WATER QUALITY REGULATIONS FOR UNCONVENTIONAL GAS PRODUCTION
UNITED STATES AND AUSTRALIA COMPARISON

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ABSTRACT
This paper identifies current water quality concerns arising from onshore unconventional natural gas production, and reviews the regulatory regime in the United States and Australia addressing these concerns. Based on each country’s experiences, actions are identified that can effectively resolve concerns. A comparative evaluation of the effectiveness of each country’s regulatory regime and areas where improvements can be made is provided.

INTRODUCTION
Production of unconventional natural gas resources has caused a recent revolution in the international energy markets and brought an economic boom in parts of the United States and Australia. Unconventional natural gas is distinct from conventional gas resources in that historically these resources were generally considered too difficult or expensive to mine. Conventional natural gas resources are the easiest and most economical to produce because the gas has migrated up into relatively accessible permeable rock formations.

Shale gas, tight gas and coal seam gas (CSG) [also referred to as coalbed methane (CBM)] are unconventional gas sources that are the focus here because both the U.S. and Australia have large known reserves of these resources with the potential for huge benefits for each country if these resources can be successfully developed. Shale gas forms in small pockets of fine-grained sedimentary rock with such low permeability that the gas is prevented from escaping. Tight gas is gas trapped in unusually impermeable and low porous formations of silt and sand. CSG is natural gas found in coal deposit seams or surrounding rock. See Figure 1.

Holding this industry back are numerous water quality concerns associated with production of these unconventional resources. Government regulatory agencies have attempted to address concerns with varying success.

U.S. unconventional gas industry
The U.S. has mostly led in the production of unconventional gas resources due to its technological advances in shale gas hydraulic fracturing, as well as the availability of supporting infrastructure in that country. The size of area mined for gas is larger for hydraulically fractured wells, requiring fewer wells and more effective draining of gas reservoirs. Technology applicable to shale gas production is generally applicable to tight gas. CSG development in the U.S. has proceeded for decades with little controversy. However, with the rapid growth of the shale industry and hydraulic fracturing, public opposition and controversy have increased substantially. The result is public misinformation and confusion, and political pressure on governmental entities to implement ever-more restrictive regulations and moratoriums.

The federal government owns 30% of total lands in the United States (primarily in the West) and a large amount of natural gas deposits lie below federal lands. Thus, the U.S. government has a lot of control over the extent of unconventional gas development in the country. The nation’s share of onshore natural gas produced on federal lands dropped from 36% to 16% in the last decade. Thus, most of the recent growth in this industry has occurred on private or...
state lands. Private landowners often own the oil and gas underlying their land and thus can enter into agreements with gas operators to sell their rights or receive royalties.

**Australia's unconventional gas industry**

Australia’s unconventional gas industry has primarily involved CSG production, mostly in Queensland (QLD) with some in New South Wales (NSW). Most States and Territories have some CSG potential. The shale and tight gas industry has been slow to develop and is not yet produced in commercial quantities. One reason is that drilling costs in Australia are relatively high because most of these resources are located in remote deserts where there is a lack of basic infrastructure. Oil and gas is owned by the Commonwealth government that receives royalties from development of these resources.

Australia has one of the world’s largest shale gas reserves. Western Australia (WA) is estimated to have one-fifth of the world’s shale gas reserves, as well as significant tight gas reserves. Hydraulic fracturing technology developed in North America is generally thought to be applicable to Australia, although there is differing geology.

Australia presently has the ability to liquefy and export gas via existing LNG terminals. Thus, Australia's extensive reserves and close proximity to Asia with increasing demand for cleaner gas-produced energy makes Australia ideal for a successful industry in unconventional gas.

**Gas production process as it relates to water**

Hydraulic fracturing is essential for the production of gas from shale and tight gas sands because these formations are typically at great depths and high pressures. Further, shale and tight gas are held within formations of very low permeability and porosity, thus must be fractured to release the gas. Vertical wells are drilled sometimes thousands of feet below the surface and then horizontal or directional sections can extend thousands of feet from the well. Large amounts of water, along with chemical additives and propping agents (typically sand), are used in hydraulic fracturing operations. The fluid mix is pumped at high pressure into the well to open or enlarge fractures in the formation. The sand keeps the fractures open to allow the gas to release. The chemical additives prevent bacterial growth and scale build-up in the well, and reduce friction in drilling. The natural pressure in the formation causes much of the fracturing fluid (15-50%) to return up the well to the surface (flowback) along with water produced from the geologic formation. Together, this recovered water must either be disposed of or treated for reuse or discharge. Some percentage of the fluid mix pumped into the well remains underground.

Hydraulic fracturing is sometimes used in CSG formations but is not always necessary because these formations are typically closer to the surface than shale and tight gas formations and under lower pressure. CSG is methane gas extracted from coal. The coal seam is first dewatered, releasing pressure to allow methane to escape. The volume of produced water is typically much more in CSG operations than in shale and tight gas operations. Thus, there is generally more wastewater to treat or dispose of in CSG extraction than for shale and tight gas.

**POTENTIAL WATER QUALITY IMPACTS**

Past experience shows that surface water impacts are the most likely to occur as a result of gas production, whereas the public is most focused on groundwater impacts. Much of the confusion results from lack of robust scientific data relating to groundwater impacts and/or inadequate public communication of data. There is little, or inconclusive, evidence of impacts to groundwater aquifers resulting from unconventional gas production (USDOE 2014; Assessment 2015). Categories of potential water quality impacts are identified below. Chemical use, recovered water quantity and quality, geologic conditions, and water resource characteristics are site specific and differ depending on the type of gas resource involved and local conditions. Water quality impacts resulting from extraction of water from local resources for use in unconventional gas production, such as increased stream nutrient and salinity levels, are outside the scope of this paper.

**Contamination of freshwater aquifers from fracturing fluids/source formation substances.**

Drilling for unconventional gas resources often intersects aquifers, raising concerns that fracturing chemicals and source formation substances such as deep brine or methane will mix with and contaminate freshwater aquifers.

There are no known confirmed cases of hydraulic fracturing chemicals or source contaminants having leaked into freshwater aquifers other than possibly from improper well design or cementing. Because unconventional gas formations are generally at great distances below freshwater aquifers, well integrity issues, not the fracturing process itself, are the likely cause. If there is not a good seal on the outside of the steel casing a conduit is created for gas to move. Old or abandoned gas wells, private water wells, and landfills in the area are potential conduits for contaminants, as well as existing faults and fractures. Baseline groundwater conditions are typically unknown, making it difficult to determine what the influences of drilling and fracturing are.
A study financed by the U.S. Department of Energy published in Sept 2014 found that well-constructed Marcellus shale wells do not cause detectable migration of gas or fluids (USDOE 2014). The Marcellus shale formation is more than 1500 meters (5,000 ft) below drinking water aquifers. The Great Artesian Basin (GAB) is the most important freshwater aquifer in Australia, extending beneath QLD, NSW, South Australia (SA) and the Northern Territory (NT). The deepest GAB aquifer, the Hutton Sandstone, is about 300-800 meters (1000-2600 ft) above shale/tight sand gas formations. Thus gas extraction beneath the GAB is of special concern.

**Impacts from disposal of recovered water.** Recovered water is flowback and the water produced from the geologic formation that together comes back up the well during drilling. If this water is treated as waste it must be disposed of either by deep well injection, evaporative ponds or transported to public treatment facility (if there is capability to treat). There is risk to water resources from spills, leaks, and groundwater contamination. This causes environmental costs to be shifted from the drilling operator to the community. Treatment of recovered water to resolve these problems can be expensive and difficult.

**Contamination of freshwater resources and ecosystems from spills.** In the U.S., the highest risk to water resources has been found to be from accidental spills during the surface transport of diesel fuel, fracturing chemicals, and wastes. Spills also occur in storage facilities or during the drilling process. These accidents are usually caused by human error rather than the production process itself. These incidences can often be traced to inadequately trained operators, improper implementation of best management practices, and/or inadequate response and mitigation measures.

**Contamination of freshwater resources and ecosystems from stormwater runoff.** Stormwater runoff from gas extraction sites can be a significant cause of water quality problems. Well pads are similar to industrial sites because of the use of chemicals and fuels. They are outside, exposed to precipitation and wind. Clearing of land and construction is required for well pads and supporting infrastructure such as roads. Watersheds are sensitive to erosion, sediment runoff, nutrient loading and toxic substances. Drinking water supplies and freshwater dependent ecosystems are put at risk. Impacts increase as the number of wells and infrastructure grow in the region.

### EXISTING REGULATORY FRAMEWORK

**United States of America**

In the U.S., the source of laws pertaining to water quality in oil and gas operations is primarily federal legislation and regulations. States are authorized to implement certain federal environmental statutes and can have laws and regulations that are more restrictive. Local governments can also adopt laws and regulations not inconsistent with State laws. The courts interpret statutes and regulations.

Production of oil and gas from federal lands is generally subject to more burdensome regulations than on private and State owned lands. Gas production on federal lands is administered by the Bureau of Land Management (BLM) in the U.S. Department of the Interior.

**Federal Regulatory Framework**

- The Clean Water Act (CWA). This is the primary law protecting surface water quality. It requires a permit for discharge of pollutants to “waters of the U.S.” (broadly defined but groundwater excluded). “Pollutant” is also broadly defined but excludes water, gas or other material injected into a well to facilitate production of oil and gas or produced water disposed of in a well. Under the CWA, the following programs are relevant to gas production:
  
  NPDES National Pollutant Discharge Elimination System (NPDES) Permit (Section 402 permit). This program regulates discharges of pollutants from “point sources” into waters of the U.S.” A point source is a discreet conveyance, such as a pipe or a ditch. Site specific permits have effluent limitations for specific pollutants and monitoring requirements. Uncontaminated storm water discharged from oil and gas field activities is exempt.

  Stormwater Regulations. A stormwater discharge permit (non-point source) is required for runoff for construction activities that disturb one or more acres of land. The unique aspects of shale gas development are not always appropriately addressed by these regulations designed for industrial and construction activities. Thus, some States have their own stormwater regulations addressing unconventional gas activities.

  Section 401 Water Quality Certifications – Before a CWA discharge permit is issued, certification is required that increased pollutant loads to a surface waterbody resulting from the discharge will not cause or contribute to exceedences of water quality standards in the waterbody.

  Section 404 Dredge and Fill Permit – No discharge of dredged or fill materials into “navigable waters”
can occur without a permit. This applies to discharge of rock, dirt, etc. into wetlands if they are adjacent to navigable waters or a jurisdictional tributary. The definition of wetlands does not require standing water and has been the subject of substantial litigation. Violations can result in substantial civil and criminal penalties. This can affect construction of storage ponds, pipelines or other structures. There are also many state and local wetland regulations.

Spill Prevention Control and Countermeasure (SPCC) Program. This applies to non-transportation related facilities engaged in drilling, producing, gathering, storing, processing, refining, transferring, distributing or consuming oil or oil products. Produced water is included. The owner or operator of the facility must prepare an SPCC plan if the facility, due to its location, could reasonably be expected to discharge oil in harmful quantities into or upon navigable waters of the U.S. or adjoining shorelines. Each SPCC Plan must be unique to the facility and the potential effects of any oil spill. The SPCC Plan must include procedures to prevent spills, measure to prevent a spill from reaching navigable waters, and clean-up and mitigation.

Facility Response Plans (FPR). A FRP is required for facilities that, because of their location, could reasonably be expected to cause “substantial harm” to the environment by discharging oil into navigable waters. The FPR requires training, testing, and drills of facility personnel.

- Safe Drinking Water Act (SDWA). The SDWA is intended to protect public drinking water supplies in the U.S., including both surface and ground water. This has implications when recovered water is reused or discharged to surface streams. The Underground Injection Control Program requires a permit for underground injection of produced/waste water (UIC Permit). Injection of water and other substances (except diesel fuels) in the drilling process are exempt from UIC permitting requirements.

- The Comprehensive Environmental Response, Compensation, and Liability Act (“CERCLA”). This requires reporting of the release or threatened release of “hazardous substances.” There is a petroleum exclusion for natural gas and natural gas liquids. Although oil that naturally contains low levels of hazardous substances falls within this petroleum exclusion, waste oil to which listed CERCLA substances have been added are not within the petroleum exclusion.

- Bureau of Land Management (BLM) and National Environmental Protection Act (NEPA). The BLM grants permits for and administers oil and gas exploration and production on federal lands. An Environmental Impact Statement under NEPA is usually required from most proposals.

The U.S. Department of Interior (DOI) recently issued rules governing hydraulic fracturing of onshore oil and gas wells on federal and tribal lands (including split estate lands where the surface lands are not federally owned). The BLM, under the DOI, will be responsible for implementing and enforcing the rules that will go into effect in June 2015. These regulations cover well integrity, public disclosure of chemicals used in fracturing, use of rigid, above-ground containers for storage of recovered waste water, and submittal of information on geology and existing wells to allow BLM to evaluate and manage site characteristics. (Nat Rev 2015) Federal lawsuits are pending including challenges by the States of Wyoming and North Dakota, claiming the regulations are outside BLM jurisdiction, interfere with state regulatory authority, result in repetitive paperwork with multiple government agencies, and will add months or years for permitting by an already understaffed BLM.

- The Migratory Bird Treaty Act. There can be no taking, capturing or killing of any migratory bird by any means. This has implications if a bird gets into stored untreated or inadequately treated produced water and dies.

- Tribal Lands. The Bureau of Indian Affairs regulates impacts to tribal lands. Tribes may also regulate water quality matters. This has implications for reuse of recovered water near or on tribal land.

State Laws. State laws implement federal programs such as the CWA and SDWA where they are permitted to do so. The States can have laws that are more restrictive and can also have laws independent from federal programs. Thus, there is substantial variation in water quality regulations relating to oil and gas production. A sampling of State laws and programs, provided below, demonstrates the complexity of regulatory regimes gas producers must navigate.

The State of Colorado has some of the most restrictive regulations on oil and gas production in the U.S. Permitting under the CWA in Colorado is handled by Colorado Department of Public Health and Environment. State waters into which a discharge permit is required under the Colorado statute include both surface and groundwater, whereas the federal statute applies only to surface waters. Additionally, Colorado has the strongest groundwater monitoring rule in the nation, requiring baseline and postline
testing for gas wells. Colorado also has its own restrictive stormwater rules applicable to oil and gas activities.

In addition to environmental laws, Colorado has a complex system of water right laws based on the prior appropriation system—first in time, first in right. Water allocation in the U.S. is governed by the individual states and there are significant differences. Under Colorado water rights law water that is replaced to the stream must be of a quality to meet the normal requirements of the senior water user. Thus, it is conceivable that the operator would need to meet additional water treatment requirements over and above CWA and State environmental standards.

An example of a State program independent of federal regulation is California’s Proposition 65. California Proposition 65 prohibits businesses from knowingly discharge listed substances into drinking water sources or onto lands where substances can pass into drinking water sources. Businesses also must provide warning to individuals they knowingly expose to listed substances. This has implications for disposal or use of recovered water and hydraulic fracturing fluids.

Local governments. There have been recent moves to ban hydraulic fracturing on a local level, some resulting in wide-reaching affects. In the State of New York, a court decision upholding one towns’ ban on fracking in the underlying Marcellus Shale formation contributed to a statewide ban. This was because the town’s moratorium resulted in little of the Marcellus Shale formation in the state being left available for gas production.

Australia
In Australia, the individual States and Territories control the water in their jurisdiction and are the primary sources of laws pertaining to water quality in oil and gas operations. Each State or Territory has its own petroleum law and accompanying regulations that govern onshore gas activities, and grant permits for exploration, drilling and production in their jurisdiction. These regulatory regimes for the most part are targeted to CSG operations, and do not specifically address shale and tight gas production activities. However, many of these regulations can most likely be adapted to shale and tight gas activities.

States and Territories also have environmental laws that typically require assessment of potential environmental impacts from oil and gas projects. In addition, there are national and regional environmental laws and programs that affect activities in States and Territories. Local laws, such as development and planning approvals, also apply.

National and Regional Laws and Programs

- Environmental Protection and Biodiversity Conservation Act 1999 (EPBC). The EPBC and accompanying regulations are Australia’s central environmental regime. Under the EPBC, any person taking an action which could have a significant impact on “matters of national environmental significance” must refer the proposed action to the Federal Minister for the Environment for consideration, potential assessment, and conditions for approval.

As of June 2013, any CSG development that impacts on a water resource automatically is a “matter of national environmental significance.” This water trigger does not now apply to shale or tight sand gas projects. Thus, these projects are assessed by the project owner/operator to determine whether there is likely to be a significant impact on a “matter of national environmental significance.” Consideration of such things as project size and proximity to national parks or wetlands play into the determination.

- National Partnership Agreement for the Regulation of Coal Seam Gas 2012 (NPA). The NPA is an agreement between the Commonwealth and the QLD, NSW, SA and Victoria (VIC) governments. Under the NPA, the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) created by the Commonwealth under the EPBC, provides advice to the Commonwealth and signatory States for CSG proposals. The IESC provides expert scientific advice on CSG proposals likely to have a significant effect on water resources. The IESC determines which water resources are a national priority, considering those of high community concern and that support a significant eco-system. If determined to be a national priority, a water assessment report is prepared outlining possible threats to the water resource from the proposal. The report is only advisory but is intended to allow regulatory agencies to make informed decisions.

- National Industrial Chemical Notification Assessment Scheme (NICNAS). Industrial chemicals used in unconventional gas production must be listed on the Australian Inventory of Chemical Substances (AICS) or have approval prior to use in hydraulic fracturing.

- Commonwealth Water Act 2007. This Act establishes the Murray-Darling Basin Authority to
ensure that the water resources in the Murray-Darling River basin are managed in an integrated and sustainable manner. The Basin extends into QLD, SA, VIC and NSW. The Authority oversees water resource planning and has enforcement powers in the Basin. Thus, unconventional gas activities affecting the Murray-Darling Basin can be governed by the Authority. Under certain conditions, an independent expert study of the proposed mining operation is required.

- National Water Initiative (NWI). Under the Intergovernmental Agreement on a National Water Initiative Between the Commonwealth of Australia and the Governments of NSW, VIC, QLD, SA, the Australian Capital Territory, and the NT, the individual States and Territories agree to develop state water planning and management plans for surface and groundwater that optimize economic, social and environmental outcomes. Thus, these plans can include consideration of oil and gas developments.

- Native Title Act 1993. This Act sets up processes and native participation to determine how future activity impacting native title lands, including gas production, can be undertaken.

**State and Territory Laws**

All States and Territories have their own petroleum laws pertaining to exploration, extraction and monitoring for oil and gas activities. The management of environmental risks associated with contaminated waste water is usually a condition of a production license. In addition, monitoring and inspection regimes apply in each jurisdiction, although there is mostly self-monitoring by gas owner/operators. States also have other regulations separate from their petroleum laws affecting gas development water quality issues. A sampling of the regulations and issues pertinent to different jurisdictions demonstrates the variation and complexity of regulatory regimes that gas operators must navigate.

QLD is Australia’s biggest CGS producer and has many laws and regulations applicable to petroleum activities. Under its Environmental Protection Act 1994 and Regulations (2008), a gas operator typically is required to apply for an environmental authority (EA). This requires assessment of likely impacts of each activity for numerous environmental values, as well as a proposed plan to manage impacts. Additionally, under the Coal Seam Gas Water Management Policy 2012, site-specific water management plans are required, including identifying the quantity and quality of produced water and how this water will be managed.

Many other applicable QLD laws and regulations include requirements include such as risk assessments for CSG wells to identify risks that may occur during well construction, operation and abandonment, as well as performance of baseline monitoring and existing spring surveys, and underground water impact report.

WA will be important for unconventional gas production in Australia. WA has been extracting and exporting conventional natural gas as LNG for more than 20 years. Commercial production of WA’s immense shale gas reserves is not yet underway, but the State has been preparing regulations in anticipation of this development.

All onshore petroleum proposals in WA are assessed by the WA Department of Mines and Petroleum (DMP). Petroleum operators must submit an Environmental Plan, Safety Management Plan and Well Management Plan. All hydraulic fracturing proposals must be assessed by DMP. Operators are required to perform detailed reporting and monitoring of activities and must self-audit their activities.

The DMP has a Memorandum of Understanding with the WA Environmental Protection Authority under which DMP will refer proposals for assessment under Environmental Protection Act 1986 (WA) if the proposed activity is within or close to an Environmentally Sensitive Area (ESA) or close to an occupied town site. This referral is in addition to referral of proposals to the Commonwealth Department of Environment under the EPBC for proposals having a significant impact on a “matter of national environmental significance.”

WA has recently released draft regulations to regulate the hydraulic fracturing process in shale gas production. Public disclosure of chemicals and additives introduced to a well or formation is required. Gas companies face harsh penalties for noncompliance and prosecution for abandoning wells.

Many States have implemented regulations protecting agricultural lands from gas activities. NSW requires proposals on “strategic agricultural land” to have a “Gateway” environmental assessment performed by the mining company before a mining application can be submitted for review. A Gateway Panel of independent scientific experts oversee the Gateway process, referring some proposals where appropriate to the IESC for advice.
In NSW, due to environmentalist and farmer concerns, the State recently put severe limits on CGS exploration and production, reducing the amount of land available in the State for mining from 60% to 15%. Similarly, VIC placed a moratorium on all hydraulic fracturing until June 2015.

**CONCLUSION**

**United States – the Good and not so Good**

The U.S. has taken the international regulatory lead in unconventional gas development due to the boom of this industry there. U.S. federal laws provide a common regulatory base in the U.S. for water quality issues. This common base provides some harmonization within the country. However, States can and have added their own more restrictive and independent regulations to the federal framework. Further, local communities have become involved.

Federal water quality regulations primarily address surface water resources, with little attention to groundwater. Injection of chemicals into gas wells and recovered wastewater into disposal wells is generally exempt from federal regulations. Protection of groundwater resources is left primarily to individual States, resulting in great variation. The outcome of litigation pertaining to the new federal regulation to go in effect in June 2015 may start to change that.

Focus on protection of ecosystems and biodiversity issues under federal water quality regulations is not strong as in Australia. Some States and local jurisdictions address these issues.

Gas activities on federally-owned lands are generally subject to more onerous regulations than on state and private lands. The BLM issues permits for gas exploration, development, and related infrastructure needs on federal lands, and politics has greatly influenced decisions. NEPA requires a comprehensive environmental assessment or impact statement for most gas-related activities on federal lands. The new federal regulations will add another layer of requirements for gas companies that may conflict or be redundant to State regulations already in place.

In the U.S., there has been a great deal of misinformation circulated with regard to hydraulic fracturing, causing governments to frequently increase restrictions and bend to moratorium demands.

**Australia – the Good and not so Good**

In Australia, States and Territories primarily govern water quality regulations pertaining to gas development in each of their jurisdictions with much variation. There are regional agreements and agencies that create further complexities. Though there are efforts to implement some consistency, there is presently little harmonization of regulations in the country. A complexity of layers of regulations primarily focus on CSG activities because shale and tight gas development is in its infancy. This provides Australia the opportunity to learn from experiences in other countries to develop an effective regulatory regime for fracking. WA is already developing its own regulations addressing shale gas and hydraulic fracturing due to its immense shale reserves.

Commonwealth regulation of water quality issues pertaining to gas activities is primarily through the EPBC with the individual State or Territory making the determination as to whether a gas proposal should be referred for consideration under the EPBC. The EPBC protects ecosystems and biodiversity. These considerations are also integrated in State and Territory laws. Increased Commonwealth involvement in gas industry regulation might be anticipated as this industry grows in the future.

Due to a predominately arid climate, Australia is much more focused on its water resources than the U.S. Australia has fewer surface water resources than the U.S. and depends greatly on groundwater resources. The GAB is of critical concern. Shale layers underlying this resource are in close proximity to GAB freshwater aquifers relative to typical U.S. formations. The growth of hydraulic fracturing for CGS extraction has increased public concern and opposition, causing States and Territories to impose moratoriums and severely limit the land available for gas development. There are also significant restrictions on chemicals used in hydraulic fracturing and disposal of produced water into deep wells.

Much of the industry opposition is due to a lack of understanding of most geologic and groundwater formations and characteristics. Thus, risks from hydraulic fracturing cannot be reasonably assessed. For example, there is evidence that suggests hydraulic fracturing in some geologic formations in Australia may have results vastly different than in the U.S., such as horizontal fractures resulting.

**What Works, What Needs Improvement, Opportunities**

Experiences in the U.S. and Australia reveal steep challenges to successful unconventional gas development related to water quality. These challenges focus primarily on three problems common to both countries in varying degrees:

- Lack of high quality scientific data pertaining to geologic formations and groundwater resources to
enable regulators to adequately assess risks from unconventional gas operations and determine appropriate mitigation.

- Lack of public support and confidence in the industry and government, putting pressure on governments to bend to hype and misinformation instead of focusing on the most serious issues and crafting regulatory responses proportionate to risk and potential impact.
- Onerous and ineffective regulations because the regulatory regime is ever-changing, complex, and not harmonized.

These challenges are interrelated. The science supporting regulatory decisions and the decision making process must be open and transparent to discredit misinformation. High-quality scientific data is required to build effective regulations and defend decision making. Efforts to gather already available data into one database should be made. For example, In the Piceance Basin in Colorado, the U.S. Geological Survey created a repository website containing water quality data collected from domestic water wells; gas and other industrial wells, and rivers and springs. All interested people have equal access to the most complete data set available for the water quality conditions in the Piceance Basin. In Australia, there is an opportunity for information obtained during gas exploration and production to increase understanding of the characteristics of the country’s water resources for more effective water planning and protection.

If a transparent and effective regulatory system is in place, along with effective implementation and monitoring, the public will gain confidence in the industry and government and support will grow. It must be demonstrated that unconventional gas production can be undertaken without substantial environmental risks and any incidental environmental harm can be effectively mitigated. Self-monitoring by petroleum companies needs to be supported with some degree of independent monitoring to add credibility. Highly-trained operators and regulators are a necessity.

Treatment of recovered water as a resource can be an opportunity to help shift the industry public image in a positive direction. The public, and especially affected communities, must perceive a net benefit from gas development. Thus, environmental costs must be borne by the mining industry. This includes consideration of recovered water as a resource. This is often expensive, with brine from produced or brackish water being the most difficult to treat. Careful consideration of the use of fracturing chemicals can reduce treatment difficulties. Recovered water can be treated to the highest quality for direct or subsurface discharge to waterways or treated for reuse in the production process, thus reducing freshwater demand. There may be opportunity for net water gain in some circumstances. Sharing of royalties by affected communities and landowners could also increase public support for the gas industry.

Economics is key to the gas industry. Harmonized, simple, and stable regulations bring certainty to the industry and encourage investment, including environmental innovation. Although site specific risks and conditions vary, there should be a national effort in each country for states to harmonize regulations where possible. Local government regulations should only be used and narrowly targeted to address specific and unique local conditions and issues. To address local concerns, some gas operators in the U.S. have taken the initiative with local jurisdictions to reach memoranda of understanding (MOUs) to put in place drilling, operating, monitoring, and mitigation procedures that address local issues. This preempts public opposition and results in more certain or expedited local government permitting.

A comparison of the effectiveness of U.S. and Australia laws and regulations addressing identifies water quality concerns related to unconventional gas development is provided in Table 1.
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<th>Issue</th>
<th>Effective Solutions</th>
<th>US Reg Effectiveness</th>
<th>AU Reg Effectiveness</th>
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| Fracking Fluid and Source Formation Contamination of Aquifers | • High Quality Data and Risk Assessment Accessible to Public  
• Assess Cumulative Impacts of Gas Wells in Region  
• Well Integrity, Monitoring, Sensing  
• Independent or Regulator Verification  
• Locate Other Wells, Faults  
• Highly Trained Operators, Regulators | • Groundwater not as uniformly well protected as in Australia  
• Inconsistent Fed/State/Local Regs  
• Cumulative Impacts Not Sufficiently Assessed  
• Need Improved Data  
• Inadequate BLM staff to effectively implement Fed Regulations | • High Level of Ground Water Protection Focus by State Regs  
• Inconsistent State Regs  
• Need Improved Data  
• Need Improved Monitoring and Verification  
• Need Highly Trained Operators, Regulators  
• Regs focus on CGS with Shale and Tight Gas Production Not Well Considered |
| Contamination of Aquifers from Recovered Water Disposal | • Treat for Reuse or Surface Water Disposal where possible  
• Options for Management of produced water must be based on site conditions  
• Independent or Regulator Verification | • Good Uniform Surface Water Protection by Fed Regs.  
• Inconsistent State/Local Regulations  
• Ecosystems, Biodiversity not Sufficiently Protected  
• Need Increased Reuse of Recovered Water | • Surface Water not as comprehensively protected as in US.  
• Inconsistent State/Local Regs  
• Ecosystems, Biodiversity Well Considered  
• Need Increased Reuse of Recovered Water  
• Need Highly Trained Operators, Regulators  
• Need Improved Monitoring, Verification |
| Surface Water Contamination from Recovered Water Disposal | • Implement Best Management Practices  
• Highly Trained Operators  
• Effective, Site-Specific Response/Mitigation  
• Independent or Regulator Verification | | |
| Contamination of Surface Water/Ecosystems from Spills | • Implement Best Management Practices  
• Isolate Stormwater originating in production/work areas  
• Independent or Regulator Verification | | |
| Contamination of Surface Water/Ecosystems from Stormwater Runoff | • Implement Best Management Practices | | |

- **Adequately addressed by current laws/regulations**
- **Current laws/regulations need improvement**
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A recent US study in the Marcellus and Barnett shale regions of Pennsylvania, USA, found that gas contamination of water wells was linked to well integrity issues and not hydraulic fracturing. These findings are consistent with earlier studies finding private water wells or very old undocumented oil and gas wells may have provided the conduit that facilitated methane migration. Analysis of the chemical footprint indicate the source of the gas and showed that it migrated in a fashion that did not interact with water and rock. The only way this can conceivably happen is if the gas migrated around the well annulus or as a result of a leaky well casing or a well integrity issue.


Water Act 2000 (QLD)


33 U.S.C. 1342

40 C.F.R. Parts 100, 112, 112.50, 122.