Environmental Issues in Unconventional Oil and Gas Resource Development

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Chapter 22: Environmental Issues in Unconventional Oil and Gas Resource Development

“You don’t get your social license by going to a government ministry and making an application or simply paying a fee… It requires far more than money to truly become part of the communities in which you operate.”

Pierre Lassonde, President of Newmont Mining Corporation

22.1 Introduction

The shale revolution in North America has completely changed the visibility of oil and gas operations throughout the world. Shale development is attractive for most countries because it can increase domestic supply (with the potential for exports) and displace the use of coal or liquid hydrocarbons. The liquid hydrocarbons produced in unconventional plays are valued like conventional oil. The economic impact (such as job creation, capital expenditures, and revenues to the state) provides positive benefits. There are potential effects on the environment that are examined in this chapter.

Although hydraulic fracturing is just one aspect of shale exploration, development, and production that has the potential for environmental consequences, hydraulic fracturing (or “fracking” as its detractors refer to it) has become a focal point for activists’ protests and government actions. This chapter discusses the social license to operate, the environmental consequences of oil and gas activity (which includes hydraulic fracturing), ways to mitigate environmental damage, and current US federal and state regulatory activities.

22.2 Social License to Operate

The first part of the discussion about environmental issues related to unconventional activities covers a topic that is rarely discussed in technical books: a social license to operate (SLO). However, the target audience for this book includes asset team members operating unconventional activities around the world, to which the topic is unmistakably important. Without a SLO, technical and financial decisions may be irrelevant. Without maintaining the SLO, ongoing production and project profitability are endangered. The primary risks to the social license to operate are environmental impacts from activities, the perception of those impacts, and effective, open communications with a broadly defined community.

Thomson and Boutilier (2011) developed a model of the social license to operate based on studies of mining activities and the surrounding communities. The social license to operate is essentially the perception of a company and its activities based primarily on the affected communities. For shale development activities, this should be expanded to include those who believe that they may be affected whether directly or indirectly and this discussion refers to community in a broad sense. A graphical depiction of their model (Fig. 22.1) shows four levels of the social license to operate hierarchy. The lowest (withheld/withdrawn) is currently the de facto status in several US states including New York and many countries (e.g., Germany and France) with significant unconventional resource potential. Much of the opposition to such activity specifically targets hydraulic fracturing. Some of this opposition arises from a 2010 film entitled Gasland that purports to show environmental damage from oil and gas operations and blames their actions for a host of environmentally damaging activities. The film is controversial and has numerous flaws debated elsewhere. The result of the withheld social license to operate doesn’t always mean oil and gas activities are immediately shut down; however, this lowest level of social license to operate generates protests, boycotts, shareholder resentment, and legal actions, along with the potential for violence or sabotage. Another consequence of a very low level of social license is increased regulatory scrutiny, which often results in the removal of the formal license to operate.

The next highest level of social license to operate is acceptance/tolerance. The model shows that moving from withheld to acceptance implies that activities pass the “legitimacy” boundary. Acceptance brings continued examination of activities, involvement of external groups, and the need for improved communication and relationships. Community acceptance should not be confused with approval or support, which is the next level in the social license to operate hierarchy. Approval implies that oil and gas development activities are viewed with some sense of pride and that a level of trust has been developed. Approval is often accompanied by a positive economic effect for the community, but this benefit is insufficient to pass the “credibility” boundary to go from acceptance to approval. At the approval stage, the community implies that communications are truthful and effective, and that they comply with acceptable practices and long-term engagement.
The highest level of social license to operate is psychological identification and implies the trust of the community. At this level, the community has gone beyond cooperating and is identifying positively with the operating company and its activities. There is both technical and social credibility, which implies a very high quality of relationship. There are oil and gas communities who are at the acceptance and approval levels of social license to operate and some areas of psychological identification.

Gaining and maintaining high social license to operate levels doesn’t happen because of a series of transactions, but rather as a result of the long-term performance and quality of relationships. It is unlikely that the most ardent opponents of oil and gas activities will ever be convinced of the legitimacy of oil and gas activities. However, effective communications, community involvement, and safe, environmentally sound activities will convince most communities of the legitimacy and credibility of activities. In the following discussions of environmental risks, challenges to the social license to operate will be reviewed.

### 22.3 Environmental Issues in Unconventional Activities

The potential environmental impacts from unconventional activities include those from well construction activities and those from production activities. Potential issues include:

- Release of greenhouse gases into the atmosphere, particularly vented methane.
- Pollution of surface water associated with disposal of produced water or from spills.
- Air and noise pollution associated with transportation to and from the wellsite.
- Road damage and accidents associated with transportation to and from the wellsite.
- Damage (visual, erosion, loss of habitat, loss of vegetation) associated with the well pads and related production and transportation activities.
- Potentially greater footprint than conventional hydrocarbon extraction activities.
- Surface spills of produced liquid hydrocarbons, hydraulic fracturing treating fluids, drilling mud, or other materials in well construction, corrosion chemicals, or byproducts from other production activities.
- Hydrocarbon migration behind the pipe from either the productive zone, or another hydrocarbon bearing zone, to a usable water zone (either potable or useful for agriculture). This is a potentially hazardous behind-pipe migration event.
- Migration of any fluids from one zone to another. This is a broader category, which includes potentially innocuous events.
- Subsurface seismic (microseismic) events.
- Use of large amounts of water in the hydraulic fracturing process.
- Naturally occurring radioactive materials (NORMs) brought to the surface in production activities or in recovered downhole equipment.
- Disruption of communities.

Some of these concerns are either minor or substantially not present. All of the concerns can be mitigated or eliminated through the application of best practices in the industry. While this chapter doesn’t address the issues that are primarily the same as with conventional oil and gas production, those unique to unconventional activities will be addressed. Some major differences between most conventional hydrocarbon extraction activities and unconventional resources are the total area affected, the magnitude of hydraulic fracturing operations, and the total number of wells involved. Unconventional resources typically cover very large areas and are developed with horizontal wells containing from 20 to more than 50 stages. A typical tight gas sand play might only have a few stages; therefore, the total volumes of injected materials are usually smaller than in unconventional treatments. This requires the transportation of significantly greater volumes of sand (or other proppant) to the location and requires significant volumes of water.
22.3.1 Greenhouse Gas Issues

Few environmental issues have gathered more attention in the last few decades than the effects of greenhouse gases on global climate. It is undisputed that CO$_2$ emissions associated with human activities have increased steadily over a long period. There remains some debate on precisely how much these emissions (along with other greenhouse gases) have—or will—impact the climate. This discussion is outside the scope of this book. There remains a larger debate about precisely what should be done to mitigate the impact of such greenhouse gases.

The United States was not a signatory to the Kyoto Protocol, which sets goals for the reduction of greenhouse gases. However, even without participation in the Kyoto Protocol, total CO$_2$ emissions in the US have decreased substantially. Increased natural gas production has played a significant role in these reductions, primarily by displacing coal-fired power plants, and this shows a typical annual change where increased natural gas has displaced coal use (Fig. 22.2). There is also a slight increase in wind turbine generation that fails to offset the decrease in hydroelectric power.

North American CO$_2$ emissions continue to drop while the rest of the world, in aggregate, continues to increase CO$_2$ significantly (Fig. 22.3). China is the biggest source of increased CO$_2$ emissions. Global CO$_2$ emissions increased by 2845 million metric tons from 2007 to 2011; China’s growth in CO$_2$ emissions represented 84% of this growth.

China continues to expand the use of coal; however, coal usage is on the rise in many other places, particularly in Europe. Germany continues to shut down old, coal-fired power plants and open or expand more modern ones. This trend will accelerate as they shut down nuclear plants and because they have restricted hydraulic fracturing for conventional, as well as unconventional, activity.

<table>
<thead>
<tr>
<th>Year</th>
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There is little doubt that unconventional activity has had a large net positive impact on greenhouse gas emissions in the US. Greenhouse gas emissions from the well construction and production processes are comparable to those of conventional activities. There remains a larger debate about precisely what should be done to mitigate the impact of such greenhouse gases.

Fugitive emissions and venting of methane has a more serious potential impact, because methane is believed to have a larger impact on climate change than comparable volumes of CO$_2$. Methane venting in conjunction with oil production should be minimized with a goal to make venting of methane as low as reasonably practicable (ALARP). Reduced emission completions should become a standard practice. However, EPA estimates of methane emissions have been dramatically lowered from prior estimates. In spite of dramatic increases in oil and natural gas production and oil drilling, methane emissions have in fact dropped substantially as shown in Fig. 22.4.

22.3.2 Air and Surface Effects

Industry best practices include minimizing the total surface footprint by drilling multiple wells from single pads, reusing produced fluids, operating wells to minimize community impact, and eliminating unnecessary wells and well fracturing stages. The use of dual fuel (natural gas and diesel) pumps during hydraulic fracturing (such as the Baker Hughes Rhino™ Bifuel pumps) can reduce diesel usage up to 70%. This carries a corresponding reduction in nitrogen oxides, particulates, and carbon monoxide. Such pumps also reduce flaring of low-pressure methane by using nonsalable gas diverted to storage for reuse rather than being vented.

Fig. 22.2—Changes in US fuel sources for electrical power generation. (Source: Energy Information Administration 2013.)

Fig. 22.3—Total carbon dioxide emissions from energy consumption, million metric tons. (Source: Energy Information Administration Statistics.)
The elimination of surface spills is another best practice that can be improved by proper fluid handling practices and effective corrosion treatment. Innovative “green chemistry” permits much more environmentally acceptable corrosion inhibitors that also reduce overall chemical demands. Proper fluid handling practices are also simplified by pad drilling and production.

A Cambridge University study compared an unconventional pad drilling project with wind turbines and solar panels that would deliver comparable amounts of energy over a twenty-year period. In terms of land area and visual intrusion, the unconventional project is the most attractive option (shaded cells in Table 22.1). In terms of truck movements, the unconventional project has the smallest impact if water for hydraulic fracturing is piped in; otherwise it could be the largest impact.

Pad drilling results in a significant number of nearly adjacent wellheads. While this generally reduces surface impact and footprint per well, some wells are artificially lifted with sucker rod pumps that have a relatively large and visible surface-pumping unit. As many as a dozen of these wellheads in close proximity is visually unappealing. Technical issues require relatively frequent work to repair or replace downhole sucker rod pumps. The use of electric submersible pumps (ESPs) can reduce the surface impact, accelerate production, and improve lease economics. The Baker Hughes FLEXPump™ series electrical submersible pumps (ESPs) have a very wide operating range, and provide operators with the operational flexibility required in dynamic well conditions to minimize ESP system change outs and nonproductive time, while at the same time reducing operating expenses. These pumps enable the ProductionWave™ production solution that often has lower HSE impact than sucker rod pump alternatives.

22.3.3 Behind Pipe Migration

Behind pipe migration of fluids (natural gas, oil, or salt water) is most successfully minimized by effective primary cementing of the casing. Proper design of cementing jobs is a conventional practice and can be improved by such techniques as Baker Hughes SealBond™ cement spacer system to mitigate lost-circulation issues. Beyond proper design and execution, assessment of the cement bonding can be made with the Baker Hughes Acoustic Cement Bond Log. This tool provides a valuable source of data pertaining to the effectiveness of the cement sheath surrounding the casing. This data is obtained by evaluating the effect of the casing, the cement sheath, and the formation on the acoustic wave emanating from an acoustic cement bond log instrument. The amplitude curve of the reflected acoustic wave is at its maximum in an unsupported casing and minimum in those sections in which the cement is well bonded to the casing and the formation. In addition, production logging tools and/or distributed temperature surveys allow the operator to monitor the efficacy of the well over the lifetime of the well.

22.3.4 Seismic Activity

Some people have pointed to seismic activity near oil and gas developments in an effort to raise an alarm about increased earthquakes with the potential for surface damage as a result of unconventional activity. This is a complex topic that is often oversimplified by industry detractors and proponents. The term “earthquake” is used both to describe the sudden slip of a fault and the resulting ground shaking and results of radiated seismic energy. Most fault slippage results in surface energy below detection levels; however, large events range from noticeable vibrations to major property damage and/or fatalities.
Current earthquake frequency (ranked by intensity) has changed very little over time, even with the industry’s increased reliance on hydraulic fracturing production methods over the last decade (Fig. 22.5 and Fig. 22.6). However, there have been a number of individual seismic events that may have been related to oil and gas production activity. Most scientific enquiries have indicated that long-term wastewater injection (rather than hydraulic fracturing) is a potential contributor to earthquake activity, and that increases are primarily in the very small earthquakes that are generally not felt at the surface. However, larger tremors have been linked to wastewater injection and a few to hydraulic fracturing. The volume of water disposed of into injection wells vastly exceeds even the largest unconventional well hydraulic fracture treatment.

In Oklahoma, there are about 10,000 injection wells, of which about 4,400 are used to dispose of “waste” water. Waste water describes both saline brines produced in association with oil and gas production and hydraulic fracture flowback water that is not reinjected. The majority of Oklahoma’s injection wells are associated with waterflooding or EOR projects. Typically, these projects are injecting fluids into a formation capable of producing oil at pressures below the initial reservoir pressure. Little evidence of significant induced seismicity is associated with these types of wells. The wastewater injection wells are widely distributed across the state (refer to Fig. 22.7) and are correlated with areas of increased seismicity (Walsh III and Zoback 2015). The increases in seismicity follow five- to tenfold increases in the rate of wastewater injection. Wastewater injection is principally into the Arbuckle formation, a saline aquifer overlying brittle basement rock.

Seismic activity is also generated during hydraulic fracturing. Tensile failure of hydraulic fractures generates very little seismic energy. However, shear events near the created hydraulic fracture can be measured. VSFusion™ (a joint venture of Baker Hughes Inc. and CGG, Inc., a geotechnical engineering firm) measures and interprets this microseismicity. The Richter magnitude scale is a mathematical measure of earthquake energy; each integer increase represents a tenfold increase in energy. For example, a 3.0 earthquake would represent only 1% of the energy of a 5.0 earthquake. The vast majority of microseismic events measured range from less than -3.0 to -1.0 on the Richter scale. For example, a -2.0 event would be 1/100,000th of a 3.0 earthquake. At these levels, these events pose no danger to life or property. Most efforts to even detect them from the surface are challenging.

Injection wells should be sited at locations designed to minimize the risk of damage from earthquakes. Best practices need to be developed and implemented to minimize the potential for damaging induced seismicity. Long-term measurements of microseismic activity near injection wells can be undertaken in populated areas if there is a significant potential for damage from earthquakes. Recycling produced or previously injected water can decrease the likelihood of such damage.

22.3.5 Reducing the Number of Wells to Develop the Resource

The performance of unconventional wells is highly variable. Some operators believe that large statistical variations in the production rates and recoveries from unconventional wells are inevitable and unavoidable. This belief leads to a commitment to “factory drilling” practices, in which hundreds of nearly identical wells are drilled with a focus on reducing well costs. Pad drilling is an important part of this development, because it reduces surface costs and enables reductions in drilling, evaluation, completion, stimulation, and production costs. However, even in commercially...
attractive unconventional plays, 25% to 40% of all wells drilled are uneconomical. Integrating surface seismic measurements, advanced petrophysics and geomechanics, and reservoir engineering into an integrated model can help operators to identify the most productive areas and eliminate the drilling of sub-economic wells. This can dramatically lower environmental impacts while improving economics.

22.3.6 Regulatory Issues

Investigations, rulemakings, legislative proposals, lawsuits, and an endless array of articles, films, books, and blogs have drawn substantial attention to environmental issues. The public initially struggled to understand the key players in the narrative (especially the technology) and remains skeptical of the energy industry’s role and motivations. The federal and state governments have also labored to “read into” their emerging roles as regulator and enforcer while trying to regain public credibility as defenders of science. Now, as the story enters its seventh, eighth, or maybe tenth season, the roles and responsibilities are clearer and the narrative may be smoothing out.

The next section reviews key federal and state developments that may shape the years ahead. Section 22.4.3 focuses on the particular challenge of water management, where operational and technological advances are poised to overcome regulatory constraints and other limitations.

22.4 Outlook on Federal and State Developments

22.4.1 Federal Developments

In this section, we review the developments in the federal outlook, which include developments related to drinking water, diesel use in hydraulic fracturing, proposed regulations for hydraulic fracturing on public land by the US Bureau of Land Management (BLM), the new Clean Water Act, and the Toxic Substances Control Act.

22.4.1.1 EPA Hydraulic Fracturing Study

The Environmental Protection Agency (EPA) continues to work on its study of the relationship between hydraulic fracturing and drinking water resources. EPA’s investigation is focused on identifying possible exposure pathways and hazards, as well as assessing the potential risks to drinking water resources from hydraulic fracturing. EPA spent much of 2013 collecting more data to support the study, hosting technical roundtables, meeting with the Science Advisory Board, and extending the time period during which stakeholders could submit to the Agency relevant technical documents and studies. EPA anticipates releasing a preliminary report toward the end of 2014. However, in June 2013, an EPA official indicated that the public would not see a final report until 2016.
While the results of EPA’s study remain uncertain, it seems likely that any risk of impact to drinking water would be tied to the typical issues experienced by traditional oil and gas operations. For example, issues such as surface spills, poor cementing, or other well-integrity issues are not related to the migration of hydraulic fracturing fluids from induced fractures through naturally occurring faults into aquifers used for drinking water. To date, several EPA officials have publicly stated that there are no proven cases where the hydraulic fracturing process has resulted in contamination of aquifers or drinking water supplies.

22.4.1.2 EPA Diesel Guidance

In September 2013, it was reported that the White House Office of Management and Budget (OMB) had received EPA’s final Underground Injection Control (UIC) Program permitting guidance for diesel use in hydraulic fracturing operations. While industry has repeatedly indicated that diesel is typically no longer used in hydraulic fracturing treatments, some members of Congress have called this into question, citing instances of diesel use reported to FracFocus.org. Based on that information, some in Congress are requesting that OMB expedite its review of the final guidance.

While the broad definition of diesel in this context may theoretically cover more operations, it appears that diesel is now so rarely used that the final guidance will have much less impact than it might have had a decade ago. From a policy perspective, the existence of the diesel guidance indicates EPA’s belief that any hydraulic fracturing operations that use diesel should first be permitted under the EPA’s UIC Program. While EPA is aware that wells have been hydraulic fractured with diesel since the amendments to the Safe Drinking Water Act by the Energy Policy Act of 2005, the agency has not indicated any plans to undertake retroactive enforcement actions.

22.4.1.3 Bureau of Land Management: Hydraulic Fracturing Rule

In 2013, the BLM reissued a proposed rule applicable to hydraulic fracturing on federal and tribal lands. According to the BLM, its proposed rule would include the minimum standards for drilling on federal land. While the comment period for the BLM’s rule officially closed in August 2013, several Congressional hearings held since that time have seen additional comments made by members of Congress and representatives from state governments that question the need for another layer of regulation on top of states’ regulations for oil and gas operations. It is not clear when BLM will issue a final rule; however, it is likely that we will see additional Congressional hearings where BLM officials will be questioned about the utility of this rule. In EPA’s letter to the National Resources Defense Counsel (NRDC) on 14 January 2014, the agency indicated that it was working with BLM to develop this rule.

22.4.1.4 New Clean Water Act Effluent Limitation Guidelines

EPA has indicated that it will issue a proposed rule to revise the current Clean Water Act wastewater regulations in order to better control discharges from shale gas extraction activities. The federal Clean Water Act authorizes EPA to promulgate water-quality and technology-based effluent limitations. Technology-based effluent limitations are based on currently available technologies for controlling industrial wastewater discharges and are implemented by states that are authorized to administer the Clean Water Act’s National Pollutant Discharge Elimination System (NPDES) permit program, or by EPA if a state is not authorized. The effluent guidelines are incorporated into permits issued under the NPDES permit program.

EPA decided to amend the Effluent Limitation Guidelines Program Plan for the Oil and Gas Extraction Point Source Category under Title 40 CFR Part 435, based on the significant increase in unconventional wastewater tied to the rapid expansion of unconventional oil and gas operations. EPA has noted that the treatment technologies employed by private centralized waste treatment facilities (CWTs) that might treat unconventional wastewater “…are not designed to treat high levels of total dissolved solids (TDS), naturally occurring radioactive materials (NORMs), or high levels of metals.” EPA has also indicated that the pollutants found in unconventional wastewater are not getting adequate treatment by CWTs and that there are rising concerns of pass-through or interference at the publicly owned treatment works (POTWs) that accept CWT discharges.

22.4.1.5 Toxic Substances Control Act

In response to petitions regarding data reporting of chemical substances and health and safety under the Toxic Substances Control Act (TSCA) of 1976 from several non-governmental organizations (NGOs), the EPA has initiated a rulemaking proceeding under TSCA Sections 8(a) and 8(d). The rulemaking proceeding is in the pre-proposal stage, and the EPA indicates that they will actively engage the public and stakeholders in the design and scope of the reporting requirements. The EPA projects that it will issue an Advance Notice of Proposed Rulemaking under the aforementioned sections in TSCA.
22.4.2 Developments by the States

Over the last five years, states with significant shale resources have reviewed and revised their oil and gas regulatory programs to address the rapid expansion of exploration and production activities. While the primary regulatory updates have focused on the addition of chemical disclosure provisions, several states have also updated rules applicable to waste treatment, setbacks, and well integrity. In 2014 and beyond, states will be tackling some of the more novel issues associated with development of shale gas resources. The following section describes recent trends in state regulatory developments.

22.4.2.1 Air Emissions

In November 2013, the state of Colorado released new rules aimed at reducing methane emissions from oil and gas operations. Colorado’s proposal is the first of its kind that would regulate the detection and reduction of methane, which is a potent greenhouse gas. In a regulatory package aimed at fully adopting EPA’s recently finalized New Source Performance Standard (NSPS) OOOO, the Colorado Air Pollution Control Division included revisions to Regulation No. 7 that would establish controls and requirements for oil and natural gas operations that exceed the requirements in the NSPS OOOO.

Generally, the proposed revisions to Regulation No. 7 would “…increase control requirements and improve capture efficiency requirements for oil and gas storage tanks; minimize fugitive emissions of hydrocarbons [including but not limited to volatile organic compounds (VOCs) and methane] from leaking components at compressor stations and well production facilities; minimize venting and flaring at new and modified oil and gas wells; and expand control requirements for pneumatic devices.” Colorado contemplates that there will be some overlap between the different requirements of NSPS OOOO and Regulation Number 7 but that the requirements “secure different emissions reductions.” Industry has estimated that the cost of the new [state] rules could be up to $80 million per year. Moving forward into 2014, we could see additional states enact similar rules—as well as legal challenges—to a state’s authority to enact such rules.

22.4.2.2 NORM and Waste Management

In March 2011, EPA sent a letter to the Pennsylvania Department of Environmental Protection (PADEP) expressing concern over reports that wastewater from Marcellus shale operations contained “…variable and sometimes high concentrations of materials that may present a threat to human health and aquatic environment, including radionuclides, organic chemicals, metals and total dissolved solids.” EPA announced in the letter that it had specific concerns regarding the concentrations of radionuclides in the effluent from the wastewater treatment plants and that it would be reopen the NPDES permits of POTWs and centralized waste treatment facilities that were then accepting gas drilling wastewater for treatment. Shortly thereafter, on 19 April 2011, PADEP requested that Marcellus shale operators voluntarily cease delivering wastewater to 15 wastewater treatment plants in the state.

Produced water and drill cuttings from Marcellus shale wells may have high levels of NORM. Recent reports and studies have claimed high levels of NORM in public landfills and in streams that receive discharges from wastewater treatment facilities. In January 2013, PADEP announced it would be studying the levels of NORM in materials associated with oil and gas drilling. PADEP’s study is expected to be completed in 2014. In November 2013, the Marcellus Shale Coalition and the Pennsylvania Independent Oil and Gas Association announced they would undertake an oil and gas-related NORM study as well.

If NORM levels in oil and gas wastewater reach a certain threshold, the wastewater must be transported and disposed of in accordance with more stringent federal and state laws. The events in Pennsylvania have led most operators in the state to either ship wastewater out of state or to implement an aggressive water treatment and recycling program. Moving forward, expect states to be more actively involved in these issues.

22.4.2.3 Abandoned Well Mapping and Downhole Communication

An interesting well-integrity issue that will be worth following is whether states increase their efforts to track downhole communication between hydraulic fracturing operations and nearby active or abandoned wells. Concerned about whether current hydraulic fracturing operations could cause pollution by altering or affecting an orphaned or abandoned well, Pennsylvania has proposed new regulations that would require operators to identify and monitor orphaned and abandoned wells.

Specifically, operators would be required to locate orphaned and abandoned wells “…within 1,000 feet measured horizontally from the vertical well bore and 1,000 feet
measured from the surface above the entire length of a horizontal well bore.” In order to identify the location of these wells, operators would be required to review the state’s database of orphaned and abandoned wells, review farm line maps, and submit a questionnaire to nearby landowners. When an abandoned well is identified, the operator would be required to submit a plat to the state showing the location and GPS coordinates of the orphaned or abandoned wells.

Beyond the identification requirement, under proposed Section 78.73, operators would be required to visually monitor the orphaned or abandoned wells during hydraulic fracturing, immediately notify the state of any changes, and take the necessary action to prevent pollution associated with discharges from those wells. Finally, if an operator “alters” an orphaned or abandoned well, that operator must properly plug the altered well. Pennsylvania has estimated the cost for these new requirements at $2,000 per well, which seems low and may not account for the costs of plugging an affected well.

22.4.3 Water: Managing, Sourcing, Treating, and Innovating

22.4.3.1 Water Management and Sourcing

Water management and sourcing presents challenges and opportunities for operators around the US and the globe. Issues with regulations for water use and disposal, water storage, and either finding sources of water or creating ways to use less water, are of utmost importance to any company involved in unconventional development.

22.4.3.1.1 Water Management Challenges

There are many challenges and opportunities for upstream companies operating in the various shale plays across the US. The challenges, some of which are described previously, generally come in the form of legal and regulatory developments that place restrictions on operations. However, these regulatory developments can lead to opportunities as companies seek new ways to push technological advances forward. One area where this dynamic is playing out is lifecycle water management.

On the front end are limitations to availability, transportation, and fresh water storage used in hydraulic fracturing operations. On the back end, companies are seeing additional restrictions on the management of wastewater after hydraulic fracturing, including requirements related to storage, transportation, treatment, and ultimate disposal. These challenges, some of which are unique to unconventional operations, are pushing the industry to develop solutions that save money and reduce impacts on the environment. The remainder of this paper will focus on the dynamic between regulatory drivers and industry-provided solutions in the specific context of water management.

22.4.3.2 Water Sourcing Challenges

Water is a crucial part of hydraulic fracturing operations, and water sourcing in particular presents numerous challenges due to plain and simple regional availability, regulatory constraints, and a lack of infrastructure. However, through innovation and a variety of technological advances companies are meeting this challenge head on by introducing new approaches to field development and hydraulic fracturing techniques that require less water.

Water sourcing is increasingly becoming an issue for companies engaged in development of shale resources. Many states now require that an operator provide a detailed water use plan before they issue a drilling permit. Additionally, interstate compact commissions, including the Susquehanna River Basin Commission (SRBC) and the Delaware River Basin Commission (DRBC), require that operators first look to “impaired” waters for their water supply. Water challenges are often unique to the shale play where operations are proposed. In the dryer shale plays, like the Eagle Ford shale of Texas, surface water supplies are limited. Groundwater supplies may be available; however, oil and gas operators increasingly find themselves in competition with industrial and municipal consumers for that water source.

In the Marcellus shale play, precipitation and local geology is such that fresh water is readily available. Water-related restrictions in the Marcellus shale are, therefore, tied to obtaining regulatory approval for withdrawal from a given water source and the proximity of that water source to a proposed well. Even if a surface water body, such as a river or a lake, is available for sourcing fresh water, transportation of that fresh water to a well pad over long distances can be costly.

One traditional solution to local water availability is the construction of man-made fresh water ponds or impoundments in proximity to the well. While fresh water impoundments can reduce transportation costs, there are regulatory hurdles to overcome. Logistically, when constructing a pond for a single well or a centralized impoundment that supplies fresh water for several wells, one thing remains consistent: the best physical location for such an impoundment typically coincides with “jurisdictional” surface water features,
such as streams and wetlands, which introduces additional legal and regulatory hurdles.

Under the federal Clean Water Act, a permit is required before conducting any work in streams or wetlands. The problem: streams don’t always look like babbling brooks and wetlands don’t always have cattails. This can lead to issues with both federal and state regulators if there are unauthorized impacts to a jurisdictional feature during construction of a fresh water impoundment. Beyond regulatory requirements tied to wetland features, states typically have laws applicable to dam safety. State dam safety laws often require preapproval and permits, and they set restrictions on the height and capacity of man-made impoundments.

Not all man-made freshwater impoundments resemble ponds. Operators are now using large aboveground storage tanks to store fresh water, and in some instances to store flowback water. These large non-traditional oil and gas structures have triggered new regulatory restrictions in states like Colorado, Ohio, and Pennsylvania.

22.4.3.1.3 Water Sourcing Innovation

With increased oil and gas development on the horizon and increased competition for fresh water supplies, operators are exploring new operational practices and technological advances to reduce the need for fresh water in hydraulic fracturing operations.

From an operational standpoint, a technique that is more efficient in terms of water management (and that is becoming more common) is the use of multiwell pads with shared water storage. The concept here is simple: operators can build one well pad with multiple wells and one large fresh water impoundment versus constructing multiple distributed well pads, each with its own impoundment and permitting requirements. The use of multiwell pads has benefits beyond the convenience of a centralized impoundment: it also minimizes surface disturbance and can minimize traffic on local roads.

Depending on the success of certain legislative and regulatory developments, another innovation that could improve water sourcing is the use of non-fresh water sources, such as acid mine drainage, in hydraulic fracturing operations. Acid mine drainage (AMD) is acidic water that is formed when water drains over, or through, sulfur-bearing minerals and is exposed to oxidizing conditions. AMD can be generated in the coal mining process; therefore, states with a long history of coal mining, such as West Virginia and Pennsylvania, have widespread AMD problems. AMD is a major cause of stream degradation in Pennsylvania and has been described as one of the most significant environmental problems associated with the mining industry in the US.

The need for water in hydraulic fracturing operations and the widespread environmental problems caused by AMD have presented what some may argue is a win-win situation. Specifically, if AMD is causing widespread pollution in states with significant shale resources, an ideal situation would be for operators to take that degraded AMD water, treat it, and then use it in hydraulic fracturing operations. This would directly minimize a significant source of fresh water pollution from mining, and, at the same time, reduce the need for fresh water sources for use in hydraulic fracturing operations.

In 2011, a Pennsylvania state commission, the Marcellus Advisory Commission, issued a report recommending that Pennsylvania “…encourage the use of non-freshwater sources where technically feasible and environmentally beneficial… [and] provide operators with immunity from environmental liability for the use of acid mine drainage water from abandoned mine pools would encourage operators to reduce their use of freshwater sources for water utilization, as well as reduce the amount of acid mine water draining into local streams.”

In November 2011, Pennsylvania State Senator Richard A. Kasunic (R–32nd District), introduced Senate Bill (SB) 1346, which was intended to amend Pennsylvania’s Title 27 (Environment Good Samaritan Act | Environmental Resources) of the Pennsylvania Consolidated Statutes, providing for use of mine drainage water. This act was intended to limit the liability of entities choosing to utilize acid mine water for hydraulic fracturing of oil or gas wells. The 2 October 2012, Pennsylvania publication Senate Appropriations Committee Fiscal Note provided the following summary of the bill:

The bill provides that a landowner or mine operator who allows for the withdrawal of acid mine water, or a natural gas operator who withdraws the water, to hydraulically fracture a well, to not be deemed to assume legal responsibility or to incur liability with respect to cost, injury, or damage that arise from the use of the acid mine water, including any injury or damage suffered by a downstream riparian landowner.

SB 411, the next iteration of Pennsylvania’s AMD bill, passed a crucial appropriations vote in January 2014. The bill appears to have the momentum to carry it through the state
legislature. A similar bill has been introduced in the West Virginia Senate.

22.4.3.2 Water Treatment

Unconventional oil and gas operations that involve hydraulic fracturing use larger quantities of water than conventional operations. Water treatment and disposal with unconventional development creates challenges that range far beyond 20th century conventional oil and gas drilling and production. The industry has been pushed to find new solutions to new problems, which has encouraged innovation in methods and solutions.

22.4.3.2.1 Wastewater Treatment Challenges

Unconventional oil and gas operations that involve hydraulic fracturing use larger quantities of water than conventional operations. Historically, oil and gas wastewater would be disposed of via a Class II Underground Injection Control (UIC) well, disposal at a local wastewater treatment facility, and in some instances, road spreading. The quantity of fresh water used in unconventional wells means that operators are also likely to see more flowback than in a conventional well. Additionally, the wastewater that flows back, or is produced, often has some unique characteristics that pose certain challenges to operators. The quantity and quality of the unconventional oil and gas wastewater stream present unique disposal challenges.

Disposal via Class II UIC wells is limited by the availability of the appropriate geology and the time needed to obtain the necessary permit from the state or the regional EPA office, which is the case in Pennsylvania. Costs associated with waste injection are also on the rise, with a 2010 estimate of $0.05 per barrel up to $0.20 per barrel for "out of region" waste.

Induced seismicity is another complication that is gaining attention over the past few years. What started as allegations in Youngstown, Ohio, was confirmed by the state regulators and resulted in the first state regulations applicable to oil and gas disposal wells in relation to induced seismicity. Since that time, there have been increasing reports of induced seismicity linked to disposal of unconventional wastewater in Class II UIC wells. The US Geological Survey (USGS) is currently working with EPA and the Department of Energy to better understand induced seismicity and even map occurrences.

Disposal of unconventional wastewater via traditional means can also be difficult because of its unique chemical make-up. Until recently, oil and gas wastewater could be disposed of at local publicly owned treatment works (POTWs). Another option is privately owned centralized waste treatment (CWT) facilities, which often treat oil and gas wastewater, and then ship it for discharge via a POTW.

As noted previously, wastewater from shale gas wells can be high in NORM, and may exhibit high concentrations of total dissolved solids (salts), organic chemicals, inorganic chemicals, and metals. As mentioned previously, EPA and Pennsylvania coordinated in 2011 to stop POTWs from accepting for treatment wastewater from unconventional wells in the Marcellus shale play. As of early 2014, POTWs in the state of Pennsylvania are still not accepting unconventional wastewater. Some have speculated that disposal of unconventional wastewater at POTWs could be barred nationwide in the future. This has led many operators in the state to start recycling. Additionally, PADEP is currently undertaking a study of oil and gas NORM in Marcellus shale oil and gas wastes.

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22.4.3.2.2 Water Treatment Innovations

As with water sourcing, the industry has shown innovative creativity in the face of regulatory, environmental, and cost challenges associated with unconventional oil and gas wastewater. Whether through the development and distribution of "greener" chemistry chemicals via new treatments that require less water, thereby reducing wastewater, or by adopting recycling programs, we can expect a wider distribution of industry answers to the challenges that come with treatment and disposal of unconventional wastewater.

22.4.3.2.3 Cleaner and Greener Chemicals

Inevitably, the chemicals used in a hydraulic fracturing treatment play a significant role in the contents of the flowback and produced water. Considering this, the use of "greener" chemicals in a treatment can have a positive effect, not only on the front end, but also on the character of the wastewater that is generated. By developing and using
chemicals that degrade quickly, there is less risk to aquatic environments, reduced potential risks when a spill does occur, and increased safety for workers handling the chemicals. Industry is rapidly moving forward with green chemical innovations, and has even developed processes to determine best performing green chemicals for a specific well.

22.4.3.2.4 Treatments Requiring Less Water

While not necessarily a new treatment, fracturing using foam as the carrier fluid may gain popularity if conditions for its use are favorable. In cases where the bottomhole pressure is low or if a reduction in the amount of liquid introduced to the reservoir is favored, a foam-based fracturing treatment may be warranted. Foam fracturing treatment systems may contain nitrogen, carbon dioxide, or a combination of both gases, in place of traditionally used water-based fluid systems. Foam fracturing treatments can reduce the amount of liquids introduced to a reservoir, as up to 80% of the liquids can be replaced with gas.

22.4.3.2.5 Recycling Programs and Water Reuse

Another area where industry is pushing forward, often beyond state regulatory requirements, is in recycling unconventional wastewater in shale plays where disposal options are limited and sourcing fresh water is either difficult or expensive. Recycling not only provides an answer to the disposal question but also helps reduce an operator’s fresh-water-sourcing requirements. The quantity of recycled flowback water that a company uses on its next hydraulic fracturing directly offsets the need for fresh water.

Trends in the use of recycling water include using both recycled flowback and produced water, either as all, or part of, a fracturing treatment. Industry has developed methods for centralizing recycling treatment and storage facilities to deliver water to multiple wells or locations efficiently. Additional treatments such as the Baker Hughes H2PrO services can service water through a variety of applications that can be completed at the jobsite to allow for efficient reuse of water. An operator in the Permian has opted to not only recycle water, but also to use brackish water in lieu of fresh water. The H2PrO Water Management Services use proven treatment technologies designed to conserve water, reduce transportation and disposal costs, and ensure compliance with regulations. The mobile treatment units eliminate the need for costly permanent equipment that may not be ideal for every application.

22.4.3.2.6 Savings Realized by Reducing the Number of Hydraulic Fracturing Stages

Production logs in unconventional wells allow operators to identify how much oil, gas, and water production is occurring along the horizontal lateral. These tools are somewhat expensive and difficult to deploy in horizontal wells (compared to vertical wells) because they need to reach the bottom of a horizontal lateral that might extend 5,000 to 10,000 feet without the aid of gravity. Although only a small fraction of unconventional wells have production log data, data from the available logs suggest that many of the hydraulic fracturing treatments along a horizontal wellbore are ineffective, producing little, if any, hydrocarbons. Many operators utilize a kind of “geometric” spacing; for example, one fracture stage every 250 feet. More advanced approaches are available that require additional formation evaluation and geomechanical analysis to identify the optimal locations of each fracture stage. Such advanced placement of hydraulic fracture stages is sometimes referred to as “surgical” and is referenced further in Chapter 8, Chapter 16, and Chapter 17. This optimization not only reduces costs, but also significantly reduces the water usage along with corresponding emissions.

22.5 Acknowledgment

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22.6 References


