	Act)[52]
	Reporting	*Michigan: Permit holders are required to record and report all "reportable" losses, spills, and releases of natural gas and products/chemicals used in association with oil and gas exploration, production, disposal, or development*	
		Any gas analysis that indicates the presence of hydrogen sulfide (H_2S) gas must be reported to the oil and gas commission and to the 'local governmental designee.'	Current Colorado rules and regulations[53]
Off-site emissions	Performance Standards & Mandates	*Michigan: Michigan does not currently require performance standards or mandates beyond federal requirements for air emissions from shale gas development.*	
		Trucks used to transport fresh water or well flowback water must meet EPA's Final Emission Standards for 2007 and Later MY Highway Heavy-Duty Vehicles and Engines for particulate matter emissions.	Center for Sustainable Shale Development performance standards[54]
		All on-road vehicles and equipment must limit unnecessary idling to 5 minutes or otherwise follow local laws if they are more stringent.	Center for Sustainable Shale Development performance standards[55]
		Operators must employ practices to control fugitive dust (for example: speed restrictions, regular road maintenance, restriction of construction activity during high-wind days, etc.).	Colorado rules and regulations[56]
	Technology	*Michigan: Michigan does not currently mandate any technological standards or interventions for managing off-site air emissions connected with shale gas development.*	
		Trucks must be required to use ultra low sulfur diesel for fuel.	Center for Sustainable Shale Development performance standards[57]

B4. LANDOWNER AND COMMUNITY IMPACTS

In addition to concerns about impacts to air and water, other primary areas that could potentially impact communities and landowners include noise, light, aesthetics, and traffic, which (with the exception of aesthetics), could all also have human and ecological health implications.[58] As shale gas exploration and development activities increase, there is generally an accompanying influx of machinery and people. The machinery used at and around well sites is frequently powered by diesel or similar motors, which, in addition to generating air emissions, also generate noise. The operating hours of well sites can vary in areas without local or other ordinances governing noise levels, with some potentially operating outside of daylight hours. When operations take place after dark or otherwise in low-light conditions, artificial lighting is usually used.[59,60] Depending upon the type of lighting used, generators could contribute to elevated noise levels, and light could travel beyond the boundaries of the well site.

Sites are not always located directly on or near existing roads, so operators will sometimes create access or service roads in order to allow equipment, personnel, and trucks to get to and from the sites. These roads have been connected with increased levels of well site traffic,[61] in addition to potentially adverse environmental consequences.[62] The increase in traffic connected with shale gas development can impact areas differently. In some communities with ample resources, such an increase may have negligible consequences, while in other communities (especially those in which residents already experience barriers–geographical, financial, or physical–to community services[63]) such an increase could have significant negative impacts on traffic control, road maintenance, parking, and other traffic related issues. In Michigan, this may be of greater relevance, considering the state's ranking as 50th out of 50 states for spending on road maintenance and quality.[64] In Texas, for instance, which is home to the Eagle Ford shale play, roads in the region have been pushed to their limits, resulting in up to a 40 percent increase in traffic fatalities in 2012 alone. However, in early November 2014, a legislatively-referred constitutional amendment passed, and some revenue from the state's oil and gas taxes will go the state's Department of Transportation, to help alleviate some of the financial constraints on road repair.[65]

Finally, aesthetic concerns have also surfaced surrounding the visibility of well sites and their associated operations.[66,67] There have been reports and claims of equipment and machinery, pipelines, and access roads all interfering with residents' "viewsheds".[68] As well site density increases in certain productive regions, greater quantities of these visual disruptions may be expected to appear, unless steps are taken to reduce their visual impact.

At the landscape scale, with shale gas development occurring on separate tracts of private land, there is risk of development occurring in an uncoordinated way that results in excessive impacts. These might include additional, unnecessary truck routes; the needless conversion of land to support oil and gas infrastructure; the resulting loss of wildlife habitat or agricultural land; altered landscape views; wear and tear on roads; and other sensory disturbances. To encourage more efficient development, several states have called for Comprehensive Development Plans (CDPs). CDPs encourage a more holistic approach to unconventional shale gas development by considering the cumulative impacts to the landscape.

Before considering the laws and regulations currently on the books in Michigan governing shale gas development and its associated community impacts, it is important to note that the State of Michigan's Zoning Enabling Act prevents townships and counties from "regulating the drilling, completion, operation, abandonment and location of oil and gas wells and other wells associated with oil and gas exploration".[69] That regulatory authority falls to the DEQ Office of Oil, Gas and Minerals (OOGM).[70] Additionally, since the DEQ receives exclusive regulatory authority in the oil and gas section of the Michigan Natural Resources and Environmental Protection Act, it appears that village and city regulation of oil and gas activities might also be pre-empted.[71,72] However, this is not to suggest that local governments have no authority in regulating shale gas development. In fact, some communities have been aggressive in their use of zoning districts and special use standards to limit oil and gas processing, since the processing, refining, and transportation of oil and gas (at least in between the drilling site and a Michigan Public Service Commission regulated pipeline) *is* something over which local governments have authority.[73] Indeed, some interpret current statutes and Michigan law as enabling local governments to regulate certain community impacts, including hours of operation, noise levels, dust control measures, traffic, transportation, and other risks or impacts from shale gas development, under the police powers to regulate health, safety, and welfare.[74] It is important to note however, that this interpretation has not yet been tested in the courts, and may or may not hold up.

Michigan does already have several state laws in place to protect residents against nuisances, in particular noise and odor. In addition to extensive regulations detailing the proper treatment of hydrogen sulfide containing wells,[75] the state's oil and gas regulations prohibit the creation of a 'nuisance odor' during any phase of the shale gas lifecycle.[76] Michigan also requires that pumps or pump jacks located in residential areas either be powered by electricity or otherwise have powerful mufflers to reduce their noise.[77] The regulation specifically requires that the residential area must have been zoned so before January 8, 1993, and the pumps/pump jacks must have been installed after the effective date of the oil and gas rules.

Michigan more generally prohibits the creation of a 'nuisance noise' from the production, handling, or use of shale gas or brine, or any product associated with them.[78] While these regulations do not require action be taken if any complaints are received, it does grant authority for the site supervisor to require the permittee (i.e., the operator) to collect noise-level readings. The law also creates specific definitions for what constitutes a 'noise-sensitive area,' and what constitutes a 'nuisance noise.' Table B.3 lists a range of approaches for addressing landowner and community impacts.

Table B.3: Landowner and community impacts – additional policy approaches

Issue	**Strategy**	**Example policy approaches**	**Source**
Noise	Administrative	*Michigan: The state lays the responsibility upon the site supervisor for preventing regular/recurring nuisance noise (and odor) in the exploration or development, production, or handling of gas.[79] Additionally, many local governments in Michigan have established maximum noise level thresholds (in decibels) for various municipal zones.*	
		Establish specific max decibel levels for residential/agricultural/rural, commercial, light industrial, and industrial zones (for instance, in Colorado, the limits range from 50 to 80 db between 7 p.m. and 7 a.m. depending on the zone)	Current rule/regulation/law in: Colorado[80,81] Arkansas[82] Farmington, New Mexico[83] Arlington, Texas[84]

		Restrict hours and times of operation to avoid or minimize conflicts	Maryland best management practices / recommendations[85]
	Monitoring	*Michigan: The state does not formally require monitoring for ambient noise levels; however, if a site supervisor receives one or more complaints of noise, the supervisor may require the permit holder to collect decibel readings to determine the noise level.*	
		Require a measurement of ambient noise levels prior to operation	Maryland best management practices / recommendations[86]
	Technology	*Michigan: If a determination is made of a nuisance noise emanating from the well-site, the site supervisor may, at their discretion, require noise control measures. If this happens, then the permit holder must submit an abatement plan and schedule for implementation. Additionally, the state lays out several constructions standards for noise abatement, including requiring that compressor motors rated for more than 150 horsepower be completely enclosed, that the interior of the enclosure be lined with sound-absorbent material, and that the compressor drive motor be equipped with a hospital-type muffler.*[87]	
		Require all motors/engines to be equipped with appropriate mufflers	Maryland best management practices / recommendations[88]
		Construct artificial sound barriers where natural noise attenuation would be inadequate (also see Aesthetics strategy below)	Maryland best management practices / recommendations[89]
		Require electric motors instead of diesel-powered equipment for any operations within 3,000ft of an occupied building	Maryland best management practices / recommendations[90]
Light	Technology & Administrative	*Michigan: The state has not established any formal requirements related to well site lighting; however, the OOGM will commonly impose permit conditions on lighting and screening, on a case-by-case basis.*[91]	
		Night lighting should be used only when necessary, directed downward, be shielded, and make use of low pressure sodium light sources when	Maryland best management practices / recommendations[92]

		possible	Current rules and regulations in Colorado[93]
Traffic	Administrative	*Michigan: The state does not have formal requirements related to trucking activities connected with shale gas operations.*	
		Site preparation, well servicing, truck deliveries of equipment and materials, and other related work conducted on the well site must take place between 7am and 6pm	Current regulation in Arlington, TX[94]
		If the well is to be established within a "Designated Setback Location," (if it's within an established buffer zone, exception zone, or urban mitigation area) then it must include a traffic plan (coordinated with the local jurisdiction, if required), prior to commencement of move in and rig up	Current rules and regulations in Colorado[95]
		Operators must submit transportation plans, which could include proposed truck routes, trucks' estimated weights, evidence of compliance with weight limits on streets, a bond and excess maintenance agreement to ensure road repairs, evidence that intersections on proposed routes have sufficient turning radii, baseline assessments of road conditions, etc.	Current rules/regulations/law in: Collier Township, Pennsylvania[96] New York[97]
	Technology	*Michigan: The state does not have formal requirements related to trucking activities connected with shale gas operations.*	
		Reduce the number of required truck trips by: • Making use of centralized pumps and impoundments with pipes, used to hydraulically fracture multiple surrounding sites ("centralized fracturing") • Installing temporary pipes to transport large volumes of water for short-term needs (such as HF)	Best management practices / recommendations[98]
Aesthetics	Miscellaneous	*Michigan: Michigan currently has setback requirements for wells and facilities from occupied structures (300 feet in*	

		general[99] and 450 feet in townships over 70,000[100]), which are in part intended to address aesthetic issues.[101] Otherwise, there are no other formal requirements related to aesthetics or visual impacts connected with shale gas development or production activities.	
		Production facilities that are observable from a public highway must be painted with uniform, non-contrasting, non-reflective color tones, matched and slightly darker than the surrounding landscape	Current rules and regulations in Colorado[102]
		Natural gas producers and operators are using large fences, made up of steel frames and neutral-colored fabrics to provide a buffer between equipment and ecologically sensitive or residential areas. The walls can help companies comply with the state's noise limits, and are being considered for wildlife habitat where operations might otherwise interfere.	Current practice in Colorado[103]
		Natural gas producers can include 'nuisance easements' as part of their lease agreements with landowners – offering them compensation in exchange for permitting specific nuisances, such as visual impacts, noise, light, or odors.	Current practice in Pennsylvania[104]
Odor	Administrative	*Michigan: The state has established detailed regulations surrounding nuisance odors connected with wells that produce hydrogen sulfide, including requiring the permit holder to conduct numerical modeling to determine H2S concentrations in the air and empowering the site supervisor to require emission control measures for hydrogen sulfide. More generally, the site supervisor is also required to prevent regular or recurring nuisance odor in the exploration for or development, production, or handling of gas.[105]*	
		If a person who resides or works on a nearby property complains of an odor, the company must meet with the Township to establish an effective "odor control plan," and the operator must pay for investigative costs associated with assessing the odors	Current regulation in Collier Township, Pennsylvania[106]
		Companies must take all precautions	Current regulation in

		to minimize odors perceptible on property within 500 feet of the well-site while drilling and fracking	Collier Township, Pennsylvania[107]
Other	Monitoring	Recently released guidelines to help local governments better understand the socioeconomic impacts caused by energy development, and support requests to industry and state government for assistance to implement appropriate mitigation. Covers population growth and worker residency patterns; employment, personal income, and local business effects; cost of living and housing; service, infrastructure, capacity, and revenue, and quality of life and other local concerns.	Headwaters Economics[108]
	Comprehensive Planning	Encourage well operators to submit a Comprehensive Development Plan (CDP) considering cumulative landscape impacts when they will either be drilling multiple wells within an area or when they know other operators will be drilling in the same area; future well permits that are covered by the CDP are offered priority processing.	Current voluntary rule in Colorado[109]
		Make a Comprehensive Gas Drilling Plan (CGDP) a prerequisite to receiving a well permit. Operators would be allowed to drill one exploratory well within a 2.5 mile radius, and a CGDP would be required for any additional exploratory or production. Plan would be subject to a mandatory public review and approval process.	Maryland best management practices / recommendations[110]

B5. AGENCY CAPACITY AND FINANCING

In most states, regulatory and oversight authority of hydraulic fracturing operations resides within state agencies, such as the DEQ and DNR in Michigan. At various points in time, agencies such as these, as well as others nationwide, have faced different types of challenges related to their capacity to properly carry out their responsibilities.

In late 2013, the Office of the Auditor General for the State of Michigan conducted a performance audit for the Office of Oil, Gas, and Minerals (OOGM) – the office within the state's DEQ that is largely responsible for shale gas wells and hydraulic fracturing operations. Their audit concluded that while the OOGM was at least moderately effective at executing their responsibilities, there was room for improvement in a few key areas. First, the audit showed that the OOGM did not complete field inspections of all well sites at the frequencies specified in OOGM policy and procedure. The number of wells that were inspected at the target frequency ranged from 31.5% (for producing wells) to 93.9% (for plugged wells).[111]

Next, the audit found the OOGM to be moderately effective at promoting compliance with relevant regulations. The audit specifically examined two types of special agreements into which the OOGM enters: stipulation and consent agreements (SCAs) and transfer settlement agreements (TSAs). If a violation is reported or uncovered at a well site, SCAs give the permit holder of the well an opportunity to resolve the alleged violation by a specified deadline. TSAs allow the permit holder to transfer a violated permit to another party, while giving the new party a chance to fix the problem. The audit found that OOGM did not always enter into these agreements in a timely manner, nor did they always enforce all the terms–such as assessing fines and penalties–and as a result, environmental concerns were allowed to exist for extended periods of time and the OOGM neglected a potential revenue source (for instance, only nine wells in violation could have been assessed over $350,000).[112]

The audit also revealed that current state law does not provide for bond amounts sufficient to cover OOGM's costs of plugging a well. In some instances, OOGM is responsible for stepping in and plugging a well, generally if it has been abandoned or as part of an enforcement action. To cover the costs connected with plugging nonproductive wells, permit holders pay a surety bond. However, current bond amounts do not sufficiently cover the costs, and OOGM itself may have to pay, potentially putting a strain on its financial resources.[113] Finally, the audit found a lack of inter-agency coordination. In particular, while the Michigan Department of Treasury is responsible for collecting a severance tax from shale gas producers or transporters, they do not know the total number of active wells, if production was being reported for all active wells, and the production totals reported to OOGM. Without this information, the Treasury could not properly ensure that severance taxes and privilege fees were accurately calculated. While the audit noted variances of less than 2% when they reconciled the production and sales totals provided to both agencies, they also noted that the two agencies did not coordinate any effort to reconcile gas amounts on a monthly, quarterly, or annual basis.[114] For all of these findings, the DEQ issued a preliminary response indicating that it agreed with the recommendations.

Michigan has also been subject to external audits. In 2002 (admittedly before HVHF operations had commenced in Michigan), a multi-stakeholder organization known as STRONGER (State Review of Oil and Natural Gas Environmental Regulations, Inc.), which formed from the Interstate Oil and Gas Compact Commission (IOGCC), conducted a review of Michigan's oil and gas exploration and production wastes against a series of guidelines from 2000.[115] This review found that the DEQ had a well-managed oil and gas environmental regulatory program, which met, and in some instances exceeded the 2000 guidelines.[116] Some of the highlights of this review include the presence of a robust contingency plan, strong public participation, well-trained personnel, and thorough regulations concerning pits, tanks, and abandoned sites.[117]

A critical part of empowering state agencies to effectively manage shale gas operations and activities is ensuring that the needed funds are available for all of the agency's activities. Below is a table that shows the level of OOGM staffing and budget for the past several years.[118,119,120,121,122] Staffing and budget have remained essentially static and Michigan thus far has seen limited HVHF activity.

Table B.4: Michigan OOGM staffing and budget, 2010-2014

FY (Ending Sept. 30 of the following year)	FTE	Annual Budget
2010	60.0	$11,173,600
2011	60.0	$11,176,500
2012	61.0	$11,670,400
2013	61.0	$11,916,700
2014	61.0	$12,031,900

In Michigan, the state receives revenue from gas extracted on its property in three main ways: royalties, fees, and taxes.[123] With a couple exceptions, royalties are calculated as a proportion of the gross revenue from the sale of gas (one-sixth of the gross revenue). The state also receives payments from producers for the right to explore and establish a well pad on state property – these are generally arrived at by auction and direct negotiation, and so do not have a set rate.[124] Additionally, the state receives payments for the underground storage of gas for later use. In Michigan gas extracted from private land is subject to two income taxes: the severance tax and the privilege tax. The severance tax is fairly stable over time, since it is adjusted by statute (in 2012, it was 5%). The privilege tax is used primarily to pay for the regulation activities of the DEQ, and is adjusted annually (in 2010 it was 0.0029%).[125]

The funds collected through these taxes, royalties, and other fees go to different end uses. A large proportion goes to finance state land development, in the form of the Michigan Natural Resources Trust Fund. This fund is intended to finance improvements on state-owned land to protect scenic areas and for recreational use. When the ceiling for this fund ($500 million) is reached, the remainder is allocated to the Michigan State Parks Endowment Fund, the Michigan Game and Fish Protection Fund, and the state general fund.[126] For additional information on the economics of hydraulic fracturing in Michigan, see the Economics Technical Report from an earlier phase of this project.[127]

Outside of Michigan, states vary in how they tax and otherwise generate enough revenue from shale gas development to ensure that communities are compensated for the infrastructure and other impacts that such development may have. According to the National Council of State Legislatures, as of 2012, thirty-five states had fees or taxes on oil and gas production. These severance taxes generally are calculated as a fraction of the market value of the gas, the volume produced, or some combination.[128] Taxes on the volume of gas produced are relatively simple to implement, but do not generally reflect price fluctuations in the same manner as value taxes. Value taxes– taxes on the market value of the produced gas–can be difficult to implement due to the close monitoring of the market that is required, and are generally applied at the point of production, before accounting for transportation and distribution costs.[129] To overcome the challenge of constant monitoring, states such as Colorado and Illinois instead tax the gross income from the produced gas.[130]

While severance taxes may currently be the most common form of taxation on shale gas development, certain states have opted to take different approaches. Pennsylvania, for instance, is the largest natural gas producer that does not impose a severance tax. Instead, it charges an impact fee on every producing gas well in the state, regardless of the volume produced.[131] For comparison, studies suggest that a 5% tax on production value would yield nearly $800 million for the state by 2015, while the impact fee will yield approximately $237 to $261 million.[132]

Several states have likewise been subject to audits from STRONGER and other agencies which have addressed hydraulic fracturing. Examples of how other states are facing the issues of agency capacity and financing are provided in Table B.5.

Table B.5: Agency capacity and financing – examples from other states

Source	**Review finding or recommendation**
Pennsylvania – 2013 STRONGER report[133]	Review team commended PA Department of Environmental Protection (DEP) for increasing its staff levels to address additional permitting, inspection and enforcement activities related to increased unconventional gas well development. Over the past 4 years, as unconventional gas well development increased in PA, the OOGM increased its staff from 64 to 202 employees. Permit fee increases enabled the DEP to expand staffing.
Pennsylvania – 2014 Commonwealth of Pennsylvania Auditor General report[134]	"DEP was unprepared to meet the challenges of monitoring shale gas development effectively." "DEP was unprepared to meet these [environmental and other] challenges because the rapid expansion of shale gas development has strained DEP, and the agency has failed to keep up with the workload demands placed upon it." "Although DEP has…raised permit fees and penalties so that it has the money to meet its mission, these efforts fell short in ensuring DEP was adequately prepared to monitor shale gas development's boom."
Ohio – 2011 STRONGER report[135]	Comprehensive review and change of oil and gas law – Division of Mineral Resources Management (DMRM) conducted a thorough assessment of its oil and gas program since 2000, and as a result, they developed a plan, with stakeholder input, that included revisions to its regulatory program, addressing hydraulic fracturing, funding, staffing levels, and workload priorities, among other things. This plan was used as a guideline in the development of SB 165. Increase in staffing levels – In July of 2000, the Division of Mines and

	Reclamation was merged with the Division of Oil and Gas. Work assignments were shared among staff. More recently, DMRM decided to realign staff into the single program areas. The oil and gas program developed a realignment plan, with stakeholder input, that included an analysis of funding, staffing levels and priority workloads. This plan was used as a guideline in the development of SB 165.
Texas– 2003 STRONGER Report[136]	The average processing time for pit and land farming permit applications is 2-4 months. RRC only has 3 staff to process these applications. They should employ additional personnel for application review, in order to ensure that all applications are processed promptly.

[1] Oil & Natural Gas Overview: Hydraulic Fracturing. Washington (DC): American Petroleum Institute; c2014 [accessed 2014 Nov 12]. http://www.api.org/oil-and-natural-gas-overview/exploration-and-production/hydraulic-fracturing.

[2] Soeder D. The Marcellus Shale: Resources and Reservations. EOS, Transactions American Geophysical Union. 2010;91(32):277–278.

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