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Watered-down: Minimizing water risks in shale gas and oil drilling

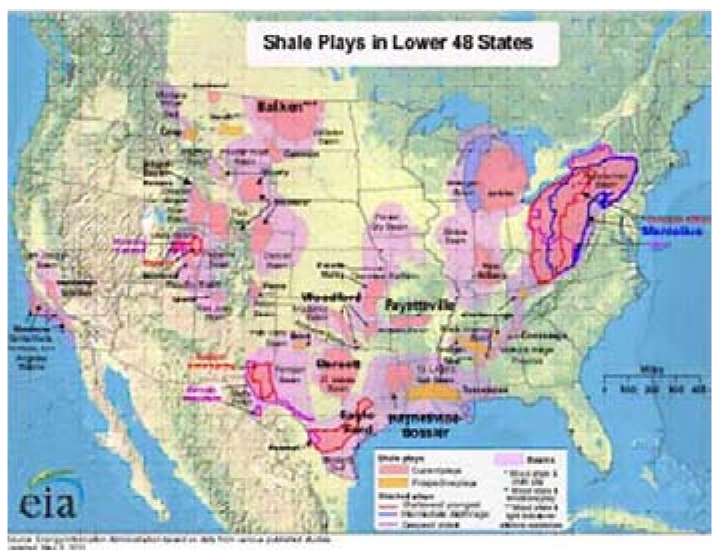
Exploring the liquid assets (and liabilities) of hydraulic fracturing

As oil and gas production from conventional sources continues to decline, companies are concentrating on unconventional sources such as shale formations. The United States has significant technically recoverable deposits of shale oil and gas. Natural gas from proven and unproven shale resources accounts for 542 trillion cubic feet (Tcf) or around a quarter of the total natural gas resource estimate of 2,214 Tcf as of January 1, 2010. In addition to the recoverable shale gas deposits, there are large shale oil formations in Monterey/ Santos, Southern California, estimated to hold 15.4 billion barrels or 64 percent of the total shale oil resources as well as in the Bakken and Eagle Ford. [1]

The drilling and fracturing of shale wells requires water. Across the United States, water availability varies and is dependent on local conditions. Significant water use for shale gas production may affect the availability of water for other uses, and may impact ecosystems. In particular, United States shale drilling companies are facing increased risk exposure to a range of water-related issues—from availability, quality, and supply to treatment, disposal, and distribution/transportation. These issues can lead to financial, reputational, and operational impacts and risks for business.

In the United States, shale basins are found across most of the lower 48 states as shown in Figure 1. The most active shale basins in the United States are the Barnett Shale, the Haynesville/Bossier Shale, the Antrim Shale, the Fayetteville Shale, the Marcellus Shale, and New Albany Shale.[2] Each gas shale basin presents its own unique set of challenges with respect to water resource management.

Figure 1: Map of United States shale basins[3]



[1] United States Energy Information Administration, *AEO2012 Early Release Overview*, January 23, 2012.

[2] United States Department of Energy, *Modern Shale Gas Development in the United States: A Primer*, April 2009, www.gwpc.org, accessed March 10, 2012.

[3] The United States Energy Information Administration, *Review of Emerging Resources: U.S. Shale Gas and Shale Oil Basins*, www.eia.gov/analysis/studies/usshalegas/, accessed March 10, 2012.

Complex regulatory compliance environment

Water-related issues in shale drilling are leading to growing and complex policy and regulatory challenges and environmental compliance hurdles that could potentially challenge shale gas production expansion and increase operational costs. According to a 2009 IHS Global Insight study, the implementation of federal regulations could lead to a decline of over 20 percent in the number of wells drilled within a five-year period of such an implementation. This may also result in a reduction of 10 percent from the natural gas production levels of 2008—which, in turn, would necessitate increased imports of pipeline natural gas.[4]

While there are water risks to be managed, studies by the United States Ground Water Protection Council (GWPC), a not-for-profit association of state regulators, and the Environmental Protection Agency (EPA) have found no significant environmental risks as a result of proper hydraulic fracturing (although the EPA study focused on coal-bed methane wells).[5]

The EPA is currently conducting a follow-up study on the potential impacts of hydraulic fracturing on drinking water resources—specifically examining factors that may lead to human exposure and risks. The study is expected to include a review of published literature, industry information on chemicals and practices, case studies with landowners and state/local/industry representatives, and baseline sampling for retrospective case studies.[6]

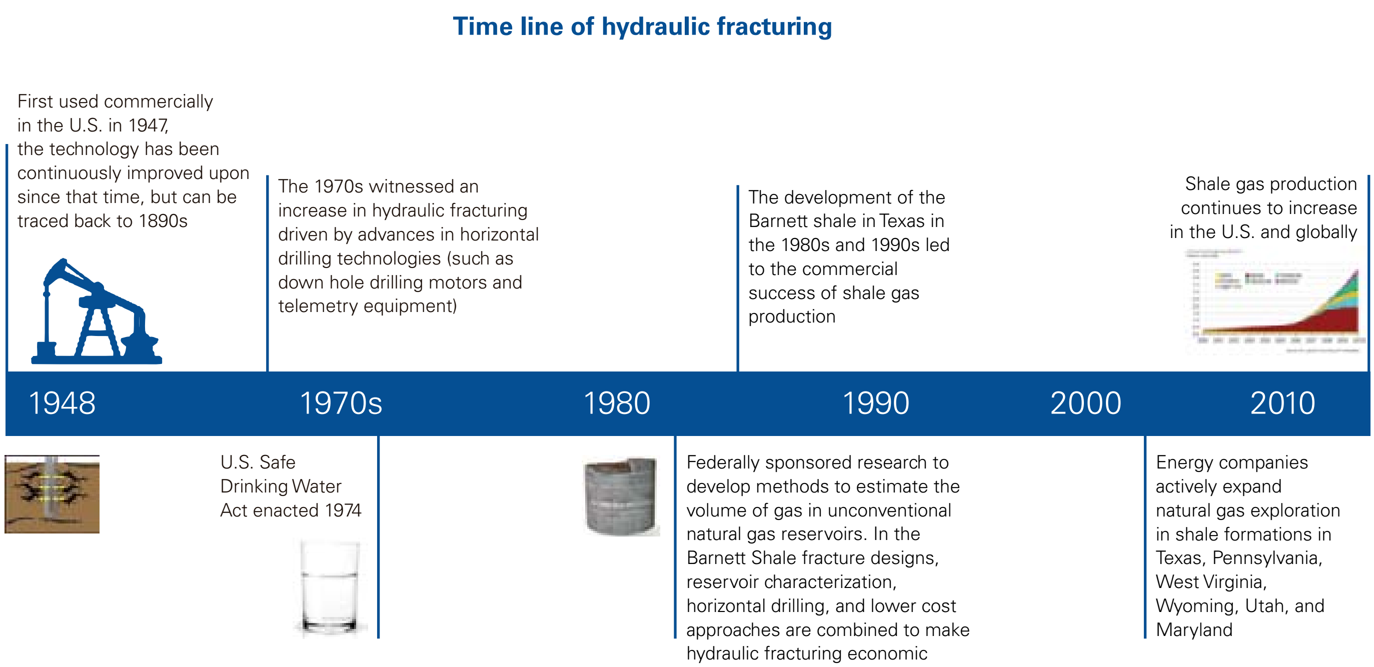
This white paper explores the environmental and regulatory challenges of shale drilling—and how to mitigate these challenges with practical and business-focused approaches and practices to help ensure compliance while enhancing profitability.

Key drivers in the surge of shale exploration

High-volume hydraulic fracturing, or "hydrofracking," is the technique of extracting gas or oil by blasting shale rock formations with a high-pressure combination of sand, water, and chemicals to depths down to 10,000 feet horizontally. This technique creates fissures in the rock to release gas or oil trapped inside.[7]

The use of hydraulic fracturing in the United States has increased and evolved as shown by Figure 2. During the past few years, advancements in drilling technology have opened up huge shale gas reserves in the United States by lowering operating costs and increasing production.[8]

Figure 2: Time line of hydraulic fracturing[9]



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4 IHS Global Insight, *Measuring the Economic and Energy Impacts of Proposals to Regulate Hydraulic Fracturing. Task 1 Report 2009*, http://s3.amazonaws.com/propublica/assets/natural_gas/ihs_gi_hydraulic_fracturing_task1.pdf, accessed March 14, 2012.

5 Energy from Shale.org, *Groundwater Protection*, http://www.energyfromshale.org, accessed March 15, 2012.

6 Environmental Protection Agency, *EPA's Study of Hydraulic Fracturing and Its Potential Impact on Drinking Water Resources*, http://www.cpa.gov/hfstudy/, accessed March 15, 2012.

7 Energy Vision, *Hydrofracking: The Need for Responsible Gas Drilling Regulation and the Role of Natural Gas*, www.energy-vision.org, accessed March 1, 2012.

8 KPMG Global Energy Institute, *Shale Gas Outlook: A United States Perspective*, www.kpmgglobalenergyinstitute.com, accessed February 14, 2012.

9 United States Department of Energy, *Shale gas: applying technology to solve America's energy challenges*, http://www.netl.doe.gov/technologies/oil-gas/publications/brochures/Shale_Gas_March_2011.pdf, graphic prepared by KPMG 2012, accessed March 15, 2012.

The estimated shale gas resource for the continental United States doubled from 2010 to 2011 to about 862 TcF. From 2006 to 2010, annual shale gas production in the United States nearly quintupled—from 1.0 to 4.8 TcF.[10]

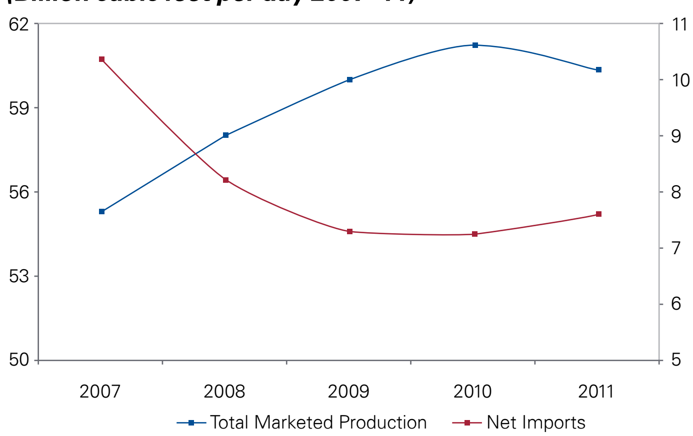
According to the United States Energy Information Administration (EIA), the shale gas portion of total gas production in the United States jumped from 7.2 percent in 2008 to 23 percent in 2010.[11] Shale gas production is projected to grow to nearly 50 percent in the United States by 2035.[12] Millions of acres have been leased in 32 states to explore shale gas and oil, with 30,000 well sites in Colorado alone.[13]

The rising production of shale gas has driven down natural gas prices in recent years, making natural gas a more cost-effective source of power generation than traditional coal. Shale gas accounts for around 20–25 percent of the United States natural gas output. Even with lower prices, technological advancements in shale development will help larger players maintain sufficient returns; however, smaller natural gas companies that are more financially burdened may be susceptible to takeovers.[14]

Increasing domestic shale gas production will have implications for the global energy sector as reliance on foreign sources of natural gas declines. In fact, from 2007 to 2011, imported natural gas dropped by 27 percent as shown in Figure 3, which shows the drop in natural gas imports.

The EIA estimates that oil production from shale basins, notably the Bakken Shale in North Dakota and Montana, has also grown rapidly in recent years.[1]

Figure 3: Domestic natural gas production and net imports (Billion cubic feet per day 2007–11)[15]



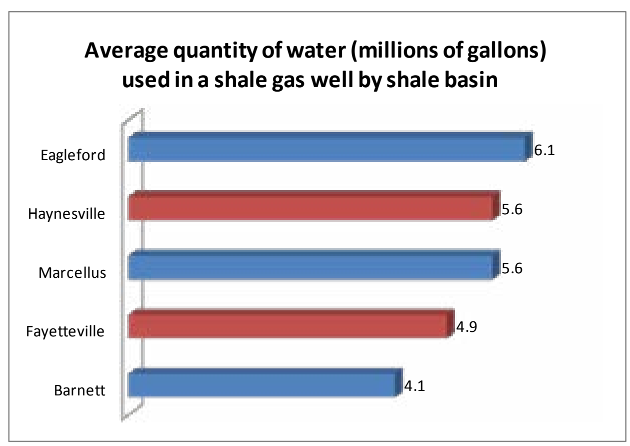
Improvements in technology have also enhanced the development of this resource and the environmental considerations associated with the hydraulic fracturing process. Digital technology advances allow companies to view geometry and flow properties of the fracturing process in three dimensions, making it easier to gather data and optimize the design of treatment simulations. These technological innovations enable the drilling of more shale wells with increased attention to potential environmental effects.

Drilling down into shale water challenges

The drilling and fracturing of shale wells requires water. Water is also a central component of the waste products produced from the fracturing process. The EPA estimates that between 50,000 to 350,000 gallons of water may be required to fracture one well in a coal bed formation, while 2 million to 5 million gallons of water may be necessary to fracture one horizontal well in deep unconventional shale reservoirs.[16] While these volumes may seem large, they generally represent a small percentage of total water use in the areas where fracturing operations occur.

Water is a local issue. Accordingly, each shale basin faces its own challenges for water access, use, treatment, and disposal. The volume of water used varies by the well and the region, according to the geology and the operator's development decisions as shown by Figure 4. The major United States shale basins have unique needs for the volume of drilling and fracturing water for its wells, due to differing shale depths and groundwater.[17]

Figure 4: Volume of water used in a shale gas well by region[18]



[10] The Energy Institute at The University of Texas at Austin, *Fact-Based Regulation for Environmental Protection in Shale Gas Development Summary of Findings*, http://energy.utexas.edu, accessed February 24, 2012.

[11,12, 14, 15] KPMG Global Energy Institute, *Shale Gas Outlook: A U.S. Perspective*, July 2011, www.kpmgglobalenergyinstitute.com, accessed February 14, 2012.

[13] Energy Vision, *Hydrofracking: The Need for Responsible Gas Drilling Regulation and the Role of Natural Gas*, www.energy-vision.org/pdf/HydrofrackingFactSheet3.pdf, accessed March 1, 2012.

[16] United States EPA, *Science in action – building a scientific foundation for sound environmental decisions*, http://www.epa.gov/safewater/uic/pdfs/hfresearchstudyfs.pdf, accessed February 14, 2012.

[17] United States Department of Energy, *Modern Shale Gas Development in the United States: A Primer*, April 2009, www.gwpc.org, accessed March 10, 2012.

[18] The Energy Institute at The University of Texas at Austin, *Fact-Based Regulation for Environmental Protection in Shale Gas Development*, February 2012, http://energy.utexas.edu, graphic by KPMG 2012, accessed February 14, 2012.

Waters flows through hydrofracking

Water consumption for hydraulic fracturing occurs during:

1. Drilling
2. Extraction and processing of proppant sands
3. Testing natural gas transportation pipelines
4. Gas processing plants.

Typically, for most shale basins, water is acquired from local water supplies, including:

- Surface water bodies (rivers, lakes, ponds)
- Groundwater aquifers
- Municipal water supplies
- Treated wastewater from municipal and industrial treatment facilities.
- Produced and/or flowback water that is recovered, treated, and reused.

In many regions where hydraulic fracturing occurs, the sources of water used are not well documented.

Much more to manage than just H_2O

In hydraulic fracturing, there is much more to manage than water demand and supply. According to Frac Focus, the U.S. chemical disclosure registry, the number of chemical additives used in a typical fracture treatment depends on the conditions of the specific well being fractured. Depending on the characteristics of the water and the shale basin the fracturing process could use very low concentrations of between 3 and 12 additive chemicals with each chemical component serving a specific, engineered purpose.[19] The chemicals used in the fracturing process typically represent less than 1 percent of the volume of fluid pumped (99 percent water and sand).[20]

In addition to fracturing fluid additives, wastewater from shale gas extraction may contain high levels of total dissolved solids (TDS) metals and naturally occurring radioactive materials.[21]

Plus, over a million pounds of "proppants" may be required to fracture a single well. These compression-resistant particles started with sand and can now include aluminum or ceramic beads, sintered bauxite, and other materials.[22]

The threat of contamination to drinking water supplies by the chemicals and materials used in the hydraulic fracturing process has attracted media attention and generated some public opposition to shale gas drilling. Most companies have concerns about revealing the contents of their hydraulic fracturing fluids to protect their research from their competition. Some companies have provided this information voluntarily; however, increasingly regulatory agencies are requiring this information.

In some oil- and gas-producing states, regulatory agencies have implemented regulations regarding the disclosure of chemicals used in the process of hydraulic fracturing. Table 1 provides a list of regulation requirements as of December 2011. In May 2012, a proposed rule was issued by the Bureau of Land Management (43 CFR Part 3160) requiring companies to disclose all fracturing chemicals on public and Indian lands after drilling is completed.[23]

Well casings provides a protective barrier from potential contamination from hydraulic fracturing fluid, oil and natural gas flowing from the well. However some of the risks to water quality occur from ground and surface spills. Study conducted by the Energy Institute of the University of Texas at Austin concluded that many reports of shale gas drilling water contamination originate from above-ground spills or other mishandling of wastewater—rather than the hydraulic fracturing process itself. An interdisciplinary team of experts examined a variety of issues associated with hydraulic fracturing at three major shale basins: the Barnett Shale in north Texas; Marcellas Shale in Pennsylvania, New York, and parts of Appalachia; and the Haynesville Shale in western Louisiana and northeast Texas.[24, 25]

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[19] Frac Focus, http://fracfocus.org/, accessed July 21, 2012.

[20] American Petroleum Institute, *Water Management Associated with Hydraulic Fracturing*, API Guidance Document HF2, June 2010, http://www.shalegas.energy.gov/resources/HF2_e1.pdf, accessed March 15, 2012.

[21] Mielke E, Anadon LD, Narayanamurti V, Harvard Kennedy School, Belfer Center for Science and International Affairs, *Water Consumption of Energy Resource Extraction, Processing, and Conversion*. October 2010, http://belfercenter.org, accessed March 15, 2012.

[22] Shale Gas Subcommittee of the Secretary of Energy Advisory Board, *The SEAB Shale Gas Production Subcommittee Ninety-Day Report*. August 11, 2011.

[23] United States Department of the Interior, "Interior releases draft rule requiring public disclosure of chemicals used in hydraulic fracturing on public and Indian lands," press release, May 4, 2012, http://www.doi.gov/news/pressreleases/Interior-Releases-Draft-Rule-Requiring-Public-Disclosure-of-Chemicals-Used-in-Hydraulic-Fracturing-on-Public-and-Indian-Lands.cfm, accessed February 24, 2012.

[24] Energy Institute at The University of Texas at Austin, *Separating Fact from Fiction in Shale Gas Development*, http://energy.utexas.edu, accessed February 24, 2012.

[25] Energy Institute at The University of Texas at Austin, *New Study Shows No Evidence of Groundwater Contamination from Hydraulic Fracturing*, http://energy.utexas.edu, accessed February 24, 2012.

Table 1: United States oil-and gas-producing state-by-state comparison of hydraulic fracturing chemical disclosure regulations[27]

	Arkansas	Colorado	Louisiana	Montana	New Mexico	North Dakota	Pennsylvania	Texas	Wyoming
Base Fluid Type	Yes	Yes	Yes	Yes	Yes (by reference to Frac Focus template)	Yes	No	Yes	Yes
Base Fluid Volume	Yes	Yes	Yes	Yes	Yes (by reference to Frac Focus template)	Yes	Yes	Yes	Yes
Additive Trade Name	Yes	Yes	Yes	Yes (trade secret only)	Yes (by reference to Frac Focus template)	Yes	No	Yes	Yes
Additive Vendor	Yes	Yes	Yes	No	Yes (by reference to Frac Focus template)	Yes	No	Yes	No
Additive Function	Yes	Yes	Yes	Yes	Yes (by reference to Frac Focus template)	Yes	Yes	Yes	No
Additive Concentration	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes
Chemical Names	Yes (unless trade secret)	Yes (unless trade secret)	Yes (if subject to 29 CFR 1910.1200 and unless trade secret)	Yes (unless trade secret)	Yes (if subject to 29 CFR 1910.1200 and unless trade secret)	Yes	Yes (if subject to 29 CFR 1910.1200)	Yes	Yes
Chemical Concentration	No	Yes (unless trade secret)	Yes (if subject to 29 CFR 1910.1200 and unless trade secret)	Yes (unless trade secret)	Yes (if subject to 29 CFR 1910.1200 and unless trade secret)	Yes	Yes (if subject to 29 CFR 1910.1200)	Yes (if subject to 29 CFR 1910.1200)	Yes
Chemical Abstract Services (CAS) Number	Yes (unless trade secret)	Yes (unless trade secret)	Yes (if subject to 29 CFR 1910.1200 and unless trade secret)	Yes (unless trade secret)	Yes (if subject to 29 CFR 1910.1200 and unless trade secret)	Yes	Yes (if subject to 29 CFR 1910.1200)	Yes	No
Chemical Family CAS Number	Yes (trade secret only)	Yes (trade secret only)	Yes (trade secret only)	Yes (trade secret only)	No	No	No	Yes (trade secret only)	No
Effective Date	January 15, 2011	April 1, 2012	October 20, 2011	August 27, 2011	Rule-Making in Progress	Rule-Making in Progress	February 5, 2011	February 1, 2012	October 17, 2010

The disposal of return water

When water returns to the surface from a shale drilling operation, it may be disposed of in a variety of ways, depending on the shale basin:[28, 29]

- Reused in a new well, with or without treatment.
- Injected into on- or off-site disposal wells regulated by the EPA.
- Hauled to a municipal wastewater treatment plant or a commercial industrial wastewater treatment facility (Most wastewater treatment plants are not capable of treating the contaminants in shale gas wastewater.)
- Discharged to a nearby surface water body.

[27] Department of Natural Resources, State of Louisiana, "Comparison of state hydraulic fracturing chemical disclosure regulations," December 2011, http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=888, accessed on June 17, 2012.

[28] Shale Gas Subcommittee of the Secretary of Energy Advisory Board, *The SEAB Shale Gas Production Subcommittee Ninety-Day Report*, August 11, 2011.

[29] Veil JA, Argonne National Laboratory, *Water Management Technologies Used by Marcellus Shale Gas Producers*, July 2010, www.netl.doe.gov, accessed February 24, 2012.

In the Marcellus Shale, one of the largest shale basins in the United States located in Pennsylvania and New York state, a large proportion of the hydrofracking fluid is usually recovered after drilling and stored on-site in evaporation pits. Recovered fluid may be trucked off-site for use in another fracking operation or for treatment and disposal in surface waters, underground reservoirs, or at a wastewater treatment facility. The remainder of the fluid remains underground.[30]

However, in the water-deprived shale basins of Texas (such as Eagle Ford), more of the hydrofracking fluid may remain underground. This water is much harder to track than surface water, which may lead to increased short and long-term risks for companies.

Four critical shale water risk categories

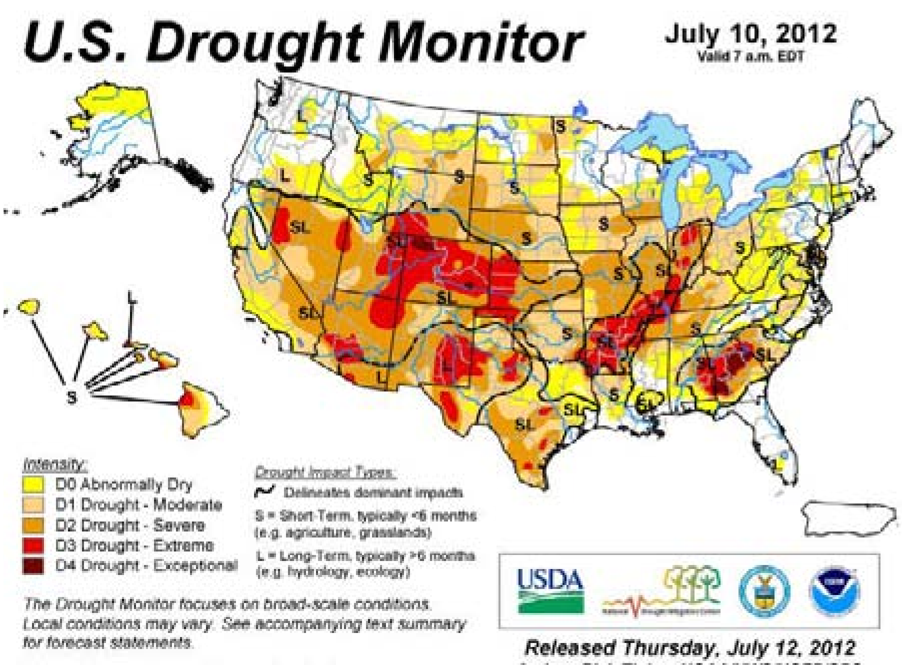
There are four key risk areas that can impact companies undertaking fracking operations. The type of risk and impact will vary according to the location and type of shale basin.

1) Physical/Environmental risks

There are a number of physical risks that can impact shale operations including:

- **Water availability** can be a serious challenge, particularly in drought-prone or high-demand areas. Water availability may be further exacerbated by the effects of a changing climate.
  - Shale gas producers rely on fracking to develop about 85 percent of the natural gas wells drilled in water-deprived Texas. The water requirements of Texas (18 million acre-feet of water) already exceed its water supplies, so rationing is being considered for industry, farmers, and manufacturers. An acre-foot is about 325,000 gallons (enough to supply three average households for a year).[31]
  - The Texas Water Development Board estimates that each shale well requires 3 million to 9 million gallons of water. Due to its geological formation, up to 13 million gallons of water is required for each well in the Texas Eagle Ford Basin (or more if the process needs to be repeated to stimulate the well).[32]The demand and supply situation in the Eagle Ford shale is leading to some companies having to go outside the Eagle Ford region to access water leading to additional trucking costs and increased water prices.[33]
  - A study by the Bureau of Economic Geology at the University of Texas forecasts that oil and gas companies will likely increase water consumption to 44,800 acre-feet of water in 2020 (from 5,800 in 2010) in the Eagle Ford Shale formation in South Texas. Water use in the Barnett Shale is projected to increase to 40,300 acre-feet from 27,900 during the same period.[34]

Figure 5: U.S. Drought map July 10, 2012



[30] Veil JA, Argonne National Laboratory, *Water Management Technologies Used by Marcellus Shale Gas Producers*, July 2010, www.netl.doe.gov, accessed February 24, 2012.

[31, 32] Parkinson G, "BHP's Texan water torture," http://www.climatespectator.com.au/commentary/bhps-chinese-water-torture, accessed February 24, 2012.

[33] Dittrick P, *Oil and Gas Journal* "Drought raising water costs, scarcity concerns for shale plays," July 30, 2012, http://www.ogj.com, accessed on July 31, 2012.

[34] Lee M, "Parched Texans Impose Water-Use Limits for Fracking Gas Wells," Businessweek.com, http://www.businessweek.com/news/2011-10-06/parched-texans-impose-water-use-limits-for-fracking-gas-wells.html, accessed February 24, 2012.

- **Weather related events** can create serious challenges to control the runoff of water at the site. This can lead to increased erosion of soil and pits on-site and increased risk of contamination to surface and groundwater.

- **Water quality issues** can arise from potential contamination due to the improper disposal of fracking fluids and/or spills. Chemicals may migrate into drinking water sources and pose threats to local people's health and the environment. Plus, methane migration from producing shale wells into surrounding drinking water wells can occur due to drilling in a geologically unstable location, loss of well casing integrity, or production pressure management.[35]

- **The environmental impact on biodiversity** in shale drilling areas is a prime concern of regulators and opponents to hydraulic fracturing. Shale gas development activities may have a detrimental impact on wildlife and habitat. Clearing acreage for well sites can also lead to biodiversity impacts.

- **Greenhouse gas emissions (GHG) and other air emissions** from shale well sites are also a key environmental concern. GHG emissions are generated in shale gas operations from exploration through processing to transmission and distribution. The EPA has finalized GHG reporting regulations from many of these emissions sources under the Mandatory Reporting of Greenhouse Gases Rule. Additional air emissions regulations on a state and federal level impact many of these operations as well. [36]

2) Regulatory risks

One of the biggest challenges to the United States shale gas industry is environmental compliance requirements and the imposition of additional regulations that may decrease production and increase operational costs. Some of these regulatory risks with respect to water resource management during the shale production life cycle include:

- **The current primary regulatory authority for shale gas** is at the state level, but most state oil and gas regulations have not kept pace with shale gas development. Some states have revised regulations specifically for shale gas development, focusing on three key areas:[37]

  1) Disclosure of hydraulic fracturing chemicals

  2) Proper casing of wells to prevent aquifer contamination

  3) Management of wastewater from flowback and produced water.

- **The Fracturing Responsibility and Awareness of Chemicals Act** was introduced by Democratic members of Congress in 2009. This amended the federal Safe Water Drinking Act by bringing hydraulic fracturing under federal jurisdiction. New local, state, and federal regulations are currently being developed, proposed, and enacted, and will be discussed in the next section of this paper.

- **Soil contamination** by fracking fluid chemicals is another consideration and can be costly to remediate. It is important to contain surface water runoff at well sites and to dispose of soil that becomes tainted by fracturing wastewater.[38]

- **Remediation requirements** can become important as wells reach the end of their life cycles. More than half of a well's total production usually is achieved in the first 10 years of drilling.[39] When a well can no longer produce shale gas economically, it is plugged and abandoned according to the standards of each state. Disturbed areas, such as well sites and access roads, are reclaimed back to the native vegetation and contours—or to conditions specified by the landowner.[40]

  – Improperly closed or abandoned shale gas wells may create human health and safety risks, as well as air pollution and surface and groundwater contamination risks. Most states require operators to post a bond or some form of financial security to ensure compliance, but also to ensure there are funds to properly plug the well once production ceases. However, the size of the bond covers only a small fraction of the site reclamation costs.[41] The economics of shale gas development encourages the transfer of assets from large entities to smaller ones. With the assets go the liabilities, but without a mechanism to prevent the new owners from assuming reclamation liabilities beyond their means, the economics favor default on well-plugging and site restoration obligations.

  – **The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)** (also known as Superfund) was enacted in 1980 to tax the chemical and petroleum industries and provide broad authority to respond to releases of hazardous substances that may endanger public health or the environment. CERCLA established a trust fund when no responsible

[35] Shale Gas Subcommittee of the Secretary of Energy Advisory Board, The SEAB Shale Gas Production Subcommittee Ninety-Day Report, August 11, 2011.

[36] Santoro RL, Howarth RH, Ingraffea AR, *Indirect Emissions of Carbon Dioxide from Marcellus Shale Gas Development. A Technical Report from the Agriculture, Energy, & Environment Program at Cornell University*, June 30, 2011, http://www.eeb.cornell.edu/howarth/Marcellus.htm, accessed March 18, 2012.

[37] Parkinson G, "BHP's Texan water torture," http://www.climatespectator.com.au/commentary/bhps-chinese-water-torture, accessed February 24, 2012.

[38] KPMG Global Energy Institute, *Shale Gas Outlook: A U.S. Perspective*, July 2011, www.kpmgglobalenergyinstitute.com, accessed February 14, 2012.

[39, 41] Mitchell AL, "*Who Will Pay for Shale Gas Well Reclamation in Pennsylvania?*" http://www.wkbn.com/media/lib/129/9/8/9/9895bc2c-d6ae-4a5c-8317-62f9f4ce5f37/Who_Will_Pay.pdf, accessed March 17, 2012.

[39, 42] The United States Department of Energy, *Modern Shale Gas Development in the United States: A Primer*, April 2009, www.gwpc.org, accessed March 10, 2012.

party can be identified to clean up hazardous waste.[42] Certain substances are excluded from the CERCLA definition of hazardous substance, such as petroleum and natural gas. CERCLA reporting only applies to shale gas production and processing sites if hazardous substances are spilled in reportable amounts.[43] However, according to the Emergency Planning and Community Right-to-Know Act (EPCRA), any release of a petroleum product containing certain substances must be reported.[44]

- **Licensing and access** issues face shale operators seeking permits to drill new wells. Risks include approval delays, extensive data requirements (well location, construction, operation, and reclamation), and paperwork.
  - The Texas Railroad Commission has jurisdiction over all oil and gas activities and surface mining in the state, in addition to any industrial use of ground and surface water.[45]
  - In other oil- and gas-producing states, the approving authority is required to issue notification to landowners potentially affected and/or the general public; this can lead to further investigations and delays.
  - In addition, cities, counties, tribes, and regional water authorities may also set or require compliance for additional regulations that affect the location and operation of the well or require additional permits and approvals.
- **Transportation of water** is critical to shale drilling when a pipeline or nearby water source is not available. Often, water is trucked into a well site for fracking. Trucks may also be used to haul away well wastewater when nearby treatment and disposal are not options.
  - In certain locations, trucking has become a problem due to significant damage caused by volume and weight loads to local roadways and traffic issues for local communities. Shale gas developers may have to negotiate to compensate communities for local road maintenance and repair.[46]
- **Spills management and surface water protection** are critical to contain hydraulic fracking fluid and prevent environmental contamination. Leaks and spills associated with shale gas production may occur at the drill pad during drilling, well production, or during transportation.
  - The primary risk from fracking fluid spills is generally to surface and groundwater sources. Companies' ability to monitor and respond to these events is important for the success of the operation. For example, without an automated trigger to notify an IT alert system in the event of a spill, it may only be observed physically on-site. By the time the spill is acknowledged and addressed, some collateral damage may have occurred to the surrounding area.
  - The **Clean Water Act (CWA)** and the **Oil Pollution Act (OPA)** include regulatory and liability provisions to help reduce the damage caused by spills to natural resources. Section 311 of the CWA regulates the prevention of and response to accidental releases of oil and hazardous substances that affect natural resources by creating and implementing facility and response plans.
  - The oil Spill Prevention, Control, and Countermeasure (SPCC) documents the measures that each facility owner has taken to prevent oil spills, and the measures in place to contain and clean up spills if needed.

3) Reputational risks

Constraints on water availability and increased demand can make companies more susceptible to reputational risks. Local conflicts can threaten a company's license to operate. Reputational risks can include:

- **Unethical behavior (or fraud)** involving water supply and disposal services can be damaging to a company's reputation and bottom line as it is held ultimately responsible for local, state, and federal regulatory compliance.
  - Some municipalities may permit the use of water for fracking, but not allow the water to be transported to a well site in another municipality—while others may ban the use of water for fracking or the treatment of shale wastewater.
  - In August 2012, Grand Prairie in the Barnett Shale in North Texas became the first municipality to ban the use of city water for fracking.[47]
  - A gas production company was recently cited with a permit violation for transporting city water from Arlington, Texas, to a well in Grand Prairie, which had banned the use of water for fracking.[48]
  - The transportation of fresh water on the services side may lead to the fraudulent writing of work tickets, adding extra hours and raising operating costs. The growing prosecution of water fraud in hauling and disposal is creating a growing need for vendor consolidation and dispatch service to monitor and prevent opportunities for unethical behavior.

[43, 44] United States Department of Energy, *Modern Shale Gas Development in the United States: A Primer.* April 2009, www.gwpc.org, accessed March 10, 2012.

[45] Railroad Commission of Texas, *Water use in association with oil and gas activities regulated by the railroad commission of Texas*, http://www.rrc.state.tx.us/barnettshale/wateruse.php, accessed March 18, 2012.

[46] United States Department of Energy, *Modern Shale Gas Development in the United States: A Primer.* April 2009, www.gwpc.org, accessed March 10, 2012.

[47, 48] Lee M, "Parched Texans Impose Water-Use Limits for Fracking Gas Wells," Businessweek.com, http://www.businessweek.com/news/2011-10-06/parched-texans-impose-water-use-limits-for-fracking-gas-wells.html, accessed February 24, 2012.

- **Environmental compliance by vendors** can present a number of challenges for companies with the primary risk of uncontrolled releases to surface and/or groundwater, leading to regulatory action and reputational impacts:
  - Leaks and spills associated with shale gas development can occur during the transportation (truck and piping) of materials and wastes to and from the well pad.
  - Transportation (truck and pipe) of wastewater from flowback and produced water for disposal either off-site or into an injection well.
  - On-site and off-site spills may occur due to accidents, inadequate facilities management, staff training, or from illicit dumping.[49]
- **Community perceptions** are critical to winning "hearts and minds" to support local shale drilling operations. Some companies have engaged with stakeholders and communities to educate and reassure communities that hydraulic fracturing can be environmentally safe when conducted properly and responsibly.[50] Overcoming negative perceptions of shale drilling in the media is also a challenge. Researchers from the Energy Institute of the University of Texas (Austin) found that approximately two-thirds of the news stories and articles reviewed took a negative position on shale gas development. In addition, fewer than 20 percent of newspaper articles on hydraulic fracturing mentioned scientific research related to the issue, compared to 25 percent of broadcast news stories and about 33 percent of online news coverage.[51]
- **Community impacts** can be felt beyond local concerns such as traffic, road damage, dust, and noise. Dairy farmers in Pennsylvania were concerned with the increase in fracking and its resulting effect on their communities. Community concerns extend to leases favorable to gas companies, liens on property, mortgage conflicts, social disintegration, loss of agricultural lands, groundwater and soil contamination, increased farming and community costs, and a drop in tourism.[52]

4) Forward-looking risks

The following risks have the potential to impact United States shale gas production in the future and warrant close monitoring by businesses.

- **A tighter regulatory environment** is threatening to curtail the rapid growth of shale drilling in the United States.
  - In March 2010, as mentioned earlier in this paper, the EPA began a two-year study on the potential impacts of hydraulic fracturing on drinking water resources, examining factors that may lead to human exposure and risks. The initial results and recommendations of this study are expected to be made public in 2012. A final report will be presented in 2014.
- **Pricing is an important issue** especially in water-sensitive areas, where the cost of obtaining, treating, and disposing of water for hydraulic fracturing can rise according to high demand and short supply. The cost of fuel may also raise transportation costs where well sites rely on trucking water in for hydraulic fracturing and out for treatment and disposal.
- **Loss of shale basin access** due to community concerns about drinking water quality and the potential environmental impact of the shale drilling process may occur. For example, while investigating the possibility of aquifer contamination from hydraulic fracturing, New York state regulators placed a moratorium on new gas drilling and have denied new permits.[53] The New York Department of Environmental Conservation is expected to release its final fracking regulation plan in late 2012.[54] In May 2012, Vermont became the first United States state to ban hydraulic fracturing. Bans of shale gas production are not unique to the United States. France banned hydraulic fracturing as of July 1, 2011, including its use for research purposes.[55]
- **New litigation** may result from increased government agency oversight and the need for compliance with tightening regulations. This can range from permit violations to major lawsuits for environmental damage or contamination.

Federal shale gas recommendations to protect water quality

In its report on August 11, 2011, the federal Shale Gas Subcommittee of the Secretary of Energy Advisory Board (SEAB) outlined recommendations for the protection of water quality. The subcommittee urged the adoption of a systems approach to water management based on consistent measurement and public disclosure of the flow and composition of water at every stage of the shale gas production process.[55]

The subcommittee recommended the following actions by shale gas companies and regulators:

- Measure and publicly report the composition of water stocks and flow throughout the fracturing and cleanup process.
- Manifest all transfers of water among different locations.

[49] Energy Institute at The University of Texas at Austin, *Separating Fact from Fiction in Shale Gas Development*, http://energy.utexas.edu, accessed February 24, 2012.

[50] Javers E, CNBC. Oil Executive, "Military-Style 'Psy Ops' Experience Applied," CNBC.com, http://www.cnbc.com/id/45208498, accessed February 28, 2012.

[51] Energy Institute at The University of Texas at Austin, *Separating Fact from Fiction in Shale Gas Development*, http://energy.utexas.edu, accessed February 24, 2012.

[52] Johnson B, "Think Progress Green. Frackers use "psy ops" to deal with Pennsylvania 'insurgency,'" http://thinkprogress.org/green/2011/11/09/364437/frackers-use-psy-ops-to-deal-with-pennsylvania-insurgency/?mobile=nc, accessed February 28, 2012.

[53] Beckwith R, JPT Online, "Hydraulic Fracturing: The Fuss, the Facts, the Future," http://www.jptonline.org, accessed March 19, 2012.

[54] Farley J, THIRTEEN WNET, "As Fracking Bans Hold Water, Other N.Y. Towns Jump on 'Ban Wagon'," http://www.thirteen.org/metrofocus/news/2012/02/as-fracking-bans-hold-water-other-n-y-towns-jump-on-ban-wagon/, accessed March 19, 2012.

[55] KPMG Global Energy Institute, *Shale Gas Outlook: A U.S. Perspective*, July 2011, www.kpmgglobalenergyinstitute.com, accessed February 14, 2012.

[56] Shale Gas Subcommittee of the Secretary of Energy Advisory Board, *The SEAB Shale Gas Production Subcommittee Ninety-Day Report*, August 11, 2011.

- Adopt best practices in well development and construction, especially casing, cementing, and pressure management. Pressure testing of cemented casing and state-of-the-art cement bond logs should be used to confirm formation isolation.
- Microseismic surveys should be carried out to assure that hydraulic fracture growth is limited to the gas-producing formations. Regulations and inspections are needed to confirm that operators have taken prompt action to repair defective cementing jobs. The regulation of shale gas development should include inspections at safety-critical stages of well construction and hydraulic fracturing.
- Additional field studies should be performed on possible methane leakage from shale gas wells to water reservoirs.
- Adopt requirements for background water quality measurements (e.g., existing methane levels in nearby water wells prior to drilling for gas) and report in advance of shale gas production activity.
- Agencies should review field experience and modernize rules and enforcement practices to ensure protection of drinking and surface waters.

The subcommittee identified several activities that deserve priority attention for developing best practices in relation to water management:[57]

Water quality	• Well completion – casing and cementing, including use of cement bond and other completion logging tools. • Minimizing water use and limiting vertical fracture growth.
Water supply	• Track and report water flows quantitatively throughout the process. • Development and use of integrated water management systems.

Proposed federal shale industry disclosure standards

The United States Department of Interior has reported that it will propose standards requiring shale gas companies to disclose the chemicals in the mixture injected underground to free trapped gas, demonstrate the well is not leaking, and check the work after fracking.[58] Drilling on federal land will also be required to meet guidelines for handling fracking water that flows back after being injected into the rock to avoid contaminating streams. Currently, more than 90 percent of natural gas wells drilled on federal land use fracking.[59] In addition, the Securities and Exchange Commission (SEC) is asking oil and gas companies to supply fracking information confidentially. The SEC may publicly disclose some of this information if circumstances in the field of operation creates uncertainty.

Opportunities to mitigate water risks with technology

Many technology providers and a variety of technology approaches are available for treating produced and flowback water from shale gas operations, depending on the quality of the water to be treated and its end use.

Acquiring alternative water sources

There are examples of oil and gas companies tapping water from salty, nondrinkable aquifers to meet demand for increased development in water-scarce regions and reducing the dependence on local water resources.[60]

Recycling and reuse

Hydraulic fracturing does not require water that is of potable (drinking water) quality. Recycling wastewater helps conserve water use and provide cost-saving opportunities. In Marcellus, there are examples of companies reusing up to 96 percent of their produced water.[61] Other examples of recycling and reuse include:

- The use of portable distilling plants to recycle water in the Barnett Shale, particularly in regions such as the Granite Wash field in North Texas, where water resources are more critical than in other shale basins in the United States. [62]

[57] Shale Gas Subcommittee of the Secretary of the Energy Advisory Board, *The SEAB Shale Gas Production Subcommittee Ninety-Day Report*, August 11, 2011.

[58, 59] Klimasinska K, "Gas Well Inspections to Be Required After Fracking, Salazar Says," Bloomberg.com, http://www.bloomberg.com/news/2012-02-14/gas-well-inspections-to-be-required-after-fracking-salazar-says.html, accessed March 15, 2012.

[60, 62] Lee M, "Parched Texans Impose Water-Use Limits for Fracking Gas Wells", Businessweek.com, http://www.businessweek.com/news/2011-10-06/parched-texans-impose-water-use-limits-for-fracking-gas-wells.html, accessed February 24, 2012.

[61] Rassenfoss S, *Journal of Petroleum Technology*, "From Flowback to Fracturing: Water Recycling Grows in the Marcellus Shale," July 2011, http://www.spe.org/jpt/print/archives/2011/07/12Marcellus.pdf, accessed February 14, 2012.

- A water purification treatment center in Kenedy, Texas, recycles 5,000 barrels of flowback and produced water per day generated from extracting oil and natural gas from the Eagle Ford Shale. This approach is also being used in the Marcellus Shale.[63]
- The Marcellus Shale also employs vapor recompression technology to reduce the cost of recycling fracturing water by using waste heat. The unit produces water vapor and solid residue that is disposed of in a waste facility.[64] In addition, to reduce contamination risks during shale operations, many gas companies in the Marcellus Shale are reducing the amount of chemical additives used in fracturing fluid while producing shale gas.[65]
- A wastewater treatment company specializing in the oil and gas industry has designed a mobile integrated treatment system for hydraulic fracturing that allows the reuse of water for future drilling. Using dissolved air flotation technology, the system can treat up to 900 gallons per minute of fracking flowback water. The accelerated water treatment reduces the equipment burdens and logistics of traditional treatment methods and could significantly reduce operational costs.[66]
- Produced water can have high total dissolved solids (TDS) concentrations that can be difficult to treat. Thermal distillation, reverse osmosis (RO), and other membrane-based desalination technologies can be deployed to desalinate produced water to a level fit for purpose.

The economics of water recycling and reuse can be a challenge, particularly in areas where there is a low cost of injection disposal. However, if there is local pressure for companies to conserve water, recycling and reuse can present opportunities to increase water security and reduce overall costs. Water reuse and recycling can be an effective economical alternative to the cost of trucking wastewater to an injection well.[67] Table 2 shows current management practices for produced water across the U.S. major shales.

Table 2: Current produced water management by U.S. shale gas basins[68]

Shale Gas Basin	Water Management Technology	Availability	Comments
Barnett Shale	Class II injection wells	Commercial and noncommercial	Disposal into the Barnett and underlying Ellenberger Group
	Recycling	On-site treatment and recycling	For reuse in subsequent fracturing jobs
Fayetteville Shale	Class II injection wells	Noncommercial	Water is transported to two injection wells owned and operated by a single producing company
	Recycling	On-site recycling	For reuse in subsequent fracturing jobs
Haynesville Shale	Class II injection wells	Commercial and noncommercial	
Marcellus Shale	Class II injection wells	Commercial and noncommercial	Limited use of Class II injection wells
	Treatment and discharge	Municipal waste water treatment facilities, commercial facilities reportedly	Primarily in Pennsylvania
	Recycling	On-site recycling	For reuse in subsequent fracturing jobs

[63] Aqua-Pure Ventures, *Aqua-Pure Expands Operations to Eagle Ford Shale*, www.aqua-pure.com, accessed March 15, 2012.

[64, 67] Rassenfoss S, *Journal of Petroleum Technology*, "From Flowback to Fracturing: Water Recycling Grows in the Marcellus Shale," July 2011, http://www.spe.org/jpt/print/archives/2011/07/12Marcellus.pdf, accessed February 14, 2012.

[65] Energy from Shale.org, *Water use*, http://www.energyfromshale.org/fracking-fracturing-water-supply, accessed March 15, 2012.

[66] Environmental leader, "Ecologix Launches Fracking Water Treatment System," *Environmental Management & Energy News*, http://www.environmentalleader.com/2012/02/03/ecologix-launches-fracking-water-treatment-system/, accessed March 15, 2012.

[68] Office of Fossil Energy and National Energy Technology Laboratory, Ground Water Protection Council and All Consulting, *Modern Shale Gas development in the United States: A primer prepared for U.S. Department of Energy*, April 2009.

Shale Gas Basin	Water Management Technology	Availability	Comments
Woodford Shale	Class II injection wells	Commercial	Disposal into multiple confining formations
	Land Application		Permit required through the Oklahoma Corporation Commission
	Recycling	Noncommercial	Water recycling and storage facilities at a central location
Antrim Shale	Class II injection wells	Commercial and noncommercial	
New Albany Shale	Class II injection wells	Commercial and noncommercial	

Taking water out of the equation

Imagine if it was possible to achieve the benefits of hydraulic fracturing without using water at all. Since 2008, liquid petroleum gas (LPG) fracturing has been used instead of water in wells in Calgary, Alberta, Canada. Under extreme pressure, the petroleum gel turns into vapor that returns to the surface where it can be recaptured with the natural gas. While this technology has been introduced elsewhere, for example, Haynesville Shale in Texas, "waterless fracturing" is still in its infancy.[69]

Reducing truck traffic

Many residents in areas where shale drilling is active are concerned about the additional traffic in the region, in particular, the increase in trucks. The number of trucks used can be reduced by shrinking the operational footprint with streamlined well site layouts. In Western Pennsylvania, one oil and gas company has reduced its truck traffic by installing water pipelines to minimize the need to haul water to fracturing sites. The use of GPS navigational systems to optimize trucking routes can also assist in reducing the truck traffic and flow.

[69] Rassenfoss S, *JPT Online*, "Fracturing Critics Take to the Air," http://www.jptonline.org, accessed March 19, 2012.

How to mitigate water risks in your operations

The oil and gas industry has many established processes and protocols around environmental risk management. Historically, these practices have focused on detecting compliance failures or breaches of laws and regulations associated with water resource management and environmental management more broadly.

As the pressure on water resources increases, it is timely for boards, management, and the environmental department to take stock of whether existing frameworks for identifying and mitigating operational (physical), regulatory, and reputational risks deliver quality information and controls for the organization. There are a number of ways in which shale gas companies can mitigate water-related risks across each stage of the shale process.

- **Understanding water risks**
  Companies need to understand the risks to water resources that their businesses depend on. Actions that companies can take include:
  - Pinpoint physical, regulatory (including incident), and materiality risk hot spots across your value chain by accounting for water demand and supply.
  - Assess the financial impacts to your business under different water availability scenarios to monitor changes in risk profiles and identify operational activities that present a material financial risk.
  - Create reporting metrics, inventories, risk, and performance metrics.
  - Identify business-to-business opportunities associated with water sourcing, use, and discharge.
  - Benchmark to assess water risk relative to competitors.
  - Position operations and supply chains for growing water stress.
- **Vendor risk (contract environmental compliance and standards)**
  Companies that can account for water use and management in their supply chains will be well placed to identify opportunities to reduce exposure to water scarcity, changes to operating licenses, supply disruptions, price volatility, and climate change impacts. Actions companies can take include:
  - Evaluate vendor environmental compliance with contractual terms and/or company environmental policy and procedures.
  - Track, monitor, and audit vendor compliance.
  - Assess supplier relationship and risk management.

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