National Governors Association

NGA Paper

State Practices to Protect Drinking Water While Developing Shale Energy

Executive Summary

Governors and other state policymakers are at the forefront of efforts to protect drinking water resources from potential risks associated with shale energy development.[1] Those efforts include measures to reduce the quantity of drinking water needed to support drilling operations, address concerns about the potential contamination of ground water and surface water, and mitigate the risks of increased seismicity associated with the use of underground injection wells for wastewater disposal.

The National Governors Association Center for Best Practices (NGA Center) convened an experts' roundtable in March 2015 to examine how states can protect drinking water while developing shale energy. The group of experts included gubernatorial advisors, state regulators, academics, energy industry representatives, environmentalists, and federal officials. This paper summarizes key points discussed at the experts' roundtable, supplemented by NGA Center research. It recommends actions governors can consider when developing protective practices.

State practices to protect drinking water reflect regional differences, the latest developments in technology and science, and recent legislative and regulatory experiences. Governors should examine measures that encompass the following five broad categories when considering actions they can take:

1. Reduce the quantity of drinking water used in hydraulic fracturing:

- Increase the reuse of flowback and produced water for hydraulic fracturing, while balancing consideration of increased risks from waste transport, storage and treatment;
- Direct operators to report the quantity of drinking water used and provide incentives for efforts to reduce;
- Support the use of lower-quality water for drilling;
- Consider market-based pricing of water to encourage water conservation; and
- Modify wastewater liability, with demonstrated good practice, to encourage recycling.

2. Ensure well integrity and plugging to minimize risks to water:

- Require "area of review"' as part of drilling permit for horizontal drilling;
- Update requirements for well construction and require confirmatory tests to account for greater pressure levels used in shale over conventional plays;
- Establish performance standards or variances to give operators greater flexibility;
- Scale financial liability or requirements to cover the potential costs of risks; and
- Engage industry and royalty owners to contribute to well plugging and cleanup funds after drilling is completed.

3. Manage risks of contamination from hydraulic fracturing fluids:

- Require testing of water quality before and after

[1] The term *drinking water* is used in this paper in the broad sense of groundwater and surface water that can potentially be used for drinking water and food preparation. Technical definitions of drinking water vary and reflect different assumptions about the level of treatment that might be needed to meet drinking water standards.

hydraulic fracturing;
- Notify neighboring operators and the public before hydraulic fracturing begins;
- Disclose hydraulic fracturing chemical ingredients by quantity for each well; and
- Consider offering incentives to operators that use lower-toxicity chemicals for hydraulic fracturing.

4. Mitigate risks from wastewater contamination and seismicity:
- Establish buffer zones between well sites and sensitive areas;
- Designate types of materials that can be stored in pits and tanks, in addition to spill-containment measures;
- Require pits to be lined and encourage waste pits and tanks to be equipped with leak-detection systems;
- Increase oversight of wastewater transportation to minimize illegal dumping and dangerous spills from truck accidents and pipeline failures;
- Engage neighboring governors to coordinate plans for managing data about transportation and disposal of wastewater;
- Characterize, manage, record, report and properly dispose of wastewater and treatment residuals;
- Avoid the base rock layer in disposal wells to minimize seismicity risk; and
- Proactively evaluate disposal well management options to reduce seismic risks.

5. Leverage the unique role of the governor to promote protective practices:
- Increase staffing to oversee enforcement of the booming industry;
- Establish program for independent auditors to ease state staffing demands;
- Consider expanding transparency rules to support a better understanding of public health impacts;
- Direct relevant state agencies to identify regulatory gaps and duplication to ensure effective oversight of shale energy development;
- Institutionalize regular external review of regulations and enforcement to continuously improve protective efforts;
- Provide governor's awards for industry best practices;
- Create "bad actor" laws to revoke licenses of problem operators;
- Convene stakeholders for educational dialogue and provide methods for stakeholder input;
- Engage local stakeholders proactively;
- Consider using a risk-based data management system to help the state aggregate and communicate data; and,
- Encourage and fund research to improve the understanding of industry impacts and best practices.

Background

Innovations in hydraulic fracturing and horizontal drilling technologies have driven the rapid development of shale energy resources across the country. Drilling operations are taking place in many new regions and in closer proximity to residential areas. Those changes, combined with the use of potentially harmful chemicals, the release of naturally occurring contaminants, the use of large amounts of water, and the occurrence of seismic events near fracking operations, have raised concerns about potential risks to the quality and availability of drinking water and the potential for induced seismicity. In response, governors and state officials are working to revise their laws and regulations governing drinking water use and protection.[2]

The NGA Center convened an experts' roundtable in Philadelphia, Pennsylvania, on March 5–6, 2015, to identify regionally-appropriate protective practices for protecting drinking water resources while developing

[2] Many state regulations affecting shale energy development are contained within the broader category of *unconventional oil and gas* (UOG), which refers to oil, natural gas, and natural gas components extracted from low-porosity, low-permeability formations. UOG includes shale gas, shale oil, tight gas, and tight oil. The definition changes over time as technology develops. For ease of discussion, this brief uses the terms *shale energy and unconventional oil and gas* interchangeably.

shale energy. The group also identified research questions and examined ways to verify performance. The group of 35 experts included gubernatorial advisors, state regulators, academics, energy industry representatives, environmentalists, and federal officials. This paper summarizes that discussion and is supplemented with NGA Center research. It recommends actions governors can consider when developing protective practices.

Various protective practices are emerging that reflect the latest developments in technology, science, legislation, regulatory changes, and public concerns. The practices address the following five opportunities:

- Reduce the quantity of drinking water used in hydraulic fracturing.
- Ensure well integrity and plugging to minimize risks to water.
- Manage risks of contamination from hydraulic fracturing fluids.
- Mitigate the risks from wastewater contamination and seismicity.
- Leverage the unique role of the governor to promote protective practices.

Broad Considerations for Protective Practices

Governors should examine new policy options with several broad considerations in mind. They need to: understand the particular risks the shale energy industry poses; consider trade-offs among risks; consider regional differences; and incorporate opportunities to verify that industry practices and government policies are achieving their goals.

Understand the Nature of the Risks

In June 2015, the U.S. Environmental Protection Agency (EPA) released a draft study that identified the risks that hydraulic fracturing poses to drinking water resources both above and below ground.[3] The study did not find evidence of widespread systemic contamination but that result should not be viewed as conclusive. Only limited data is available on the effects of hydraulic fracking on drinking water quality that allows comparison between the quality of water before and after hydraulic fracking. In addition, only a limited number of studies address long-term and systematic effects. Other sources of contamination may preclude a definitive link between hydraulic fracturing activities and changes in water quality, and some information on hydraulic fracturing activities and potential effects is not accessible. The potential risks to human health and effects on the environment aside from those on drinking water resources were beyond the scope of the study. The protective practices highlighted in this paper present state policymakers with various options to address the risks and vulnerabilities identified in the study.

A recent survey of 215 technical experts from academia, industry, nongovernmental organizations, and from state and federal governments found a high degree of consensus about the highest priority environmental risks associated with shale gas development.[4] The experts agreed on 15 priority risks, with 12 of them relating to water protection, suggesting priority areas for state oversight. Of those 12 risks, two are unique to shale gas development technologies and processes and 10 are typical of any type of gas and oil development, such as leaks from casings and cement. Leaks from on-site pit or pond storage of flowback water were the most commonly identified risks. Other water-related risks included the quantity of water used, release of wastewater from municipal and industrial treatment plants, storm water flows, storage of fracturing fluids at drilling sites, and the potential for accidents through failures in cement and casings. Although public attention has focused on the risk to groundwater contamination, the experts ranked that as less likely

[3] U.S. Environmental Protection Agency, *External Review Draft of the Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources* (June 2015). p. ES-6

[4] Alan Krupnick, ed., *Managing the Risks of Shale Gas: Key Findings and Further Research* (Washington, DC: Resources for the Future, 2013), http://www.rff.org/rff/documents/RFF-Rpt-ManagingRisksofShaleGas-KeyFindings.pdf (accessed May 25, 2015)

and ranked surface water contamination more likely.

Although most states are moving forward with shale energy development and adopting measures to mitigate risks, some states have determined that development should not proceed until the risks are better understood. The **New York** State Department of Health and Department of Environmental Conservation conducted broad reviews of hydraulic fracturing effects on air, water, public health, ecosystems, wildlife, and community character. The review found a potential for many significant adverse effects and determined that remaining uncertainties about the effects of hydraulic fracking and the effectiveness of some mitigation measures are significant enough to recommend a ban until the risks are better understood and addressed.[5] The state legislature in **Maryland** has adopted a temporary moratorium on hydraulic fracturing that requires the state Department of the Environment to adopt regulations for the practice by October 2016 and bars the state from issuing permits until October 2017.[6] **Vermont** adopted a ban on hydraulic fracturing in 2012.[7]

Consider Trade-Offs Among Risks

Protective practices may reduce some risks but increase others. For instance, encouraging operators to use recycled wastewater for their fracturing process reduces the need for drinking water withdrawals but concentrates pollutants, raising risks if a spill should occur, and may increase the chances of a spill if the process involves trucking wastewater to another site rather than piping it to a disposal location. Similarly, encouraging reduced use of drinking water in the hydraulic fracturing process might lead to the use of higher-toxicity chemicals in fracturing fluids. Those examples illustrate that some protective practices cannot be considered universally, and state officials should carefully evaluate practices in light of the potential trade-offs among risks.

Consider Regional Differences

The development of shale oil and gas currently takes place in 27 states over a range of geologic, hydrologic, climatic, and regulatory conditions. States will want to keep in mind that what constitutes a protective practice differs across sites based on those varying conditions. For example, regions that have high amounts of rainfall may want to consider how the risks of wastewater pits compare to those for tanks; those in tornado regions need to examine their unique set of challenges to wastewater storage. Some regions have extensive pipeline infrastructure while others do not and may therefore face an increased risk of spills from the transportation of oil, gas and wastewater. Some regions have naturally occurring radioactive materials in wastewater while others do not. In light of those and other variations, states should consider how to tailor protective practices to their region.

In some instances, states need to consider whether more stringent regulations used in one region improve the protective value of current practices in another area in the absence of clear scientific direction. For example, appropriate setback distances from oil and gas activity can be informed by site-specific information and vary based on the local geology and hydrology, the ecological sensitivity of the resource, and the potential effect of the activity. A larger setback between a drilling well and an ecologically sensitive area might be assumed to be more protective, but currently, there is no standardized optimal setback distance for protection. In such instances, states need to balance the basic principle that setbacks offer protections with the recognition that larger setbacks come with resource development trade-offs and do not necessarily increase protection for the environment in proportion to the setback distance.

Ensure Implementation

Policymakers can adopt measures to verify that

[5] New York State Department of Health, *A Public Health Review of High Volume Hydraulic Fracturing for Shale Gas Development*, (December 2014). (accessed June 9, 2015) http://www.health.ny.gov/press/reports/docs/high_volume_hydraulic_fracturing.pdf
[6] Maryland General Assembly, House Bill 449, (May 30, 2015), http://mgaleg.maryland.gov/2015RS/bills/hb/hb0449f.pdf (accessed June 23, 2015).
[7] Vt. Stat. Ann. tit. 29, § 571, http://legislature.vermont.gov/statutes/section/29/014/00571 (accessed June 23, 2015).

protective practices are being implemented and achieving their goals. Adopting new monitoring technology coupled with transparency measures allows both industry and states to increase public confidence that responsible development is occurring. For instance, states can require or provide an incentive for operators to use alarms on wastewater pits or tanks that are triggered by sensors; those alarms alert operators or regulators by telemetry when a leak occurs. Operators can be encouraged to use independent auditors to document the use of industry best practices in exchange for state regulators granting them expedited permitting. State officials can help the public understand the risks of shale energy development by disclosing data and providing additional context for the data by, for example, describing how chemical levels found in a well compare to naturally occurring levels and what health risks may exist.

State Protective Practices to Protect Drinking Water While Developing Shale Energy

With the above broad considerations in mind, governors should consider the following practices for protecting drinking water while developing shale energy resources. The practices include examples that are underway in at least a few states or are recommendations from experts that state policymakers could consider adopting.

Reduce the Quantity of Drinking Water Used in Hydraulic Fracturing

The development of shale gas is less water-intensive than coal, nuclear or oil,[8] but nearly half of U.S. shale gas and oil wells are being developed in counties that have high water stress.[9] Governors can look at the following protective practices to reduce drinking water use:

- **Increase the reuse of flowback and produced water for hydraulic fracturing, while balancing consideration of increased risks from waste transport, storage and treatment.** By reusing wastewater from hydraulic fracturing in multiple rounds of drilling, industry can reduce its use of new drinking water. Only freshwater should be used for the initial drilling until the protective casings are installed. **Illinois** recently passed a law allowing for the use of produced water in hydraulic fracturing fluids. To address the increased risk of accidents, the state set waste management and storage standards, including the thickness of pit liners and having secondary containment for tanks.[10] **New Mexico** passed a rule to encourage the recycling of produced water while establishing new procedures for managing waste transport and recycling containments.[11]

- **Direct operators to report the quantity of drinking water used for hydraulic fracturing and provide incentives for efforts to reduce.** Operators typically do not have to report the source of water used for hydraulic fracturing, making it difficult for states to assess the water resource needs and impacts of the industry. States can require operators to report the source of their water. A state can also provide incentives to operators to use fracturing solutions that greatly reduce the amount of water and proppant (an additive to fracturing fluid used to keep a

[8] Shale-gas extraction and processing are less water intensive than most other forms of energy extraction except conventional natural gas and renewables. The water intensity per unit of energy from coal, nuclear, oil, and irrigated corn ethanol extraction are approximately 2 times, 3 times, 10 times, and 1,000 times greater than for shale gas, respectively. These findings are reported in Jackson et al., *The Environmental Costs and Benefits of Fracking*, Annual Review of Environment and Resources (August 2014). Accessed http://www.eenews.net/assets/2014/09/16/document_ew_02.pdf

[9] Monika Freyman, *Hydraulic Fracturing and Water Stress: Water Demand by the Numbers* (Boston, MA: Ceres, 2014), http://www.ceres.org/resources/reports/hydraulic-fracturing-water-stress-water-demand-by-the-numbers/view (accessed May 25, 2015).

[10] 225 Illinois General Assembly Compiled Statutes 732/1 et. al. enacted 6/17/2013, http://www.ilga.gov/legislation/ilcs/ilcs5.asp?ActID=3493andChapterID=24" Senate Bill (June, 2013), (accessed May 25, 2015).

[11] New Mexico Administrative Code section 19.15.34

fractured opening flowing during or after a fracturing treatment) required to stimulate shale production. Gas and oil cannot be extracted from all types of shale with those types of solutions, and some alternative fracturing solutions could be more toxic, adding to the risk of accidents. Some companies are developing synthetic fracking fluids that use little or no water but are as effective as traditional fluids,[12] but those fluids can be more expensive. In **Utah**, operators must create a water management plan that demonstrates that they have adequate water for drilling and completing the well and explains how they will handle wastewater.[13] The state regulators encourage reuse of water to reduce demand on drinking water. **West Virginia** operators must demonstrate water withdrawal plans that maintain in-stream flows that can sustain aquatic life populations.[14] **Illinois** requires drilling permit applicants to specify how they are going to minimize water use, thereby encouraging companies to analyze their options and foster technological innovations.[15]

- **Support the use of lower-quality water for drilling.** Most shale deposits can be extracted by using water that is below drinking water standards, thereby conserving drinking water supplies. Brackish water, treated municipal and industrial wastewater, and blow-down water from power plant cooling can be used. Saltwater is particularly promising given that large volumes can be found underground in some regions with large shale production. Lower-quality water should not be allowed for the initial drilling before the proper surface casings are installed. The Susquehanna River Basin Commission promotes using lower-quality water by speeding up the review and approval of permits that use degraded water. The Susquehanna River Basin Commission offers waivers of application fees and require those seeking permits for higher-quality water in watershed degraded by mining activities to consider using lesser-quality water first.[16]

- **Consider market-based or block-rate price of water to encourage water conservation.** Many states subsidize the price of water for all types of customers but industry is more likely to innovate and use alternatives to freshwater if it has to pay the full market value of that water.[17] Typically, it is cheaper to buy freshwater than to treat, or buy and use, wastewater for recycling, which can eliminate the economic incentive to recycle in some areas. If market-based pricing is introduced for all customers, states will need to consider whether they want to protect residential and agricultural users. Another option is to use "block rate" price structures by which the unit price of water increases as the volume consumed increases in order to encourage reduced water use. **Colorado** has developed water markets for surface water rights that allows for selling or renting of water, and several Colorado municipalities have

[12] GASFRAC is pioneering a liquid petroleum gas (LPG) closed-loop system that uses no water to complete hydraulic fracturing. Chevron has also begun to use LPG technology to fracture a few of its wells in Colorado. See GASFRAC, "Waterless Fluid Systems," http://www.gasfrac.com/proven-proprietary-process.html (accessed April 22, 2014); and Chevron, *2011 Supplement to the Annual Report*, p. 56, http://www.chevron.com/documents/pdf/chevron2011annualreportsupplement.pdf (accessed May 25, 2015).

[13] Utah Department of Administrative Services, Rule R649–9–2, *General Waste Management*, http://www.rules.utah.gov/publicat/code/r649/r649-009.htm#T2 (accessed May 27, 2015).

[14] *Natural Gas Horizontal Well Control Act*, sec. 22–6A–7 (2011), West Virginia Code, http://www.legis.state.wv.us/wvcode/Code.cfm?chap=22andart=6A (accessed May 27, 2015).

[15] Illinois Permit Application Requirements, *DNR 62 Illinois Administrative Code*, section 62 Illinois Administrative Code 245.210(a)(10)(iv), http://www.ilga.gov/commission/jcar/admincode/062/062002450B02100R.html.

[16] Susquehanna River Basin Commission, Policy No. 2007-01, "Aquifer Testing Guidance," http://www.srbc.net/policies/docs/2007-01AquiferTestingGuidance.PDF (accessed May 27, 2015).

[17] Jeffrey, L. Barnett, et.al, 2012 Census of Governments: Finance State and Local Government Summary Report (Washington, DC: U.S. Census, 2014).

established block rate structures to encourage reduced water use.[18] Those types of market based pricing or block rates could be considered for wholesale market sales to shale developers.

- **Modify wastewater liability with demonstrated good practices to encourage more recycling.** Operators may be hesitant to provide their wastewater to other operators for recycling because of concerns that they will be held liable for future contamination. If those liability concerns could be addressed through a liability modification based on demonstrated good practices, it could expand the use of wastewater. States are in the process of establishing regulations on water recycling. Operations should not be fully exempt from liability until those regulations are understood and protocols for good practices are established.

Ensure Well Integrity and Plugging to Minimize Risks to Water

The integrity of the well structure is one of the most important factors for protecting water sources in shale development.[19] Improperly cemented wells can leach methane into groundwater. Horizontal wellbores can inadvertently intersect with abandoned wells, and improperly plugged wells can cause the accidental release of contaminants into drinking water. Several established regulations and best practices can encourage industry to design, drill, and plug wells with high quality. Governors can consider the following measures:

- **Require "area of review" as part of drilling permit for horizontal drilling.** The state permit application can require the operator to survey the geology and structures in the area that could interfere with fluid containment during hydraulic fracturing. Because horizontal drilling covers a wide area underground, the area of review should address subsurface fluid pathways, abandoned wells, public water supplies, and private water wells. That area of review can help determine the placement of the well to reduce the level of risk. **Arkansas** directs operators to include a map of all nearby plugged and abandoned wells in their permit application to demonstrate that they are aware of potential contamination pathways.[20] **Alaska** requires all operators seeking approval of fracking operations to demonstrate that both the mechanical integrity of the proposed well and its trajectory do not threaten freshwater aquifers or the integrity of any wells by conduits through geologic features within a half mile radius of the proposed well.[21]

- **Update requirements for well construction and require confirmatory tests to account for greater pressure levels used in shale over conventional plays.** The amount of pressure used to stimulate a well for high-volume hydraulic fracturing and horizontal drilling can be greater than what is used for conventional plays, so well integrity standards should be updated. Because old wells were not designed for these greater pressure levels, their mechanical integrity should be tested before and during well stimulation. The additional risk of gas rising along the outside of a wellbore into drinking water can be addressed by isolating potential zones of migration with high quality cementing. Key protections include high standards for well casing, centralizing, and cementing.

[18] Western Resource Advocates, Water Rate Structures in Colorado: How Colorado Cities Compare in Using this Important Water Use Efficiency Tool, (Western Resource Advocates, 2004).
[19] Ground Water Protection Council, *State Oil and Gas Regulations Designed to Protect Water Resources*, http://www.gwpc.org/sites/default/files/state_oil_and_gas_regulations_designed_to_protect_water_resources_0.pdf (accessed May 27, 2015).
[20] Class II Disposal and Class II Commercial Disposal Well Permit Application Procedures, *Arkansas Oil and Gas Commission General Rules and Regulations*, Rule H-1, http://www.aogc.state.ar.us/PDF/.%20FINAL%202-17-2012.pdf (accessed May 27, 2015).
[21] Alaska Administrative Code 20 AAC 25.283(a).

Various types of well integrity tests assess the likelihood of a high-quality cement job while a confirmatory test is an experiment to demonstrate well performance under actual pressure so can be most helpful to ensure the cement quality.[22] States can require operators to conduct a confirmatory test before drilling subsequent sections of the well. **West Virginia** requires operators to case and cement horizontal wells to prevent the migration of gas and other fluids into fresh groundwater and coal seams, and prevent pollution of or diminution of fresh groundwater. The state also requires the use of well blow-out preventers and that used well casings undergo confirmatory tests at a pressure 20 percent greater than the anticipated maximum pressure to which the casing will be exposed.[23] **Texas** upgraded its well integrity standards – including casing, cementing, drilling, well control and completion[24] – and blowouts reduced by nearly 40 percent within a year while drilling levels increased.[25]

- **Establish performance standards or variance process to give operators greater flexibility.** Although most regulations to protect water from the risks of shale energy development involve traditional "command and control" standards that specify technologies or practices, some particular regulations establish performance-based standards that specify the result rather than the means. Given the wide variety of drilling practices and the rapid pace of technological innovation, states can consider giving industry more flexibility in the ways it achieves public goals. A state could, for example, set a performance standard for operators to protect drinking water, or it could provide sufficient-quality casing and allow the operator to determine how to accomplish the goal. Another route is to have a variance process, in which an operator can demonstrate equal protective value through means other than the prescriptive state regulation. Both performance standards and variances can require high levels of technical expertise within the state that can be a challenge to fund and manage. **Montana** sets a performance standard for suitable surface casing. The regulations have some parameters on the cementing processes allowed but grants the operators independence to determine how they achieve suitable and safe surface casings.[26]

- **Scale financial liability or requirements to cover the potential costs of risks.** Most states have financial bonding requirements that cover some portion of the cost of plugging and abandoning a well when drilling is complete. States could consider extending those requirements to include other costs tied to industry, including monitoring cleanup, or compensating the public for adverse effects, such as water contamination. Assessing the risks and potential costs are difficult. Governors' offices could advance a dialogue between insurance companies and state regulators to examine the potential for expanding the role of bonding requirements.[27] **Maryland** requires that an oil and gas permit holder have

[22] Confirmatory tests are known as a "Formation Integrity Test (FIT)" or a "shoe test" because they test the cementing bond of the casing shoe.
[23] Casing and Cement Standards, *Natural Gas Horizontal Well Control Act*, sec. 22–6A–24 (2011), West Virginia Code, http://www.legis.state.wv.us/wvcode/ChapterEntire.cfm?chap=22andart=6Aandsection=24#06A (accessed May 27, 2015); and Rules Governing Horizontal Well Development, West Virginia Code, R., sec. 35–8–5.7 and sec. 35–8–9.2, http://www.dep.wv.gov/pio/Documents/2013%20Proposed%20Rules/35CSR8%202013.pdf (accessed May 27, 2015).
[24] Railroad Commission of Texas amended Statewide Rule 13 of Texas Administrative Code, sec. 3.13.
[25] Nathanial Gronewold, "Drilling well blowouts down in Texas after a year of new rules", E and E News, January 14, 2015. http://www.eenews.net/energywire/stories/1060011620 (accessed June 8, 2015).
[26] Rotary Drilling Procedure, *Administrative Rules of Montana*, Rule 36.22.1001, http://www.mtrules.org/gateway/ruleno.asp?RN=36.22.1001 (accessed May 27, 2015).
[27] Very few insurance firms offer broad liability to this industry, while such insurance exists for other industries. One company called Energi Insurance Services offers this type of coverage and provides training and auditing of operators to ensure their compliance with the insurance terms for using best practices.

comprehensive general liability insurance coverage, environmental pollution liability insurance, as well as a performance bond, a blanket bond, cash, a certificate of deposit, or a letter of credit.[28]

- **Engage industry and royalty owners to contribute to well plugging and cleanup funds.** The safety, cleanup, and monitoring costs of abandoned wells can overload an already-tight state budget. Governors can engage industry officials and royalty owners to establish a state fund dedicated to those activities. The fund can be established through voluntary donations or through a new or expanded user fee, excise tax, or severance tax. In addition to its requirement for well plugging bonds – that are funded through the excise tax – **Oklahoma** established an Energy Resources Board that remediates surface damages caused by historical oil and gas drilling and is funded through a voluntary fee of one-tenth of one percent of sales from oil and gas producers and royalty owners in the state.[29]

Manage Risks of Contamination from Hydraulic Fracturing Fluids

Lowering the potential that hydraulic fracturing fluids will contaminate water supplies can be largely achieved through the practices addressed above—ensuring well integrity and adequate plugging of old wells. Governors might also consider the following best practices:

- **Require testing of water quality before and after hydraulic fracturing.** One of the challenges of shale energy development is that water extracted from wells can contain many naturally occurring or existing chemicals or gas, which can make it unclear whether and when contamination occurred. To address that concern, states can require operators to take water samples from surface and subsurface waters before and after drilling so that data are available for comparison in the event of claims of contamination. States could require a test or allow operations to perform post-drilling tests to protect themselves against future claims of contamination. **Wyoming** requires that oil and gas drillers sample at least four existing wells or springs within a half-mile radius of the proposed well within a year before drilling and conduct two tests following the well completion.[30]

- **Notify neighboring operators and the public before hydraulic fracturing begins.** Horizontal drilling can accidentally intersect with nearby wells, which can threaten water supplies and reduce the productivity of nearby wells. Furthermore, drilling can effect neighbors with noise, odors and other impacts. Proactively informing neighboring operators and the public of planned drilling can help avoid some of the impacts and potentially ease tensions. Operators in **California** must identify all surface property owners and tenants within a 1,500-foot radius of the wellhead or within 500 feet of the horizontal path of the well and notify the identified neighbors that the operator will be stimulating the well. The notification must be made at least 30 days before well stimulation begins. The third party must also inform the neighbors that they can request water well testing.[31]

- **Disclose fracturing chemical ingredients by quantity for each well.** The level of detail

[28] General Assembly of Maryland, Senate Bill 854 (May 16, 2013).
[29] 43 Oklahoma Statute, sec. 52–318.1; Oklahoma Energy Resources Board, "Funding," http://www.oerb.com/about/funding (accessed April 24, 2015). The plugging fund can found at 68 O.S. §1103 while the restoration funds are in 17 O.S. §180.10.
[30] Wyoming Oil and Gas Conservation Commission, Chapter 3, sec. 45, http://soswy.state.wy.us/Rules/RULES/7928.pdf (accessed May 25, 2015).
[31] Application for Permit to Perform Well Stimulation Treatment, 14 California Code of Regulations, sec. 1783.2.

industry discloses about the chemical makeup of hydraulic fracturing fluids varies depending on state disclosure laws and trade secret protections. Increasingly, some companies and states, encouraged by requests from academics and public advocates, are agreeing to disclose the fracturing chemical ingredients in a method called the *systems approach*."[32] The systems approach is like a food label that discloses the individual ingredients but protects the manufacturer's recipe. In this instance, it means that each chemical is identified by its Chemical Abstract Service (CAS) number and its quantity, by mass, in the entire hydraulic fracturing fluid system in each well; the particular recipes for each fluid product with those chemicals in them remain private.[33] This approach can increase disclosure by making it significantly more difficult to reverse engineer trade secrets.[34] Many states are using the FracFocus Web portal for chemical disclosure. The default setting of FracFocus is being changed to the systems approach but allows states and operators to customize other types of disclosure settings.[35] **Wyoming** requires that operators disclose to the state agency the chemical additives' names, types, concentrations, and amounts, both planned and actual. The state agency determines whether industry claims for trade secrets exempt them from public disclosure. In shallow deposits or sensitive areas the state could disallow the use of certain additives.

- **Consider offering incentives to operators that use lower-toxicity chemicals for hydraulic fracturing.** Some fluids used for hydraulic fracturing contain toxic chemicals that can be replaced with less toxic products. The efficacy of 'green chemicals" versus traditional chemicals needs to be considered including any differences in the volume or quality of water needed.[36] Accordingly, regulators might consider offering incentives – such as expedited permitting or lower taxes – for the use of less toxic chemicals after establishing that they are compatible with other policy objectives.

Mitigate Risks from Wastewater Contamination and Seismicity

After an operator has completed the fracturing process, it has thousands of gallons of flowback of subsurface fluids and wastewater used to fracture the shale and unlock its oil and gas resources. It also has produced water, which is highly saline and can contain many risky materials. Operators may store that waste in lined pits or storage tanks onsite temporarily, and then reuse it onsite for another fracturing job (called *reuse*), transport it offsite for treatment and recycling at another well site (called *recycling*), transport it for treatment at industrial or commercial treatment plants, transport it for disposal in an underground injection well, dispose of it in through commercial treatment and discharge, or reuse it in irrigation or ice control. According to research from the Ground Water Protection Council, based on 2012 data, more than 90 percent of wastewater from all types of oil and gas development is injected underground, seven percent is sent to commercial facilities that inject it in disposal wells or treat and discharge, three percent is discharged to surface water,[37] and less than one percent is reused in applications such

[32] Maryland Institute of Applied Environmental Health, *Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland* (College Park, MD: University of Maryland, 2014), 89–90.
[33] A *CAS number* is a unique code that designates a single substance and information relevant to that substance. CAS numbers serve as an easy identification method for chemical substances by both industry and regulators.
[34] U.S. Department of Energy, Secretary of Energy Advisory Board, *Task Force Report on FracFocus 2.0* (March 28, 2014).
[35] "FracFocus: Chemical Disclosure Registry," http://www.fracfocusdata.org/DisclosureSearch (accessed April 20, 2015).
[36] For an examination of green chemicals, see: URS Corporation, "Water-Related Issues Associated with Gas Production in the Marcellus Shale," Prepared for NYSERDA, Albany, NY, p. 6-1 – 6-3, (accessed June 23, 2015).
[37] The study covers all types of oil and gas development, including coal bed methane. Surface water discharge includes traditional produced water found naturally in the same formation, water injected for enhanced recovery, flowback water, and some produced water that has been exempted by EPA. Reuse of wastewater has increased since this data was collected in 2012 but the updated data has not been compiled.

as road deicing and subsequent fracturing.[38]

New research links increased seismicity with increased underground injection of wastewater but not with the hydraulic fracturing process itself.[39] Various adjustments to underground injection protocols can mitigate those risks.[40] Governors can consider the following measures to address the risks from each of those disposal methods and other on-site spill risks:

- **Establish buffer zones between well sites and sensitive areas.** Improvements in horizontal drilling techniques have made it easier for operators to select their well location and access shale deposits from farther away. Each location has unique variables to consider in establishing an appropriate buffer zone. **Michigan** requires that the surface locations of wells be located at least 300 feet from reasonably identifiable drinking water wells and that drilling and storage equipment be 800 to 2,000 feet from municipal water sources.[41]

- **Designate types of materials that can be stored in pits and tanks, in addition to spill-containment measures.** Some of the types and chemical intensity of materials produced by hydraulic fracturing may not always be appropriate for storage in pits and tanks without additional design measures to match their contents. Tanks are of particular concern as they are increasingly being used instead of pits in some regions. Although they might have secondary containment provisions, many states do not have design, siting or operational regulations on tanks.[42] **Illinois** requires that tanks that store waste from shale oil and gas production be made from materials compatible with the chemicals found in the fracking waste materials.[43]

- **Require pits to be lined and encourage waste pits and tanks to be equipped with leak-detection systems.** Pits that store the wastewater can leak so requiring pit liners prevents fluids from seeping into the ground and potentially contaminating groundwater. **Utah** requires waste water impoundments used for evaporative disposal to use a two liner system with leak detection in between the liners. The primary liner must have a minimum thickness of 60 mils and the secondary liner must have a minimum thickness of 40 mils.[44] Tanks and pits can be fitted with sensors that detect changes in weight and use telemetry technology to alert operators or regulators in real time. **Colorado** requires pit leak-detection systems in some sensitive areas.[45]

[38] Ground Water Protection Council, *U.S. Produced Water Volumes and Management Practices in 2012* (April 2015), 10.
[39] A small number of incidents have occurred in which hydraulic fracturing has likely caused an earthquake, but those incidents are rare and unlikely to occur, finds the National Research Council in its 2013 study, *Induced Seismicity Potential in Energy Technologies*. The nature and duration of hydraulic fracturing are different from underground injection in several ways. For instance, the hydraulic fracturing process lasts for hours or days, while wastewater injection can last for months, thereby increasing the pressure on existing fault lines. Research on the seismicity risks can be found at U.S. Geological Survey, *Incorporating Induced Seismicity in the 2014 United States National Seismic Hazard Model—Results of 2014 Workshop and Sensitivity Studies* (April 2015); Lawrence Berkeley National Laboratory, *Induced Seismicity Primer*; and Mark D. Zoback, "Managing the Seismic Risk Posed by Wastewater Disposal," Earth, entry posted April 17, 2012, http://www.earthmagazine.org/article/managing-seismic-risk-posed-wastewater-disposal (accessed May 25, 2015).
[40] Ronald Bergman, memo to UIC program managers, February 6, 2015, http://www.epa.gov/Region5/water/uic/ntwg/pdfs/induced-seismicity-201502.pdf (accessed April 20, 2015); and M. Zoback, "Managing the Seismic Risk."
[41] Natural Resources and Environmental Protection Act of 1994, Michigan Code R, sec. 324.301, http://www.legislature.mi.gov/(S (lxkx1zaxdfehqkj22jhay4yk))/mileg.aspx?page=GetMCLDocumentandobjectname=mcl-324-301 (accessed May 27, 2015).
[42] Ground Water Protection Council, *State Oil and Gas Regulations Designed to Protect Water Resources*, p. 11, http://www.gwpc.org/sites/default/files/state_oil_and_gas_regulations_designed_to_protect_water_resources_0.pdf (accessed June 22, 2015).
[43] 225 Illinois Compiled Statutes 732/1-70(b)(3), http://www.ilga.gov/legislation/ilcs/ilcs5.asp?ActID=3493andChapterID=24.
[44] Utah Rule R649-9-4-7.1; Utah Rule R649-9-7.2.
[45] Pit Lining Requirements and Specifications, Colorado Rule 904e, https://cogcc.state.co.us/RR_Docs_new/rules/900Series.pdf (accessed May 27, 2015).

- **Increase oversight of wastewater transportation to minimize illegal dumping and dangerous spills from truck accidents and pipeline failures.** Oil and gas wastewater in **Colorado** must be transported to permitted facilities, and waste generators must maintain records of the waste transfer for five years, including the type and volume of waste and the name and location of the treatment or disposal site.[46]

- **Engage neighboring governors to coordinate plans for managing data about transportation and disposal of wastewater.** Given the risk of illegal disposal of wastewater, including across state borders, governors can create cross-state agreements to track the disposal of wastewater. A first step is to require trucking companies to install global positioning system trackers on their trucks, and neighboring states can then agree to collect and exchange data to monitor where wastewater is going. **Ohio** requires that trucks carrying wastewater install electronic tracking systems so the state can verify that haulers operating in their state are registered operators.[47]

- **Characterize, manage, record, and properly dispose of wastewater and treatment residuals.** Wastewater and flowback can contain hazardous constituents, including technically enhanced, naturally occurring radioactive materials (TENORM) as well as residuals such as sediment, sludge, and filter cakes. Properly identifying and disposing of those wastes are important. State regulators can evaluate and, if necessary, modify the landfill disposal protocol for sludge and other solid waste based on the contents reported. State-specific research can be appropriate because different shale formations have significant variations in the concentration of chemicals and radioactive parent elements uranium and thorium. Some wastewater had been treated in publically owned treatment works and released into streams, but that practice has mainly stopped because high levels of toxic residuals were found. Questions remain about the safety of water releases from commercial and industrial wastewater treatment facilities, so more precise characterization and tracking of waste can help assess their appropriate treatment.

- **Avoid injection into natural faults, fractures and the base rock layer in disposal wells to minimize seismicity risk.** According to most scientists, the safest form of wastewater disposal is the use of underground injection wells, yet new research has linked that practice to the potential for inducing seismicity in some regions.[48] Seismologists generally agree that injected wastewater fluids that reach critically stressed faults and basement rock can induce seismicity.[49] For injection wells, operators and regulators can determine the proximity to and potential connectivity of the disposal zone to the basement rock and use that information to inform placement of injection wells. **Oklahoma** Governor Mary Fallin appointed a working group made up of state regulators, researchers, and industry representatives to organize state resources and ensure an efficient and effective response to the increased seismicity. Based on findings by the Oklahoma Geological Survey, the state regulators require, as of May 2015, disposal well operators in areas of interest to demonstrate that they are

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[46] Management of E and P Waste: Waste Transportation, Colorado Rule 907(b), https://cogcc.state.co.us/RR_Docs_new/rules/900Series.pdf (accessed May 27, 2015).
[47] Ohio General Assembly, Senate Bill 315 (June 11, 2012), http://archives.legislature.state.oh.us/bills.cfm?ID=129_SB_315 (accessed May 25, 2015).
[48] Ground Water Protection Council, *Injection Wells: An Introduction to Their Use, Operation and Regulation* (September 2013), 30; and U.S. Environmental Protection Agency, "Frequently Asked Questions about the UIC Program," http://www.epa.gov/region5/water/uic/faq.htm (accessed April 24, 2015).
[49] U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts from Injection-Induced Seismicity*.

injecting at safe depths above the basement rock.[50] The state is continuing to monitor seismic activity and evaluate whether additional regulatory steps are needed to address risks.

- **Proactively evaluate disposal well management options to reduce seismic risks.** Several ways to manage seismic risks from disposal wells involve changing how injection wells are sited and operated to minimize underground pressure buildup. Those methods include reducing injection rates, injecting fluids intermittently to allow pressure to dissipate, and spacing injection wells farther apart.[51] Those measures are useful in areas with seismic risks and may not be necessary in other areas. **Kansas** developed rules governing the wastewater injection process that prohibit injecting wastewater into wells that will not accept waste using gravity alone and recently released an order to reduce the allowed volume of wastewater in injection wells in earthquake-affected counties.[52] The U.S. Environmental Protection Agency recently released a set of recommendations informed by state regulators. As part of the States First Initiative, the Ground Water Protection Council (GWPC) and Interstate Oil and Gas Compact Commission, are expected to release recommendations developed by a working group of state regulators in the fall of 2015.

Leveraging the Unique Role of the Governor to Promote Protective Practices

In addition to helping shape the development, promulgation, and enforcement of the protective practices described above, governors have unique opportunities to enhance coordination, communication, and research through the following actions:

- **Increase staffing to oversee enforcement of the booming industry.** The scale and speed of shale development is outpacing many government regulatory agencies' enforcement capacity. Increasing the number of inspectors who are available to monitor the drilling and completion progress can help governors ensure that as many wells are receiving adequate attention as possible. **Pennsylvania** more than doubled the staff levels of its oil and gas regulators in 2009 and 2010 by increasing its well permitting fee and is in the process of increasing staff again.[53]

- **Establish program for independent auditors to ease state staffing demands.** Even with increased regulatory staffing, government officials cannot feasibly monitor each well regularly. Independent auditing of business practices is a common approach in many industries to help inform companies and government and to shift some of the oversight costs to the business. Under such a program for shale energy development, operators would pay an auditing firm that has been approved by the state to conduct a review of their practices. If the operator receives a certificate from the auditor, the state could grant some benefits such as expedited permitting, access to leases in sensitive areas, or variances. That approach is being piloted by at least one private-sector entity that provides oil and gas companies with an evaluation and rating, or audit, of

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[50] Oklahoma Corporation Commission, Oil and Gas Conservation Division directive released March 25, 2015, http://www.occ.state.ok.us/News/2015/03-25-15%20Media%20Advisory%20-%20TL%20and%20related%20documents.pdf (accessed May 25, 2015).

[51] U.S. Environmental Protection Agency, *Minimizing and Managing Potential Impacts from Injection-Induced Seismicity*.

[52] Rex Buchanan, "Hydraulic Fracturing and Induced Seismicity in Kansas" (Kansas Corporation Commission, April 3, 2013), http://www.kcc.state.ks.us/conservation/kgs_induced_seismicity_040313.pdf (accessed May 25, 2015); and Kansas Corporation Commission, "Order Reducing Saltwater Injection Rates" (Docket 15-CONS-770-CMSC, March 2015), http://estar.kcc.ks.gov/estar/ViewFile.aspx/15-770%20Order.pdf?Id=05630050-78a3-4800-a08b-85202375305a (accessed May 25, 2015).

[53] State Review of Oil and Gas Environmental Regulations, *Pennsylvania Hydraulic Fracturing State Review*, (September 2010), p. 19-20, http://strongerinc.org/sites/all/themes/stronger02/downloads/PA%20HF%20Review%20Print%20Version.pdf (accessed June 9, 2015).

their key processes and efforts to protect the environment.[54] The audit allows flexibility for various efforts that are justified for the site-specific conditions. States could require operators to achieve a certain rating that reflects high performance without dictating particular controls. Another program developed in the Marcellus region by representatives of industry and environmental groups offers operators a certification of excellence for meeting standards in excess of regulatory requirements that have been audited.[55] Certification from those types of programs could be considered for granting operators expedited permitting or variances.

- **Consider expanding transparency rules to support a better understanding of public health impacts.** Most settlements or property buyouts between operators and individuals who claim water contamination from shale energy development have included a confidentiality agreement.[56] Confidential settlement terms are commonly used across industries and do not demonstrate culpability, but they prevent access to data about potential incidents. Many states have "sunshine laws" that allow access to confidential legal documents that could increase public protection. Most sunshine laws, however, do not address settlements made outside of the courts, and most shale-related suits are settled privately. Governors can improve scientific research and build public confidence by expanding transparency measures, such as sunshine laws, to enable scientific research on industry practices. **Arkansas** does not allow private settlements to restrict disclosure of environmental hazards that may cause harm to people other than the contracting parties.[57] **Texas** has a presumption of public access to court records and private settlements that restricts disclosure of information that has a probable adverse effect on public health.[58]

- **Direct relevant state agencies to identify regulatory gaps and duplication to ensure effective oversight of shale energy development.** Government oversight of this sector is typically distributed between multiple agencies including environmental, transportation, oil and gas commission, and others. A governor can address regulatory gaps and duplication through executive orders or proposed legislation. A governor also can direct agencies to share the results of their respective inspections to help reduce staffing burden and increase oversight. **California** legislation directed and provided funding for agencies to dedicate time to collaborate and integrate their oversight efforts.[59]

- **Institutionalize regular external review of regulations and enforcement to continuously improve.** Governors can direct their agencies to undergo a regulatory review and consider whether opportunities to update rules exist. Given the rapid pace of technological development and best practices in this field, periodic review of regulations institutionalizes

[54] Independent Energy Standards Corporation, "About Us," http://www.independentenergystandards.com/#!about/c1vw1 (accessed April 22, 2015).
[55] The Center for Sustainable Shale Development has performance standards that were created by environmental groups and industry for Marcellus shale operators.
[56] Jim Efstahiou and Mark Drajem, "Fracking Companies Silence Water Complaints with Sealed Settlements," Bloomberg News, June 10, 2013, http://www.insurancejournal.com/news/national/2013/06/10/294608.htm (accessed May 25, 2015).
[57] Arkansas Code Ann. § 16-55-122 (2015).
[58] *Settlement, Secrecy, and Judicial Discretion*, Texas Rules of Civil Procedure, Rule 76, http://www.epcounty.com/jp/jp2/rcp_all.pdf (accessed May 27, 2015).
[59] Oil and Gas: Well Stimulation, California Senate Bill 4, sec. 3160(c)2 (September 20, 2013), http://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140SB4 (accessed May 27, 2015); and California Department of Conservation, "Development, Regulation, and Conservation of Oil and Gas Resources," in Pre-Rulemaking Discussion Draft, http://www.conservation.ca.gov/dog/general_information/Documents/121712DiscussionDraftofHFRegs.pdf (accessed May 25, 2015).

a commitment for continuous improvement. Such action can be undertaken with assistance from the State Oil and Gas Regulatory Exchange (SOGRE), which offers state-based peer review of certain regulatory elements, or the State Review of Oil and Natural Gas Environmental Regulations (STRONGER), an organization that includes state regulators, industry, and public advocates. Many states, including **Arkansas** and **Pennsylvania,** have undergone STRONGER reviews of their hydraulic fracturing programs.[60]

- **Provide governor's awards for industry best practices.** Granting awards and positive public attention can encourage industry to compete for best-practice designation and foster a culture of continuous improvement. **Utah** Governor Gary Herbert presents annual awards to operators who voluntarily go beyond the law to improve environmental conditions.[61]

- **Establish "bad actor" laws to revoke licenses of problem operators.** If an operator repeatedly violates state laws, government should revoke their operator's license to prevent further violations. A "bad actor" law can provide operators an inventive to improve, especially when a financial penalty might not be effective, and can strengthen public confidence in the entire industry. **New Mexico** denies permits or the authority to transport product to operators who are not in compliance with the state code. Non-compliance includes not meeting financial assurance requirements, having a violation order, having an unpaid penalty assessment, or possessing a certain number of inactive wells that are out of compliance.[62]

- **Convene stakeholders for educational dialogue and provide methods for stakeholder input.** Governors are uniquely positioned to convene citizens, industry representatives, academics, environmental advocates, and government officials for educational forums on efforts to address water protection and other public concerns. In addition to those efforts, oil and gas commissions may need to create protocols for public involvement. Creating easily accessible methods for stakeholder input and complaint registration can build public engagement and confidence in the process.

- **Engage local stakeholders proactively.** Governors can help foster additional dialogue concerning the jurisdictional issues that have accompanied various shale energy development efforts and help identify potential areas of agreement. Through an executive order, **Colorado** Governor John Hickenlooper established a task force to develop cooperative strategies for shale energy development among municipalities, industry, and the state. The task force developed nine consensus-based recommendations and a longer list of ideas that the state is considering.[63] Two of the consensus-based recommendations forwarded to the Governor provide for increased local government input in the siting of large scale oil and gas facilities. Operators are required to submit their five-year drilling plans to local governments who request them, so they can include oil and gas development in their local zoning development plans. If the operator and municipality cannot come to an agreement, the operator must offer to go to mediation. If the mediation is not successful, the state makes the final decision.

[60] More information about SOGRE can be found at http://www.statesfirstinitiative.org/#!sogre/c22zj and examples of completed STRONGER reviews can be found at http://strongerinc.org/past-reviews.
[61] Utah Department of Natural Resources, "Earth Day Awards Overview," https://fs.ogm.utah.gov/bbooks/2010/12_Dec/Briefing/Briefing1_EarthDayAwardsOverview.pdf (accessed April 1, 2015).
[62] New Mexico Statute 19.15.5.9 Subsection A.
[63] Governor John Hickenlooper, "Oil and Gas Task Force Makes Recommendations Related to State and Local Regulatory Jurisdiction," Press Release, April 18, 2012, http://www.colorado.gov/cs/Satellite/GovHickenlooper/CBON/1251621390178 (accessed April 2, 2015).

- **Consider using the risk-based data management system to help states aggregate and communicate data.** Developed through the GWPC, state agencies have developed a database that they can tailor to state needs and aggregate to allow for research into regional trends of risks and oversight. Many states use some version of that system. Governors can encourage state regulators to consider what additional information could be shared to facilitate cross-state learning, improve public confidence, and foster improvements in mitigation measures.

- **Encourage and fund research to improve the understanding of industry impacts and best practices.** Although studies of the environmental and health risks of hydraulic fracturing and horizontal drilling are taking place, more research on a number of topics would be helpful—for example, identifying more accurate levels of contamination rates from well leaks, improving the understanding of the potential for shale energy development to affect the health of citizens living nearby, evaluating the different levels and types of risks associated with shallower shale deposits, determining whether the level of toxic and radioactive residue from wastewater treated in commercial and industrial treatment plants can be released into waterways, and identifying beneficial uses of wastewater that are both economical and environmentally safe (such as using it to cool power plants). Governors can encourage their state universities, non-profits, and other institutions to evaluate research questions particular to their state context or of interest to states seeking continuous regulatory improvement. State-specific assessments have been done in **California** and **Michigan**.[64]

Conclusion

Governors and other state policymakers are leading the way in devising and implementing protective practices to protect drinking water resources from potential risks associated with shale energy development. Those practices reflect regional differences along with developments in technology and science. The measures that states have taken include those that reduce the quantity of drinking water needed to support drilling operations, address concerns about the potential contamination of groundwater and surface water, and mitigate the risks of increased seismicity associated with the use of underground injection wells for wastewater disposal.

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[64] Michael Kiparski and Jayni Foley Hein, *Regulation of Hydraulic Fracturing in California: A Wastewater and Water Quality Perspective* (Berkeley, CA: Wheeler Institute for Water Law and Policy, Center for Law, Energy, and the Environment, UC Berkeley School of Law, 2013),; and Michigan's Technical Report was conducted by the University of Michigan, Graham Sustainability Institute, *Hydraulic in Michigan* (2013), with the final report to be released in 2015.