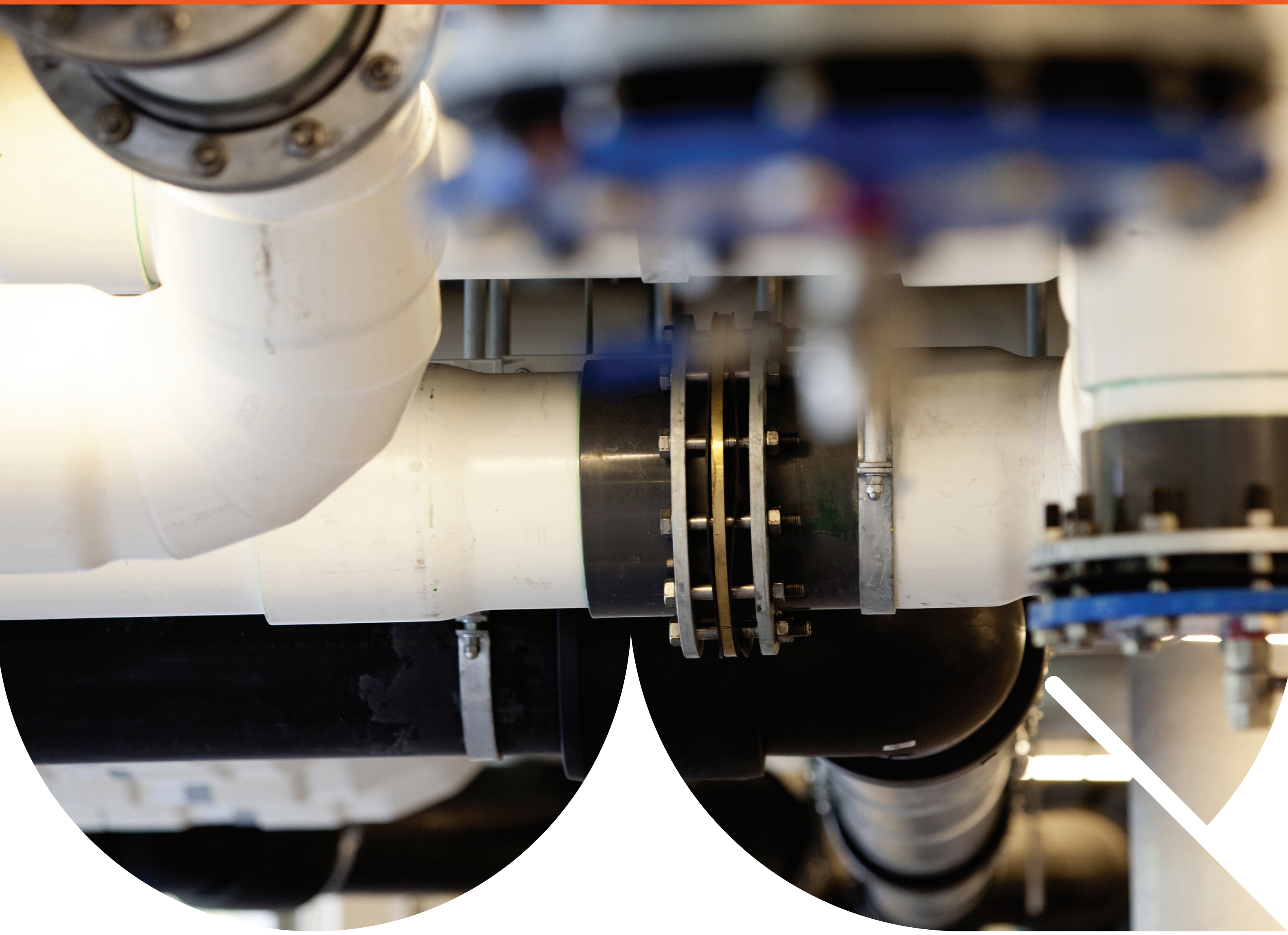

COAL SEAM GAS:
An Annotated Bibliography

by Dr Tina Hunter and Madeline Taylor, with funding provided by

SMI CCSG
Centre for Coal Seam Gas

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PURPOSE AND SCOPE

This Annotated Bibliography comprises a comprehensive identification and analysis of publications globally related to all aspects of the regulation, policy and development of coal seam gas. In particular it identifies resources relating to the regulation and/or management of the following aspects of CSG activities, including:

- water management (ground water and surface water);
- well design and construction and abandonment;
- hydraulic fracturing (including fracture-induced seismicity);
- use of chemicals down hole;
- social and environmental issues; including food security; and
- disclosure of chemicals.

In many instances these aspects are also closely aligned to the development of shale gas. Where such literature addresses shale gas activities, the publication has been included in this bibliography.

It is important to note that this bibliography represents an attempt to bring together the literature surrounding aspects of CSG activities, it is likely that some sources have not been included. Such omissions are the responsibility of the authors and not the funding body.

Sources are divided into the following categories;

- Journal Articles;
- Regulation, Guidelines and Policy
- Reports;
- Books and Book Chapters;
- Key Statutory Materials;
- Key Case Law; and
- Conference Proceedings.

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The bibliography is current to 1 October 2013.

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JOURNAL ARTICLES

Citation: Ihsan Hamawand, Talal Yusaf, Sara G. Hamawand, 'Coal Seam Gas and Associated Water: A Review Paper' (2013) 22 *Renewable and Sustainable Energy Reviews* 550-560.

Jurisdiction: Australia

Topic Area: Water Use and Management

Introduction: Management of large volumes of associated water with CSG production is a potential concern due to the elevated water salinity and sodicity. The produced water is managed in different ways in different states in the United State and offshore. While large portions of the onshore produced water, if applicable, is re-injected for enhanced gas recovery, the remaining portion is directly disposed to the environment. Much of the offshore produced water is directly discharged to the ocean. Land application of the onshore CSG associated high saline–sodic water is a common management method that has been practiced in the Powder River Basin of Wyoming and Montana. The irrigation of lands with the co-produced waters from CSG is one management option. However the use of produced water for irrigation can result in deterioration in soil quality and changes in physical and chemical parameters of the soil. One study[1] has shown that irrigation with slightly saline water is a possible option. The irrigation method of the produced water from coal bed has to be applied at a rate to maintain soil moisture at field capacity. A preliminary short term greenhouse study has showed the growth of sorghum-Sudan grass is optimized when irrigated by CSG associated water of total dissolved solids of 2000 mg/L.

Aims & Research Methods: The aim of this paper is to address many aspects regarding the coal seam gas such as production worldwide, its impact on the environment, its benefit and the impact and management of the associated water. This paper also addresses the different methods that have been applied to control the negative impact of the produced water when used for irrigation.

Scope: The first section of this paper will discuss the production size of CSG worldwide and the future of the industry. The usage of the coal bed seam for the sequestration of CO_2 is also an added benefit. The reduction of CO_2 released to the environment may help in the future mitigation of global warming. In addition, the re-injecting of the co-produced CO_2 enhances the commercial recovery and production of CSG wells. In the second section, the impact of the CSG industry's by-products on the environment, the freshwater ecosystem and human health are analysed. The second section includes issues associated with the large volume of co-produced water with undesirable composition in the CSG industry. The management of this enormous amount of water requires cost effective technologies and methods. Many methods for dealing with water problems are discussed and analysed in this paper.

Conclusions: Regardless of the environmental problems associated with the CSG production industry, it remains an important resource of energy. Its energy content is approximately 90% of NG and count for 256 Tm^3 gas resources in the world. At the current production rate, CSG

[1] GL Mullins, BF. Hajek, 'Effects of coal bed methane-produced water on Sorghum–Sudan grass growth and soil chemical properties' (1998) 29 *Communications in Soil Science and Plant Analysis* 2365–2381.

may last for the next 100 years. However coal seam gas comes from underground at different proportions, it is mainly a mixture of methane (95%) and carbon dioxide (3%). In addition, a huge amount of undesirable water is associated with the gas during the whole period of production. The management of both the carbon dioxide and the co-produced water are adding an extra expense to the cost of the methane. Many studies suggest the sequestration of carbon dioxide into the coal seam. Sequestration will not only help to reduce the impact of CO_2 on the environment but also may enhance the gas production. The major components of the water associated with the gas are sodium, bicarbonate, and chloride. Different researchers have shown the destructive impact of this produced water when used for land irrigation or discharged to streams. This paper has addressed the different methods that have been applied to control the negative impact of produced water for irrigation. The complete treatment of the CSG co-produced water requires advanced technologies which come with expensive costs. Further research is needed to distinguish cost-effective and environmentally friendly methods.

Citation: Laura Letts, 'Coal Seam Gas Production- Friend or Foe of Queensland's Water Resources?' (2012) 29 *EPLJ* 101-112

Topic Area: Water Use and Management

Jurisdiction: Australia

Introduction: The emerging coal seam gas (CSG) industry in Australia is promoted as providing unparalleled opportunities for Australia's economic and regional development, as well as delivering numerous employment opportunities. However, the CSG industry is also strongly opposed by some people, who cite possible risks to the environment and water resources and health impacts as grounds for prohibiting CSG extraction.

Aims & Research Methods: This article considers whether, in the context of CSG production in Queensland, the 2010 amendments to the Water Act 2000 (Qld) are sufficient to ensure water resources are used and regulated in such a way that protects both the short and long-term quality and availability of Queensland's water resources. The Queensland regulatory regime is considered against the National Water Commission's 2010 position statement on CSG.

Scope: This article begins with a brief outline of the benefits that may be derived from a CSG industry and the possible risks associated with it. Recent legislative changes are then reviewed and it is considered whether the current regulative regime is sufficient to ensure that water resources are used and regulated in such a way that protects both the short and long-term quality and availability of Queensland's water resources. It is not intended that this article attempt to identify what will amount to an adequate level of "quality" or determine an appropriate level of "availability", as these issues are better dealt with from a scientific and policy perspective. The benchmark against which the

Queensland regulative regime is measured is the principles for managing CSG and water as provided by the National Water Commission (NWC) in its 2010 position statement. This article considers whether the Queensland regulatory regime implements the principles set out by the NWC, and the mechanisms by which this is done.

Conclusions: The regulatory framework seeks to implement a regime that "strikes the right balance" between Queensland's economic needs, the needs of other industries, community needs and the wider environmental needs. By way of comparison to the 11 NWI Principles proposed by the NWC for the management of CSG and water, it can be seen that Queensland's regime incorporates a number of the principles. The Queensland regulatory regime for CSG extraction is robust and attempts to be sufficiently flexible so that advancements in extractive practices and scientific knowledge can be readily reflected in CSG processes. While Queensland has some way to go in order to meet all 11 NWI Principles, the current regulatory regime is, in the author's opinion, close to striking the right balance between the various considerations.

It has been stated that managing environmental impacts caused by CSG extraction through an adaptive management approach "essentially focuses on waiting for impacts to occur before changing damaging practices and learning from mistakes".80 In essence, this is exactly what an adaptive management approach will do; however, the alternative to a robust and flexible regime that can adapt overtime is a complete ban on CSG extraction until the science is certain that CSG can be accessed and used in such a way as to guarantee no harm will occur to groundwater – a proposition that may never be realised.

Citation: Joe Schremmer, 'Avoidable Fraccident An Argument Against Strict Liability for Hydraulic Fracturing' (2013) 60 *U. Kan. L. Rev.* 1215-1255

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: Fraccidents that cause environmental contamination should not be held unavoidable as a matter of law. Fracking has been a common occurrence in the oil and gas industry for over half a century. Yet, the EPA's own study of the issue has been unable to definitively prove a link between fracking and water pollution-at least for the present time.

Aims & Research Methods: Part II.A of this Comment will present background on the process and known environmental impact of fracking. Part II.B will survey the development and current laws of strict liability for abnormally dangerous activities, negligence, and res ipsa loquitur. Part III will then apply the Second Restatement of Torts' factors of strict liability to fracking. Part IV will conclude with recommendations for courts to apply res ipsa loquitur in fracking cases.

Scope: This Comment examines plaintiffs' strict liability claims for injuries arising as a result of fracking. Trespass, unlike strict liability, has received ample treatment from the academy and, recently, the courts. The law, though not settled, is at least thoroughly analysed. Nuisance and strict liability claims are not. The laws of nuisance and strict liability intersect and overlap so as to lead many courts to analyse them together. Therefore, much of this Comment's analysis is germane to both claims.

Conclusions: This Comment's position is intended as a compromise. Res ipsa loquitur might not be entirely fair to defendants, but it is rebuttable. Res ipsa loquitur is a concession for plaintiffs, too, in cases in which strict liability otherwise might have been available. More broadly, res ipsa loquitur strikes a balance between enterprise liability and enterprise subsidy. The merits of res ipsa loquitur seem to speak for themselves.

Citation: Fred Pontuis, ‘Hydraulic Fracturing: Is Regulation Needed?’ (2009) 101 *American Water Works Association Journal* 24- 32

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: In 1994, the Legal Environmental Assistance Foundation (LEAF) challenged USEPA because it believed the state of Alabama's UIC program should regulate the injection of fluids to hydraulically fracture coal beds for methane production. In 1997, the 11th Circuit Court of Appeals (1997) ruled that hydraulic fracturing of coal beds in Alabama should be regulated under the SDWA as underground injection.

Aims & Research Methods: This article outlines current fracturing UIC Regulations, the USEPA Coal Bed Methane Study and provides an opinion as to whether regulation of hydraulic fracturing is needed in the US.

Conclusions: Following issuance of the USEPA's 2004 report, a provision was included in the 2005 Energy Policy Act excluding hydraulic fracturing from SDWA jurisdiction. Only Alabama regulates the practice under the UlC program as a result of the court action discussed previously. H.R. 2766 and S. 1215 would remove the prohibition to regulate the underground injection of fluids or propping agents pursuant to hydraulic-fracturing operations related to oil and gas production activities but would exclude the underground injection of natural gas for purposes of storage. The bills would also require disclosure of the chemical constituents used in the fracturing process. Approximately 35,000 wells are hydraulically fractured in the United States each year. Proponents of the proposed legislation point out that the research on potential effects to underground sources of drinking water is limited and therefore it is not completely clear how well underground sources are being protected under the current regulatory framework. Recent sampling by USEPA Region 8 in Pavillion, Wyo., in 37 residential wells and two municipal wells found adamantanes (a naturally occurring hydrocarbon found in crude and gas condensate) and 2-butoxyethanol (a foaming agent) as well as elevated methane levels (USEPA, 2009). This sampling was undertaken in response to homeowners filing complaints about a foul taste and odour in their groundwater. Opponents of the proposed legislation argue that exploration and production of gas reserves using hydraulic fracturing have been regulated by states and conducted safely for 60 years. New regulatory burdens on exploration and production would adversely affect development of needed energy supplies (Harmon, 2009}. For example, a recently released study by Penn State University (Considine et al, 2009) concluded that proposals to regulate hydraulic fracturing under the SDWA pose a serious threat to development of the Marcellus Shale natural gas formation and other unconventional gas sources.

Citation: Andrew Ross and Pedro Martinez-Santos, 'The Challenge of Groundwater Governance: Case Studies from Spain and Australia' (2010) 10 *Reg Environ Change* 299-310.

Topic Area: Water Use and Management

Jurisdiction: Australia and Spain

Introduction: Effective groundwater governance remains an important challenge to ensure long-term sustainability. Governance refers both to setting objectives, principles, and rules for managing the resource, and to processes for implementing the rules. Ostrom (1990) derived eight design principles for self-governing common property resource management systems from studies of long enduring resource management institutions. Although Ostrom's principles remain a good starting point for thinking about groundwater governance most of the empirical work has been on small-scale resources. This paper examines the application of Ostrom's principles in the management of larger scale groundwater resources where robust governance systems depend on effective collaboration between governments and water users.

Aims & Research Methods: A flexible and adaptive management approach is required, with collaboration between scientists, policy makers, water suppliers, and water users. Key management challenges include agreeing on a sustainable level of extraction, and establishing effective coordination and collaboration, and monitoring and control systems. Further case studies of groundwater management and their synthesis could make a useful contribution to the transition towards sustainable groundwater management regimes.

Scope: This paper examines the relevance to groundwater management of Ostrom's design principles for managing common property resources. Experience in four case studies of groundwater management in the Murray Darling Basin in Australia and the Upper Guadiana Basin in Spain suggests that while Ostrom's design principles are relevant, sustainable groundwater management depends on the effective collaboration between government authorities and water users.

Limitations (If Applicable): Further case studies of groundwater management and their synthesis could elaborate and refine the classification and analysis of groundwater governance systems. This could make a useful contribution to the transition towards sustainable groundwater management regimes.

Conclusions: The case studies illustrate the influence of water resource and user attributes and implementation issues on water management outcomes. Uncertainties about sustainable yields, the diffuse nature of groundwater resources and their extraction and the fragmentation of authorities and user groups constrain the achievement of sustainable groundwater management to a varying extent in different cases. This supports the case for diagnostic approaches that take account of different resource and user characteristics. Adaptive management approaches are needed in response to evolving knowledge about groundwater availability, the impacts of groundwater use, and the effectiveness of various rules, incentives and management organisations in promoting collaboration to achieve sustainable groundwater management. As pressures on groundwater resources increase the need for effective metering, monitoring and sanctions also increases. Although there are in principle and practical arguments for groundwater users to take a leading role in monitoring and compliance, the case studies underline the importance of collaborative efforts by responsible authorities and users.

Citation: Braverman, Stephen C; Braverman, Michael R, 'Regulation of Surface Coal Mining: The End of a Thirty-year Balancing Act?' (2012) 27 *Natural Resources & Environment* 28-35.

Topic Area: Water Use and Management

Jurisdiction: Australia

Introduction: In *re Permanent Surface Mining Regulation Litigation*, 653 F.2d 514 (D.C. Cir. 1981), the District of Columbia Circuit confronted a challenge to the scope of the secretary's authority to promulgate regulations dictating minimum information requirements for permit applications submitted to state regulators. Moreover, the coal industry is not monolithic it is by no means certain that limitation on mountaintop mining will not affect electric consumers in the future.

Aims & Research Methods: This article explores current developments in regulatory federalism under the Surface Mining Control and Reclamation Act of 1977, 30 U.S.C. §1201 et seq. (SMCRA) and the Clean Water Act, 33 U.S.C. §1252 et seq. (CWA), in the context of the original congressional intent in enacting SMCRA to "strike a balance between protection of the environment and agricultural productivity and the Nation's need for coal as an essential source of energy," 30 U.S.C. §1202(f).

Scope: One of the challenges inherent in regulating the production of coal is the physical and geographical diversity of the conditions under which coal is mined and the methods used to mine it. Coal is actively mined in twenty-four US states. There are five principal coal basins: Appalachia (Northern, Central, and Southern), the Illinois (Interior) Basin, Gulf Lignite (Texas and Louisiana), Western Bituminous (Colorado and Utah), the Powder River Basin (Wyoming and Montana), and numerous minor and subbasins within these principal basins. The principal methods of mining-underground and surface-have very different environmental and safety challenges. The diversity of conditions and mining methods in the various regions would suggest that local or state-level regulation of mining would be the best approach; experience has proven otherwise.

Conclusions: A national, public dialogue on the costs and benefits of restricting mountaintop mining must take place and a coherent national regulatory framework developed that will provide legal and economic certainty, regardless of the policy choice made. Ideally, whatever the decision, it should be implemented in a way the preserves the state-federal balance that is the centrepiece of SMCRA's regulatory scheme. In the meantime, regulatory predictability and certainty are goals that should be pursued. Unfortunately, it would appear that continued uncertainty will remain the norm for the foreseeable future.

Citation: Stephen Hancock and Christian Wolkersdorfer, 'Renewed Demands for Mine Water Management' (2012) 31 *Mine Water Environ* 147-158

Topic Area: Water use and Management

Jurisdiction: Australia

Introduction: The intensity and diversity of resource development projects has increased by orders of magnitude over the past two decades. At the same time, there has been an emphasis on environmental issues, decontamination of former industrial sites, a recognition of global warming issues, and a focus on the ability of project developers to initiate, operate, and close transient projects without compromising the land and water resource values that underpin existing and future land uses. This concurrence of issues is creating a massive demand for hydrogeologists and groundwater engineers throughout the world.

Aims & Research Methods: In the past, mine water related work for groundwater professionals has been subject to uncertainties because of the cyclical (‘‘boom and bust’’) nature of the mineral and energy industries. Those cycles have flattened and the continuous increase in membership numbers in the International Mine Water Association (IMWA) since 1997 proves this! This paper will mostly focus on the demand for groundwater professionals in Australia, but Australia is just a case study, since other regions in the world face similar issues. European and Canadian perspectives complement this Australian perception.

Scope: This article analyses a shortfall in the numbers of competent groundwater specialists are known to exist in other countries. This is going to become increasingly apparent as they too seek to develop CSG and CS projects. Australia is ahead of many other countries on the learning curve in having had over a generation of large project developments in mining, energy, and geothermal projects. It is a place where professionals can gain skills and experience in these relatively new resource development projects.

Conclusions: The authors believe that there is an urgent need for groundwater managers to take up the learning opportunities and expand their skills by working even more internationally. This process should ensure cross fertilization of experience to the benefit of all the countries where groundwater issues are taken seriously.

Citation: Neil Saintilan, ‘Towards Evidence-based Water Management in the Murray Darling Basin, Australia’ (2012) 32 *Wetland* 199-202

Topic Area: Water use and Management

Jurisdiction: Australia

Introduction: This Special Feature of Wetlands draws together papers from a range of scientific disciplines around a common theme of water and wetland ecology in the Murray Darling Basin, and the standards of evidence required by adaptive, empirically based management. The River Murray, and its tributary the Darling, combine to form Australia’s largest river system, covering an area of over 1 000 000 square kilometres, one seventh of the continental land mass. Though rising from humid subtropical and temperate climates in its eastern headwaters, much of the basin is situated in semi-arid lowlands where rivers traverse gently sloping floodplains. The meandering and anastomosing of river channels in deltaic lowlands of the Murray-Darling has given rise to over 30 000 wetlands, 16 of which have been listed as internationally important under the Ramsar Convention. The basin supports several of the most important waterbird rookeries on the continent.

Aims & Research Methods: The paper introduces a Special Feature of Wetlands concerned with the ecology and management of the Murray Darling Basin, Australia. The Murray and Darling River systems in SE Australia combine to form the largest draining basin on the continent and the most economically important. The river system supports 16 wetlands listed as internationally important under the Ramsar convention, and sustains nationally significant populations of waterbirds, and endemic flora and fauna.

Conclusions: The recent intervention by Federal and State governments to arrest the decline in ecological condition of the Murray Darling Basin has provided impetus to the development of improved hydrological and ecological response models specific to rivers and wetlands within the basin. The development of these models and their application in water planning has exposed many deficiencies in data and system understanding. Significant amongst these include: & an incomplete inventory of wetlands within the basin and their flood dependency, preventing basin-wide prioritisation and optimisation in environmental water delivery & a lack of gauging information in critical wetlands, preventing the calibration and improvement of hydrologicalmodels at important nodes & a paucity of quantitative studies relating flow and ecological condition for many important species of aquatic biota, & a poor understanding of the trophic and competitive interactions between biota occupying rivers and floodplain wetlands, and their importance to overall ecosystem health and resilience & limited understanding of the vulnerability of biota to climatic variability and climate change The above-listed model deficiencies should provide a focus for monitoring and research programs within the Murray Darling. Nichols and Williams (2006) have argued for a close link between monitoring and the specific intention

of management interventions. In the case of the Murray Darling, environmental flows are delivered on the assumption of specific hydrological and ecological outcomes being attained, at the scale of the individual flow and the flow regime. Ideally, these assumptions should be made explicit, as the outputs of hydrological and ecological response models. Post-event monitoring provides an opportunity to test model assumptions against ecological and hydrological data (Saintilan and Imgraben 2012). In this way, each environmental flow becomes an opportunity to test and refine predictive models that in turn are used as the basis for long-term water planning. This iterative, or ‘adaptive management’ process will, if properly resourced and supported, overcome many of the impediments that have led to poor environmental outcomes and suboptimal use of water in the past.

Citation: Hannah Coman, ‘Balancing the Need for Energy and Clean Water: The Case for Applying Strict Liability in Hydraulic Fracturing Suits’ (2011) 39 *Environmental affairs* 132-159

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: Although natural gas is a relatively clean source of domestic energy, there have been numerous allegations of water contamination caused by hydraulic fracturing, and several lawsuits have been filed as a result. Two of these suits (*Berish v. Southwestern Energy Production Co.* and *Fiorentino v. Cabot & Gas*) are pending in the U.S. District

Court for the Middle District of Pennsylvania. Both complaints seek recovery under a strict liability cause of action—asserting that hydraulic fracturing is an "ultrahazardous and abnormally dangerous" activity.

Aims & Research Methods: Part I introduce hydraulic fracturing and its environmental concerns, current federal and state regulation of the process, and the pending lawsuits in Pennsylvania. Part II examines the historical foundations and rationale of strict liability. Part III analyses the current status of the strict liability doctrine and pertinent case law. Finally, Part IV examines the likelihood of successfully applying a strict liability framework to the two pending hydraulic fracturing cases in Pennsylvania. The Note concludes that strict liability is both legally appropriate and socially beneficial, although it is highly unlikely that the court will apply this form of liability in these cases.

Scope: This Note argues that such a framework is both legally appropriate and beneficial to helping balance our energy needs and the importance of clean water. These pending cases will likely set the standard for future hydraulic fracturing contamination cases in Pennsylvania, and potentially across the United States.

Conclusions: Natural gas exploration and drilling will not necessarily contaminate the nation's water supply. But, strict liability would serve as a strong incentive to limit future contamination. As the nation continues to seek solutions to improve its energy options and retain a clean water supply, water quality issues and energy production issues will clash with greater frequency. The decision currently facing the court is an opportunity to create a strong precedent for addressing these issues.

Citation: Dennis Stickley, 'Expanding Best Practice: The Conundrum of Hydraulic Fracturing' (2012) 12 *Wyoming Law Review 1*-17

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: It is increasingly difficult to predict where the HF debate will lead or how it will be resolved. The significance of the discussion is highlighted by weighing the economic benefits against the potential impacts on individuals and the environment. Currently, these issues are being heard in the court-of-public-opinion.

Aims & Research Methods: This article analyses HF technology, scientific opinion, HF policy, HF internationally and how to expand HF best practice.

Scope: This article discusses the conflicting and scientific assessments and policy recommendations expressed about HF, or "fracing," as it has come to be known. On one hand, supporters of this technology point out the benefits in terms of allowing an unconventional source of domestic energy to be developed within the context of state oil and gas conservation laws. On the other hand, it is argued with equal force that the technology represents a significant threat to the environment that only federal legislation can address. This article concludes by advocating for the expansion of the current "best practice" approach by operators and regulators, in the context of Wyoming, regarding the use of this technology

Conclusions: There is no question that unconventional resources will play a vital role in supplying energy for the future. None of the suggested expansion of best practice is novel as to be discounted by prudent operators.114 The industry can go further in terms of best practice in order to maintain credibility. The adoption of so-called “green” HF practices to reformulate additives and reduce water requirements has shown that the industry is responsive to public concern.

Citation: Tim Poise, ‘Coal Seam Gas Exploration and Production in New South Wales: The Case for better Strategic Planning and more Stringent Regulation’ (2012) 29 EPLJ 129-151

Topic Area: Fracking Activities, Well Design, Construction and Abandonment, Water Use and Management, Land Access and Land Title Issues and other Environmental Issues

Jurisdiction: Australia

Introduction: In May 2011, the New South Wales government implemented a 60 day moratorium on new CSG exploration licences, designed to address concerns about land-use conflicts between mining and other uses. However, at the end of this period, these concerns remained unresolved and yet, CSG activities went back to business as usual. Given the potential long-term devastating impacts of CSG operations on water, soil and air, it is the author’s view that the precautionary approach requires a further moratorium on CSG operations be imposed until such time as the findings and recommendations of the inquiries being undertaken by the Federal and NSW State Governments are known and implemented.

Aims & Research Methods: This article identifies the potential impacts of CSG operations and determines whether the current regulation of these activities is adequate. First, a brief overview is provided of the rapid expansion of the CSG industry in New South Wales and Queensland, the process of CSG extraction and the regulation of the industry in New South Wales, including the process for obtaining mining approvals and the preparation of environmental assessments. This is followed by a summary of the issues of concern with CSG operations that have been identified in the public submissions to the New South Wales Legislative Council CSG Inquiry, and the CSG industry’s response to these concerns. Thereafter, an analysis of the approaches to the regulation of CSG operations in Queensland and at the federal level is undertaken. Finally, it is concluded that, given the potential impacts and scientific uncertainties of CSG operations, a precautionary approach must be taken and a temporary moratorium imposed.

Scope: This article analyses the Australian Gas Rush, CSG Operations and Regulation in New South Wales, Environmental Assessment, Access to Land, The Legislative Council Inquiry and Social and Economic Impacts of CSG Operations

Conclusions: In May 2011, the New South Wales government implemented a 60-day moratorium on new CSG exploration licences, designed to address concerns about land-use conflicts between mining and other uses. The question is, since then, to what extent has the land-use conflict been addressed? Put simply, it hasn’t. The first of a series of regional strategic plans is due to be released in early 2012 and the final report in respect of the NSW Inquiry into the impacts of CSG operations is not due until April 2012. If prime agricultural land has not been identified and plans have not yet been prepared to protect such land (through strategic plans), and knowledge of the impacts of CSG operations have not become better informed (through the Inquiry), then land-use conflicts cannot be said to have been addressed and the moratorium should still stand.

Citation: David Pierce, 'Developing a Common Law of Hydraulic Fracturing' 71 *University of Pittsburgh Law Review* 685 1-12

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: Regarding existing shale development, trespass claims can have a direct effect on the use of hydraulic fracturing. Because it is not possible to control the precise location of fissures created by the fracturing process, imposing liability for fissures that cross property boundaries would cause operators to limit their use of hydraulic fracturing and may, ultimately, cause them to abandon the process altogether-which would mean abandoning development of most shale formations.

Aims & Research Methods: This article explores the three common law dimensions of hydraulic fracturing: property, tort, and contract. Although there is a limited amount of "law" on hydraulic fracturing, sufficient case law and commentary exist to frame and evaluate the analysis likely to guide development of a common law of hydraulic fracturing.

Scope: This article analyses the property dimension of Hydraulic Fracturing, the tort dimension of Hydraulic Fracturing and the contract dimension of Hydraulic Fracturing.

Conclusions: Once hydraulic fracturing is proven to enhance production from a particular reservoir, lessors of lands within the reservoir, as a matter of private contract, will demand that their lessees diligently pursue the technique. As with any industrial process, things will go wrong. For those situations, the common law will respond to provide a remedy against negligent and willful conduct. Because hydraulic fracturing is now perceived as impacting a new array of private and public interests, the common law will have to evolve to account for legislative initiatives that appear inevitable at this time.

Citation: Bruce Kramer, 'Federal Legislative and Administrative Regulation of Hydraulic Fracturing Operations' (2012) 44 Tex Tech L Rev 837-862

Topic Area: Water Use and Management, Fracking Activities, Well Design, Construction and Abandonment, Other Social Issues Associated

Jurisdiction: USA

Introduction: The role of the federal government in regulating hydraulic fracturing operations has yet to be defined. Ongoing EPA studies are not expected to be completed for several more years at the earliest. Draft reports, such as the one involving the alleged contamination of well water near Pavilion, Wyoming, will encourage those who believe that only the federal government has the will and the power to regulate hydraulic fracturing operations.

Aims & Research Methods: The importance of the development of shale plays in the United States is unquestioned.2 53 The EPA's critical role in the immediate future appears to be focused on scientific investigations into the potential for hydraulic fracturing operations to create public health issues. In the meantime, state oil and gas conservation agencies appear to be moving from a position of benign neglect to active regulation of hydraulic fracturing operations.

Scope: This article analyses US Federal Environmental Regulations, the LEAF Decisions and The EPA Response to CSG regulation.

Conclusions: The future of an active federal regulatory role in dealing with hydraulic fracturing operations is problematic at best, but one should not simply ignore the potential for federal regulation.

Citation: Hannah Wiseman, 'Fracturing Regulation Applied' (2012) 22.2 *Duke Environmental Law & Policy Forum* 361

Topic Area: Water Use and Management and Fracking Activities

Jurisdiction: USA

Introduction: Hydraulic fracturing for natural gas and oil in shales has changed the American energy landscape and has immensely expanded state responsibilities for environmental protection. States have core regulatory authority over drilling and fracturing operations, and as the number of wells drilled has quickly risen, many agencies face overwhelming responsibilities. Inspectors are traveling to well sites, noting violations, and, in some cases, taking enforcement action. Some states, like Pennsylvania, have issued substantial penalties yet still experience a significant number of violations of state environmental laws. Penalties may not be adequately deterring sloppy drilling and fracturing activity, or the state may be unusually active in noting violations that other states have missed. The types of violations noted among states vary significantly, suggesting that some are simply focusing on different problems, that different companies cause different environmental harms, or that local conditions cause these harms to vary. The presence of more surface water, for example, will likely lead to more violations of state water quality laws. Enforcements also fall along a continuum, from no action to severe penalties, with variations again likely arising from a range of factors--some due to legitimate differences, and others perhaps arising from insufficient agency will or capacity to enforce.

Aims & Research Methods: States have taken a variety of approaches to address these potential effects. Several states have begun updating their regulations, for example, to require stronger casing, to prevent leakage of oil and gas wastes from surface pits, and to prohibit the use of certain chemicals in fracturing. Furthermore, states continue to apply new and pre-existing regulations by inspecting well sites, noting violations, and, in some cases, by taking enforcement action, such as issuing administrative orders, entering into consent orders, and imposing penalties. This article addresses these latter inspection and enforcement activities, exploring how state agencies have applied regulations to oil and gas operators.

Scope: Part I briefly introduces state regulatory programs and provides examples of the types of violations that states have noted at oil and gas sites since shale or tight sands development became more common. Part II describes the types of enforcement actions that states have taken in response to these violations. It is important to note that the violations and enforcement actions explored here are not comprehensive because full data sets from each state were unavailable at the time of publication. It is also important to recognize that the violations and enforcement actions described are associated with a variety of well types-- Antrim Shale wells in Michigan, for example, require substantially different fracturing and drilling techniques than Barnett Shale wells in Texas. With these caveats in mind, the data described paint a preliminary picture of regulations beyond their text, showing that states' notations of violations of environmental and oil and gas laws and resulting enforcement actions vary substantially.

Conclusions: As the drilling and fracturing of wells rushes forward, states are revising regulations, inspecting well sites, and translating violations into enforcement. The data set, in the meantime, continues to grow, providing more lessons about the types of effects caused by fracturing, the best means of avoiding these effects, and the violations that are being overlooked or are simply uncommon. These lessons suggest that states face a daunting task: some violations appear to have caused substantial environmental harm, yet well numbers are rising quickly and state officials often may not have the resources, the will, or the authority to keep up. This preliminary analysis of regulations as they are applied by states is in anticipation of future, more detailed work. Hopefully, data and improved analysis of existing violations and enforcement matters will provide a more thorough understanding of how to properly enforce regulations. This understanding is vital; dusty text within codes tells only a partial regulatory story.

Citation: Patrick Siler, 'Hydraulic Fracturing in the Marcellus Shale: The need for Legislative Amendments to New York's Mineral Resources Law' (2012) 86 *St John's Law Review* 351-385

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: Faced with the conflict between pressure to develop one of the world's largest natural gas fields and equal pressure to protect one of its most vital sources of drinking water, the New York State Senate chose to err on the side of caution. In August of 2010 the State Senate passed a bill suspending the issuance of new permits for hydraulic fracturing in the Marcellus Shale formation in order to "continue the review and analysis of the effects of hydraulic fracturing on water and air quality, environmental safety and public health." The Governor vetoed the legislation, but enacted a narrower moratorium by Executive Order. The Order prohibited the issuance of permits for "high-volume, horizontal hydraulic fracturing" until July 1, 2011.17 The ban has since remained in place pending the further revision of State regulations.

Aims & Research Methods: This Note explores the regulatory framework currently in place in the state and tests it against several issues of practical application evident from the experiences of other states that have dealt with the matter.

Conclusions: This Note concludes by recommending the following discrete amendments to the current regulatory framework. First, the legislature should adopt a more comprehensive definition of waste that includes environmental waste and disposal. Second, legislators must reconcile the conflict between landowners' rights and the practice of compulsory integration in one of two ways: either by recognizing that the rights of landowners are subservient to the state's interest in facilitating the recovery of gas, or by preserving the right of landowners to keep their land free from industrial drilling and ending the practice of compulsory integration. Third, legislators should define the rights of operators on land compulsorily integrated under the present system. Finally, recognizing that the municipality is the political entity most receptive to the will of the public at the local community level, the power of local governments to determine what procedures may be imposed on industry to safeguard their local resources must be made clear. The state legislature should define the term "regulation" in Article 23's supersession clause to specify how much control local governments may exercise over the location of drilling and the traffic to drilling sites.

Citation: Edwards, Blaine D; Shepherd, E James; Deutsch, Nick, 'Hydraulic fracturing: protecting against legal and regulatory risk' (2011) 109 *Oil & Gas Journal* 28-30

Topic Area: Fracking Activities and Chemical Use and Disclosure

Jurisdiction: USA

Introduction: Newspaper articles and television reports make hydraulic fracturing appear to be a new technology that pollutes drinking water, causes flames to leap from kitchen faucets, and constitutes the next great threat to freedom and democracy. The truth differs from the media reports. The issue focuses on a sophisticated well-completion operation that, used in conjunction with horizontal drilling, has made possible the production of large volumes of oil and gas that are otherwise immobile in reservoirs of extremely low permeability.

Aims & Research Methods: This article discusses media and public relations issues relating to hydraulic fracturing, as well as legislative, regulatory, and litigation trends, and provides guidance to the industry to avoid legal pitfalls. With the current EPA position and changing regulatory environment, the legal environment for operators and service companies is fraught with risk. The real issue driving disclosure and EPA action the last several years is the concern, whether real or not, that hydraulic fracturing has impacted USDW.

Scope: This article analyses water concerns regarding Shale Gas by the EPA, Regulatory Disclosure, New risks and EPA Issues.

Conclusions: Oil and gas drilling and hydraulic fracturing in particular exist in a highly unstable regulatory climate at this time. In such a situation, being proactive and moving to protect the company's interest can potentially save millions of dollars in future costs of litigation and judgments if an USDW becomes contaminated.

Citation: William Brady, 'Hydraulic Fracturing Regulation in the United States: The Laissez-Faire Approach of the Federal Government and Varying State Regulations' (2012) *University of Denver Publication* 1-19

Topic Area: Fracking Activities**,** Chemical Use and Disclosure

Jurisdiction: USA

Introduction: The utilization of hydraulic fracturing to exploit these vast reserves of shale oil and gas in the U.S. raises significant concerns about its effect on human health and the environment. Specifically, there are concerns over four exposure pathways that could cause the pollution of drinking water. First, there is the concern that fracking chemicals might enter drinking water aquifers directly, due to improper well construction or an over-aggressive "frack." Second, there is the potential for pollution from the vast amounts of produced water and flow back, which the industry sends to a publicly owned treatment works (POTW), discharges into surface waters, or injects back into the ground. Third, surface drilling operations create the potential for spills and leaching of harmful waste products into the groundwater. Fourth, the fracturing of underground rock formations could potentially cause oil and gas reservoirs to communicate with groundwater aquifers. The first three exposure pathways are particularly important, because among the chemicals used in the hydraulic fracturing process are chemicals that are known to be toxic to humans and wildlife, in addition to known carcinogens.

Aims & Research Methods: The United States, as does Europe, contain vast amounts of oil and natural gas in shale formations. For decades, the US oil and gas industry has employed the process of hydraulic fracturing to exploit these natural resources. The process raises significant concerns about air and groundwater pollution, which has led to a polarizing, often heated public debate that continues to this day, and will likely continue for the foreseeable future.

Conclusions: Current US federal regulation of hydraulic fracturing, and oil and gas industry extraction operations, largely consists of a string of *ad hoc* exemptions and little oversight. The bulk of the regulatory responsibility is given to the several states, and these regulations vary widely in their complexity and level of protection of human health and the environment. New Jersey, for example, has banned hydraulic fracking. New research findings, proposed regulations, and allegations of groundwater contamination are released on an almost daily basis. With newly proposed federal regulations, studies being conducted by the states, the federal government, public interest NGOs and mounting pressure from environmental groups, the state of hydraulic fracturing regulation in the U.S. is, quite literally, up in the air.

Citation: Keith Hall, 'Hydraulic Fracturing: What are the Legal Issues?' (2012) 59 LABJ 250

Topic Area: Fracking Activities, Well design, construction and abandonment

Jurisdiction: USA

Introduction: Hydraulic fracturing uses a mixture of water and additives at high pressure to create fractures in underground rock formations, thereby facilitating the production of oil or natural gas from low-permeability formations such as the Haynesville Shale in north-western Louisiana. In recent months, the process has received
substantial publicity and has become controversial. Numerous media sources describe the process, explain its various economic and other benefits, and discuss the concerns many people have about the process.

Aims & Research Methods: This article provides an overview of several legal issues raised by hydraulic fracturing.

Conclusions: This article has outlined major legal issues relating to hydraulic fracturing that have arisen to date, but the regulatory landscape continues to evolve quickly and will require close attention by those who represent affected parties.

Citation: Keith Hall, 'Hydraulic Fracturing: Trade Secrets and the Mandatory Disclosure of Fracturing Water Composition' (2013) 49 *Idaho L Rev* 1-43

Topic Area: Fracking Activities, Chemical Use and Disclosure, Trade Secrets

Jurisdiction: USA

Introduction: About sixteen states have enacted regulations that require companies to disclose information regarding the composition of fracturing flu-id.91 Viewed at a general level, the various regulations are similar in that each requires companies to disclose information regarding fracturing fluid composition, and such information generally is made available to the public. Further, all of the regulations appear to protect trade secrets from public disclosure.

The regulations differ, however, regarding the scope and level of detail of the information that must be disclosed, the processes for dis-closing information, the methods for making it available to the public, and the extent to which trade secret claims are subject to verification and challenge.

Aims & Research Methods: This article identifies many of the differences between the states' mandatory disclosure regulations, evaluates which of the differences are most important, and offers conclusions regarding which of the approaches taken by various states are better than other approaches.

Scope: This article begins with background discussion of hydraulic fracturing and the movement toward mandatory disclosure. The article then examines ways in which the states' regulations differ, analyses which differences are most important, and offers conclusions regarding which regulatory approaches are best. Finally, the article discusses several other issues that have arisen with respect to mandatory disclosure.

Conclusions: In general, states need not require companies to report a predicted fracturing fluid composition in advance of fracturing. A post-fracturing disclosure of the actual composition used is sufficient. Requiring advance disclosure should not create problems, and is justified in the apparently few jurisdictions in which the state's regulators actually use the information in making permitting decisions, but otherwise disclosures serve little purpose. Similarly, requiring companies to disclose trade secrets to regulators should not create significant problems, but it also serves little purpose and increases the chance that regulators will be sued by persons seeking disclosure of the information or that inadvertent disclosures will occur.

Citation: Daniel Steinway, 'Hydraulic Fracturing and the Shale Gas Boom' (2012) 5 *IELR* 180-182

Topic Area: Water Use and Management. Fracking Activities

Jurisdiction: USA

Introduction: Despite a long history of successful regulation of hydraulic fracturing operations by the states and the safe and effective use of the technology in the United States, increased production of shale gas has given rise to concerns among environmental and citizen groups. Notwithstanding the absence of any hard evidence that hydraulic fracturing has impacted drinking water resources, regulators and legislators at both the federal and state levels have taken steps to address these concerns by imposing additional regulatory requirements on hydraulic fracturing. These new requirements could significantly impact the nation's energy security.

Aims & Research Methods: While the prospects for federal legislative activity in the near future are slight, EPA will proceed with its study of hydraulic fracturing and may continue to explore its regulatory authority over hydraulic fracturing operations. State regulators and legislators will likely continue to undertake efforts to impose increased regulatory requirements on hydraulic fracturing operations regardless of whether those additional requirements actually serve to mitigate any real risk.

Scope: This article analyses fracking technology, federal and state initiatives aimed at regulation and drinking water contamination.

Conclusions: Ultimately, where we end up on both the federal and state regulatory front will impact the extent to which the nation can economically access and produce the vast natural gas supplies that could significantly affect the United States energy security and lower greenhouse gas emissions generated by America's energy use.

Citation: Adam Shedletzky, 'Holding Frackers Accountable for Groundwater Pollution: An Analysis of Canada's Liability Regimes for Hydraulic Fracturing' (2012) *University of Toronto Law School for Environment Probe*

Topic Area: Fracking Activities

Jurisdiction: Canada

Introduction: Because the use of fracking in the extraction of shale gas in Canada is still very limited, there has been little opportunity to test the laws governing it. The lack of precedent makes it unclear whether the current legal liability regime is sufficient to ensure the sustainability of the fracking industry and the safety of the groundwater it potentially endangers.

Aims & Research Methods: This paper will focus on the legal provisions governing groundwater pollution due to fracking for shale gas. More specifically, it will examine the legal liability regimes that regulate the compensation of individuals and the public in the event of groundwater pollution due to fracking activities in Ontario, British Columbia, and Alberta.12 It will conclude with several recommendations for strengthening the regulatory regime to enhance frackers' incentives to take care and to ensure that those who are adversely affected by fracking can be "made whole."

Scope: This article analyses the Canadian Regulatory Scheme for Hydraulic Fracturing.

Conclusions: There are several flaws with the current regulatory scheme. The Crown can choose whether to prosecute a polluting company or give it a free pass, with little recourse for concerned citizens. As long as a company takes "all reasonable precautions," groundwater pollution could go unpunished (except, in some circumstances, in Ontario), and adversely affected individuals uncompensated. Individuals can sue under the common law, but only for damage to their own property. Additionally, there do not appear to be specific provisions to ensure that fracking operators are financially able to pay any fines or damages awarded against them.

Citation: The Widener School of Law's Environmental and Natural Resources Law Clinic, 'A Citizen's Guide to Legal Issues of Marcellus Shale Gas Drilling' (2012) *Environmental & Natural Resources Law Clinic*

Topic Area: Land Access and Land Title Issues, Other Social Issues, Co-Existence, Fracking Activities

Jurisdiction: USA

Introduction: The Clinic receives many inquiries about issues arising out of Marcellus Shale gas drilling, and so the purpose of this Guide is to provide you with some basic information concerning such drilling to help you understand and put in context the complex legal issues that often arise. That complexity increased when Pennsylvania passed Act 13, which significantly changed the central laws governing drilling activity.

Aims & Research Methods: There are many people and organizations that assisted in the preparation of this Citizens Guide. First and foremost are Widener Law students who poured so much into the research and writing of this Guide, especially Brian Calabrese, Matthew McDonnell, Jon Johnson Jonathon Spadea, and Sarah Stoner. The Widener Environmental Law Centre, and especially co-directors (and Widener Professors) John Dernbach and James May, provided valuable assistance and guidance.

Scope: The Guide is informational in nature—that is, it does not provide strategy about particular legal issues as much as give you some sense of what the issues can be so that you can work with your attorney to formulate a strategy. The Guide is general in its scope – it covers many but not all legal issues, and does so in a way that does not and cannot be definitive for a particular situation. Our hope instead is that you will know the basics so that you can understand this complex subject better and start to see the questions you can ask your lawyer.

Conclusions: The Citizen's Guide provides a practical approach to informing citizens of their legal rights regarding Shale Gas exploration in the Marcellus Shale.

Citation: Nicola Swayne, 'Regulating coal seam gas in Queensland: Lessons in an adaptive environmental management approach?' (2012) 29 *EPLJ* 163-185

Topic Area: Water Use and Management, Well Design, Construction and Abandonment, Land Access and Environmental Management Approaches

Jurisdiction: Australia

Introduction: The current regulatory approach to coal seam gas projects in Queensland is based on the philosophy of adaptive environmental management. This method of “learning by doing” is implemented in Queensland primarily through the imposition of layered monitoring and reporting duties on the coal seam gas operator alongside obligations to compensate and “make good” harm caused.

Aims & Research Methods: The purpose of this article is to provide a critical review of the Queensland regulatory approach to the approval and minimisation of adverse impacts from coal seam gas activities. Following an overview of the hallmark of an effective adaptive management approach, this article begins by addressing the mosaic of approval processes and impact assessment regimes that may apply to coal seam gas projects. This includes recent Strategic Cropping Land reforms. This article then turns to consider the preconditions for land access in Queensland and the emerging issues for landholders relating to the negotiation of access and compensation agreements. This article then undertakes a critical review of the environmental duties imposed on coal seam gas operators relating to hydraulic fracturing, well head leaks, groundwater management and the disposal and beneficial use of produced water.

Scope: This article analyses the adaptive environmental approach, environmental approvals for CSG projects, rights to extract CSG in Queensland, the EPBC Act, Access to land issues and the negotiation of conduct and compensation agreements.

Conclusions: Adaptive management, if properly implemented, does have the potential to provide significant assistance in dealing with the complexity and uncertainty surrounding the introduction of CSG activities to Queensland. However, the Queensland approach to adaptive management, in its current manifestation without clear objectives, performance indicators or criteria for evaluation or response, is unlikely to be successful. A radical paradigm shift in the Queensland regulatory approach would be required for an effective adaptive environmental approach to occur. This would require, among other matters, that the adaptive management approach be integrated into statutory provisions for the approval and management of CSG projects. It would require the creation of an appropriate decision-making framework against which the Queensland regulatory approach could be tested and amended. And it would require that the statutory regime be designed with sufficient flexibility to enable changes to be made to the regulatory framework in response to the improved knowledge and understanding of the impacts of these CSG projects. Most significantly, a truly adaptive environmental management approach must be able to embrace the hard decisions that go with “learning by doing” including the ultimate decision of ceasing CSG activities in Queensland in the face of significant information gaps and/or an unacceptably high risk of cumulative adverse impacts.

Citation: Jonathan Entin, ‘The Law and Policy of Hydraulic Fracturing: Addressing the Issues of the Natural Gas Boom’ (2013) 63 *Case Western Reserve Law Review* 965-969

Topic Area: Fracking Activities and other social issues

Jurisdiction: USA

Introduction: For at least four decades, energy and the environment have occupied important places in American policy and legal debates.' At one time nuclear power played a central role in the energy field. More recently, advances in drilling technology and changes in energy economics have made the potential for obtaining oil and gas from shale formations around the United States increasingly attractive while provoking widespread controversy about environmental and health effects. Much of the debate about hydraulic fracturing (popularly referred to as "fracking") has generated more heat than height.

Aims & Research Methods: In an effort to illuminate the many issues raised by these recent developments, the *Case Western Reserve Law Review* sponsored a symposium on "The Law and Policy of Hydraulic Fracturing: Addressing the Issues of the Natural Gas Boom" in November 2012. This issue of the *Review* contains papers presented at that symposium.

Scope: The first piece is an essay by Thomas W. Merrill, the Charles Evans Iiughes Professor at Columbia Law School and the symposium keynoter. Professor Merrill explores four questions that set the tone for what follows. First, why did fracking emerge in this country rather than elsewhere in the world? The rest of the articles revolve around four main themes. One of those themes relates to who decides whether and how to engage in hydraulic fracturing. John Nolon and Steven Cavin note the limited scope of federal regulation in this area and focus primarily on the tensions between state and local government oversight.^ In contrast to Nolon and Gavin, who emphasize the role of government, and Merrill, who draws on the common law of torts, the next paper looks to a distinctive theory of property. Peter Gerhart and Robert Gheren examine the promise of private agreements subject to judicial oversight that further a paradigm of shared property The last paper on this broad theme surveys various regulatory approaches that states have taken. Ghristopher Kulander first summarizes many of the new state laws that address specific aspects of hydraulic fracturing and then looks at a broad range of specific state regulatory regimes. The other piece that seeks to place hydraulic fracturing into existing regulatory frameworks is by Nicholas Schroeck and Stephanie Karisny. These authors emphasize provisions applicable to the Great Lakes that might have implications for the regulation of fracking in the region: the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agi-eement, which was negotiated by the eight Great Lakes states in the United States and the two Great Lakes provinces in Ganada, as well as the Great Lakes-St. Lawrence River Basin Water Resources Gompact, which was endorsed by the legislation of the Great Lakes states and approved by Gongxess The last paper exploring the risks of fracking comes from Heidi Gorovitz Robertson, who analyses the implications of the 2010 *Deepwater Horizon* oil spill in the Gulf of Mexico for regulations of hydraulic fracturing. The final piece in the symposium focuses on economic issues. Timothy Fitzgerald addresses three different aspects, of this subject: the extent to which the new technology enables substantial productivity increases, the growth in energy supply arising from this technology, and the trade-offs between increased energy production and environmental quality.

Citation: Ellen Burford, 'The Need for Federal Regulation of Hydraulic Fracturing' (2012) 44.3 *The Urban Lawyer* 577-588

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: Hydraulic fracturing is currently the predominant method used to extract natural gas from the earth. While natural gas has many benefits, there are health concerns surrounding the hydraulic fracturing process, primarily the resulting groundwater contamination. Although hydraulic fracturing is currently regulated by the individual states, hydraulic fracturing should be regulated at the federal level.

Aims & Research Methods: If passed, FRAC would provide authority for the EPA to regulate hydraulic fracturing, repealing the Energy Policy Act of 2005, which excludes hydraulic fracturing from regulation in the underground injection program. The second major amendment to the SDWA is the requirement to disclose the ingredients used in hydraulic fracturing. Companies, however, would not be required to disclose proprietary information - meaning the amounts of the chemicals used or the manner in which they are used, which would provide the companies protection against competition "stealing" the secret recipe. The one exception to the protection of proprietary information is in the case of an emergency like that of Cathy Behr in Durango, Colorado. FRAC would require the disclosure of the amounts of the chemicals used and other proprietary chemical information to medical providers to aid in the care of individuals potentially harmed by the mixture in some way.

Scope: This commentary will begin with a discussion of natural gas and its benefits to the environment. It will then link natural gas to hydraulic fracturing. Next, this article will explain the process of hydraulic fracturing and discuss some of the benefits of hydraulic fracturing, as well as many of the criticisms that surround the process. Then, this article will examine the strengths and weaknesses of the regulatory scheme - currently, regulation by state governments and not the federal government - and look to what the U.S. Environmental Protection Agency (EPA) has done to regulate hydraulic fracturing. This article will continue by examining what the EPA could do in terms of regulating hydraulic fracturing, analysing the possible drawbacks and benefits of federal regulation. Finally, this article will conclude with an overview of a proposed federal regulation, Fracturing Responsibility and Awareness of Chemicals Act of 2011 (FRAC).

Conclusions: The United States is dependent upon fossil fuels to provide energy for the country. Until research advances to the point that the country can rely on other forms of energy, the fossil fuel that has the least impact on the environment is natural gas. It is the cleanest burning fossil fuel available and has the fewest greenhouse gas emissions.

Citation: Joshua Fershee, 'The Oil and Gas Evolution: Learning from the Hydraulic Fracturing Experiences in North Dakota and West Virginia' (2013) 19 *Tex Wesleyan L Rev* 23-36

Topic Area: Fracking activities, environmental and social impacts

Jurisdiction: USA

Introduction: Two of the country's major shale plays are the Bakken Shale, which is located primarily in North Dakota and Montana, and the Marcellus Shale, which is largely in West Virginia and Pennsylvania. While similar, these formations also have some key differences. The main similarity between the Bakken and Marcellus is that advanced hydraulic fracturing techniques have made the minerals found in both formations accessible and cost effective under current market conditions.' The main difference is the commodity that comes from each of the respective formations. The Bakken Shale formation is an "oil play," but the Marcellus Shale, on the other hand, is a "natural gas play."

Aims & Research Methods: This Article will thus consider major differences and similarities in United States oil and gas extraction via hydraulic fracturing through a comparison of the experiences in North Dakota and West Virginia. Although there are other parts of the country experiencing growth in oil and gas extraction, Pennsylvania and Texas are two good examples, North Dakota and West Virginia are particularly apt for comparison. Both states have relatively small populations, meaning that the impact of large-scale energy extraction in each state is likely to have a large impact on the state, economically, environmentally, and socially.

Scope: There are three main areas worth considering in this comparison. In Part II, this Article will discuss the impact of the oil industry in North Dakota and the gas industry in West Virginia. Part II will also consider some of the financial, environmental, and social impacts of the hydraulic fracturing boom. Part III will then consider the legislative and regulatory landscape of both states and how each state's approach to enforcement and planning can and is likely to impact development in the state.

Conclusions: Finally, this Article concludes that the North Dakota and West Virginia experiences can and should inform state and federal policy with regard to hydraulic fracturing and energy policy generally and provides some suggestions about how best to maximize the value of the lessons already learned.

Citation: Andrew Bruton and Amir Kordvani, 'Tougher Controls on Fraccing' (2011) *IETY* Journal 1-2

Topic Area: Fracking Activities

Jurisdiction: Australia

Introduction: Despite the existing uncertainties surrounding the extent to which using hydraulic fracturing fluids will be regulated, lawyers must carefully assess the impact of legislative measures on companies' fracture stimulation activities in Queensland and NSW.

Aims & Research Methods: This article provides a brief explanation of fracking, Queensland and NSW regulatory frameworks.

Conclusions: In Queensland, regulation is expected to be introduced to prescribe the threshold amount for BTEX fluid under the new s.312W of the EP Act. In NSW, whatever regulatory path the government decides to take (that is, outright ban or restricted use), the use of fraccing fluids is expected to become subject to regulation. Solicitors acting for coal seam gas companies and drilling contractors should therefore plan for the new regulatory environment and carefully assess the impact of legislative measures on their clients' fraccing activities in Queensland and NSW and on their existing and future contractual arrangements.

Citation: Nicholson, Barclay;Blanson, Kadian, 'Trends emerge on hydraulic fracturing litigation' (2011) 109 *Oil & Gas Journal* 80

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: As of the writing of this article, none of the up-to 30 cases currently pending before US courts has reached final judgment; so it is difficult to estimate the viability of these lawsuits and their claims. Additionally, many of the cases are simply too early in the litigation process for defendants to seek an early dismissal or summary judgment requesting the judge dispose of certain claims.

Aims & Research Methods: A review of lawsuits involving fracturing and general themes and theories of current cases can reveal trends that are emerging from this body of litigation, and one can make some predictions about what is on the horizon. These are important times for anyone in the natural gas industry because hydraulic fracturing will be required to access most of the sizable US recoverable gas reserves, estimated at about 1,176 tcf. As it stands now, it seems unlikely that most states, especially those that are traditionally energy-resource friendly such as Texas or Oklahoma, will ban hydraulic fracturing outright or even regulate it to an extent that would discourage development. That being said, the growing trend makes it likely that most areas with fracturing activity will adopt regulations requiring disclosure of chemicals used as a prerequisite for granting a permit. Recently, several studies extolled the benefits of developing the vast reserves of US shale gas.

Conclusions: Despite the challenges facing the natural gas industry on numerous fronts, the overwhelming importance of developing natural shale gas reserves cannot be overstated. Issues ranging from decreasing unemployment rates and increasing economic activity to helping the US become more energy independent and strengthening national security are tied to shale gas development.

Recently, several studies extolled the benefits of developing the vast reserves of US shale gas. It is hoped that these new studies will add to the dialogue that must continue on the exploration and the development of this important and abundant natural resource.

Citation: Bejamin Sovacool, ‘Who Shale Regulate the Fracking Industry’ (2013) 24 *Vill Envtl L K* 189

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: Recently, the Environmental Protection Agency (EPA) took an interest in Pennsylvania's gas industry, which has resulted in conflict between the federal and state environmental agencies. Federal and state agencies disagree over how to "get it right," including which agency should spearhead the regulation efforts and what type of regulation and oversight should exist for the fracking industry.

Aims & Research Methods: This Comment highlights the water usage, water quality, and fracking fluid regulatory issues emerging between the federal government and the Marcellus Shale states.

Scope: Part II explains the history, benefits, and consequences of Marcellus Shale natural gas extraction. Part III addresses the current federal and state regulatory frameworks. Part IV highlights issues caused **by** the current governing format. Part V poses two possible theories to restructure the Marcellus Shale regulatory powers and posits a possible solution for the problem. Finally, Part VI concludes with a discussion of the future of the Marcellus Shale gas industry in Pennsylvania and surrounding states.

Conclusions: By attempting to regulate hydraulic fracturing, the federal government will only serve to impose costly regulatory hurdles that will inhibit the development of the United States' vast natural gas resources. Moreover, "[e]ach state has a vested interest in the protection of its natural environment." To that end, state should be allowed to continue to regulate the natural gas industry in the twenty-first century

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Citation: Paul Dodds and Will McDowall, 'The Future of the UK Gas Network' (2013) 60 *Energy Policy* 305-315

Topic Area: Energy Policy, Scientific pipe, infrastructure and fracking analysis

Jurisdiction: UK

Introduction: The UK has an extensive natural gas pipeline network supplying 84% of homes. Previous studies of decarbonisation pathways using the UK MARKAL energy system model have concluded that the low-pressure gas networks should be mostly abandoned by 2050, yet most of the iron pipes near buildings are currently being replaced early for safety reasons.

Aims & Research Methods: We examined the importance of these trends for the residential sector by iterating the model scenario with an off-line spread sheet that recalculates the distribution and service pipeline residuals (i.e. the energy that the system supplies) as a function of the average gas consumption and the proportion of houses supplied by gas.

Scope: Our study suggests that this programme will not lock-in the use of gas in the long-term. We examine potential future uses of the gas network in the UK energy system using an improved version of UK MARKAL that introduces a number of decarbonisation options for the gas network including bio-methane, hydrogen injection to the natural gas and conversion of the network to deliver hydrogen.

Conclusions: We conclude that hydrogen conversion is the only gas decarbonisation option that might enable the gas networks to continue supplying energy to most buildings in the long-term, from a cost-optimal perspective. There is an opportunity for the government to adopt a long-term strategy for the gas distribution networks that either curtails the iron mains replacement programme or alters it to prepare the network for hydrogen conversion; both options could substantially reduce the long-term cost of supplying heat to UK buildings

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Citation: Corey Johnson and Tim Boersma, 'Energy Insecurity in Poland the Case of Shale Gas' (2013) 53 *Energy Policy* 389-399

Topic Area: Shale Gas Policy, Fracking Activities, Other Social Issues

Jurisdiction: Poland

Introduction: Drawing on research on both sides of the Atlantic, this paper assesses the most pressing issues for research and policy makers related to shale gas extraction.

Aims & Research Methods: This paper examines the shifting centre of gravity of the debate over fracking and shale gas development from North America to Europe and assesses the complex mix of market, environmental, and geopolitical considerations that set the tone, and likely the outcome, of this debate in Europe.

Scope: We examine geologic, economic, environmental and political issues of shale gas. ► Poland is used to assess prospects for shale gas development in Europe. ► Debate in Poland has largely been framed as an energy security issue. ► A number of significant hurdles may prevent large scale development there.

Conclusions: While certain market conditions are certainly ripe for additional supplies of natural gas coming on stream in this part of Europe, high consumer prices and dependence on a small number of suppliers are by themselves not sufficient to ensure that this resource is developed in the future. Geological realities, coupled with infrastructural limitations, valid environmental concerns, and regulatory uncertainties, pose significant hurdles to shale gas development in Poland. In short, it is far from certain whether the obstacles facing industry and policy makers will be overcome. What stands out in the Polish case is that even under favourable geologic and market conditions, there are substantial infrastructural, political and regulatory hurdles to be overcome. At least part of the key to shale gas development therefore seems to lie in the halls of government of Warsaw.

Citation: Richard Selley, 'UK Shale Gas: The Story So Far' (2012) 31 Marine and Petroleum Geology 100-109

Topic Area: Gas Exploration and Exploitation, Other Social Issues

Jurisdiction: UK

Introduction: Cuadrilla Resource's Preese Hall No. 1 well drilled in 2010 was the first well drilled to specifically test for UK shale gas. The same drilling and fracturing techniques that led to the shale gas renaissance in the USA are now being applied to extracting oil from organic-rich shales that are currently in the oil window. It is interesting to speculate that oil may be produced by such techniques from the thermally mature Jurassic shales in the Wessex and Weald basins in the southern UK.

Scope: The UK's first well to find shale gas was drilled in 1875. Twenty five years ago Imperial College evaluated the UK's shale gas potential. Without encouragement from HMG no exploration resulted from this initial research. The BGS and DECC have recently re-evaluated UK shale gas resources. In 2010 the first well was drilled to specifically test for UK shale gas.

Conclusions: A timely re-evaluation of the UK's shale gas potential has been recently carried out by the British Geological Survey and the Department for Energy & Climate Change. The UK government's current policy is now to actively encourage shale gas exploration. In 2008 the 13th round of Onshore Licensing resulted in the award of several blocks for shale gas exploration, though often combined with conventional prospects. At the time of writing the results of the first UK well drilled to test for shale gas test are eagerly awaited.

Citation: Francesco Fracceva and Peter Zeinewski, 'Exploring the uncertainty around potential shale gas development – A global energy system analysis based on TIAM (TIMES Integrated Assessment Model)' (2013) 57 *Energy* 443-457

Topic Area: Energy Policy, Other Social Impacts

Jurisdiction: Global

Introduction: Global energy system models based on MARKAL/TIMES are used quite extensively to assess the perspectives of energy technologies (e.g. the periodic IEA (International Energy Agency) study Energy Technology Perspective is based on a TIMES (The Integrated MARKAL-EFOM System) model). These models are well-suited to systematic analysis of global energy issues, such as climate mitigation options, a fully renewable energy system, alternative fuels for personal transport, and the deployment of electric vehicles.

Aims & Research Methods: This paper aims to quantitatively explore the uncertainty around the global potential of shale gas development and its possible impacts, using a multi-regional energy system model, TIAM (TIMES Integrated Assessment Model). Starting from the premise that shale gas resource size and production cost are two key preconditions for its development, our scenario analysis reveals the way these and other variables interact with the global energy system, impacting on the regional distribution of gas production, interregional gas trade, demand and prices.

Scope: The articles purpose is to simplify and explain the complex behaviour of the system, by illustrating the chain of actions and feedbacks induced by different shale gas economics, their magnitude, their relative importance, and the necessary conditions for the global potential to be realised.

Conclusions: The analysis shows how the reciprocal effects of substitutions on both the supply and demand-side play an important role in constraining or enabling the penetration of shale gas into the energy mix. Moreover, we systematically demonstrate that the global potential for shale gas development is contingent on a large number of intervening variables that manifest themselves in different ways across regionally-distinct energy systems. A simple theoretical model is derived from the results of the scenario analysis.

Citation: Kate Galloway, 'Landowners VS Miners Property Interests' (2012) 37:2 *Alt LJ* 77-81

Topic Area: Land Access

Jurisdiction: Australia

Introduction: As a landholding system founded in feudalism, and perfected in the individualism of Enlightenment thinking, ' the common law understanding of land and property more generally remains predicated on individualism and classical utilitarianism in a world that can no longer afford to operate on these assumptions. What the CSG issue highlights is the centrality of a competition between *private* interests, in what is more sensibly categorised as a *public* interest debate. In the private sphere, however, there appears to be no room for the deeper public concerns that underlie the present debate over CSG exploration and extraction.

Aims & Research Methods: This article highlights 'the inadequacies of considering interests in land (property) in terms of individualistic private interests, in light of the ecological issues facing society at large. It does so using the CSG debate as an example of the limitations inherent in our system of private land holding.

Scope: It first provides a background to Australian law's understanding of the nature of private property and its attendant rights, then examines how this framework is unable to accommodate deeper community concerns such as food security and ecological sustainability. Finally, it assesses whether the issue to be addressed in the CSG debate is one of , competing private property interests, or rather one of re-thinking the very nature of private property to reflect a more sustainable ecological. framework.

Conclusions: There is a way to go in re-thinking the terms of granting CSG mining interests. The terms need to be cast according to true sustainability rather than in terms of developing a petroleum industry. So long as the focus is on environmental management, CSG interests would exist in a system that is super-imposed on an outdate justification for, and expression of, private property interests. Instead, what is called for is a re-thinking of the very foundation of property so that it encompasses concepts of connection of ecological systems, of communities and people with the environment.

Citation: Daniel T.B. Leather , Alireza Bahadori , Chikezie Nwaoha , David A. Wood, 'A review of Australia's natural gas resources and their exploitation' (2013) 10 *Journal of Natural Gas Science and Engineering* 68-88

Topic Area: Coal Seam Gas Exploration and relevant legislation

Jurisdiction: Australia

Introduction: Australia's gas resources are large enough to support projected domestic and export market growth beyond 2030 and are expected to grow further. Most (around 92 per cent) of Australia's conventional gas resources are located in the Carnarvon, Browse and Bonaparte basins off the north-west coast. Large coal seam gas (CSG) resources exist in the coal basins of Queensland and New South Wales. Tight gas accumulations are located in onshore Western Australia and South Australia, while potential shale gas resources are located in the Northern Territory, Western Australia and South Australia.

Aims & Research Methods: This report provides a review of Australia's gas resources in a global context including coal seam gas, tight gas, shale gas and coal seam gas projects, environmental challenges and Queensland and New South Wales government regulations pertinent to CSG.

Conclusions: Australia is expected to significantly expand LNG exports over the next two decades. This reflects not only Australia's abundant gas reserves and their proximity to growing Asian Pacific markets, but also Australia's attractiveness as a reliable and stable destination for investment. CSG fuelled LNG is also expected to contribute significantly to the growth of the sector. The exploration and development of other unconventional gas reserves is yet to unfold. It is first necessary to determine the extent and the quality of the resources present.

Citation: LoValerie Mullins, 'The Equity Illusion of Surface Ownership in Coalbed Methane Gas; The Rise of Mutual Simultaneous Rights in Mineral Law and The Resulting Need for Dispute Resolution in Split Estate Relations' (2009) 16 *Mo. Envtl. L. & Policy Review* 109 1-84

Topic Area: Land Access, Dispute Resolution, Other Social Issues

Jurisdiction: USA

Introduction: The push for alternative energy resources in America has caused a phenomenon in American jurisprudence: the dichotomizing of legal approaches to interpreting mineral law. Analysis of the small collection of landmark coal bed methane gas (CBM) ownership cases reveals a chaotic trend in the interpretation of mineral law as a movement from traditional judicial reverence for property rights toward a growing preference for contract theory. Problematically, this trend is redefining mineral law in a manner foreign to traditional interpretations of mineral theory and in contravention to historical practices of mineral conveyancing.

Aims & Research Methods: This article is an effort to scrutinize the coal bed methane phenomenon and its effect on a new class of split estate surface owners. Analysis will include my assessment of historical conflicts between contract theory and property law which have come to disturb the continuity of modern mineral law.

Scope: Part I of this article addresses the physical properties of CBM and describes its new mineral value. Part II analyses the chaos behind CBM case law as it involves the Virginia Supreme Court Case *Harrison-Wyatt, LLC v. Donald Ratliff; et al.* n1 Part III considers the "interface" n2 issues between contract theory and property law, which disturb the continuity and predictability of mineral law. Part IV retraces the historical conflict between contract theory and property law. Part V looks at the big picture in coal bed methane production as it affects the nation. Part VI reviews the nature of equitable intervention on the part of recent courts in the treatment of split estate issues. Part VII explains why there exists the equity illusion of just intervention in CBM ownership cases. Part VIII suggests the best practice in managing CBM issues is a focus on extraction rights. Part IX advocates for the use of alternative dispute resolution to mitigate the chaos of CBM extraction issues.

Conclusions: Essentially, in re-contractualizing Virginia's mineral law, the Virginia Supreme Court has prompted the deterioration of equity in mineral law. The question becomes therefore, "How can the practice of equity survive Virginia's new common law approach to mineral ownership?" The answer is that it most likely cannot. A systemic tool with greater reach is needed. That tool is alternative means of dispute resolution. The alternative to judicial equity lies in the collaborative efforts of dispute resolution, particularly as alternative fuel production expands to new reaches, and into new communities of surface owners.

Citation: Jennifer Hayes, ‘Protecting Pennsylvania’s Three Rivers Water Resources form Shale Gas Development Impacts’ (2012) 22 *Duke Environmental Law & Policy Forum* 385

Topic Area: Water Use, Impact and Regulation

Jurisdiction: USA

Introduction: In an attempt to gain some regulatory control in a state that does not require permits for surface or groundwater withdrawals, the Pennsylvania Department of Environmental Protection (PA DEP) "has claimed authority through a combination of the Pennsylvania Oil and Gas Act and the Pennsylvania Clean Streams Law to review and approve "water management plans' governing water sources utilized by Marcellus Shale gas operators."

Aims & Research Methods: This article focuses on the threats to Pennsylvania's water resources from hydraulic fracturing in the Marcellus Shale.

Scope: Part I introduces basic Pennsylvania water resource law and the practice of hydraulic fracturing and its impacts. Part II delineates the regulatory context of hydraulic fracturing at the federal and state levels and concludes that the current regime is inadequate to address the water-resource challenges posed by hydraulic fracturing. Part III focuses on the impacts of this inadequate regime on the three most significant rivers in South-western Pennsylvania: the Allegheny, the Monongahela, and the Ohio. It then suggests changes to the management of water resources and regulations to better address the impacts on the Three Rivers region.

Conclusions: There are four basic categories of state regulation that a state could implement or improve to better protect the water resources of a region: (1) well development activities at the surface, (2) collection and disposal of flow back, (3) proximity of well sites to surface waters, and (4) information collection Page 1 and reporting. As most of Pennsylvania sits atop the Marcellus Shale, the negative impacts of hydraulic fracturing have the potential to significantly damage the state's water resources.

Citation: Joseph Dammel, ‘Notes from Underground: Hydraulic Fracturing in the Marcellus Shale’ (2011) 12 *Minnesota Journal of Law, Science and Technology* 773

Topic Area: Fracking Activities, Land Access, Chemical Use and Disclosure

Jurisdiction: USA

Introduction: This article begins in analysing a 2004 study by the Environmental Protection Agency (EPA) focused on the effect on drinking water supplies of hydraulic fracturing injection into coal bed methane wells and found that injection of fracing fluids poses "little to no" threat to underground sources of drinking water and thus required no further study

Aims & Research Methods: This Note focuses on hydraulic fracturing in Pennsylvania, the epicenter of the Marcellus Shale controversy. Unlike some of the other states where hydraulic fracturing is practiced, Pennsylvania has relatively little recent experience in the extractive industries. n13 The state provides a case study for the nexus of energy, climate, and water issues, as well as the role of state and federal regulation.

Scope: Part I of this Note will give an overview of the context surrounding hydraulic fracturing, as well as a brief technical primer on the process. Next, a discussion on the legal principles governing subsurface disputes will lead into a summary of state and federal regulatory action regarding fracing, with a focus on Pennsylvania's regulatory structure. Part II presents a summary of previously proposed changes to regulation of hydraulic fracturing and provides a collection of proposals that protect public concerns and bolster private interests. Natural gas is a critical chapter of our present and future energy story and hydraulic fracturing will be an important character as the rest is written. The great potential of this practice is bounded by significant public concern and scientific uncertainty.

Conclusions: The article argues that moving forward, a clear and equitable legal and regulatory framework must buttress effective management of this important resource.

Citation: Sharon Christensen, Pamela O'Connor, W D Duncan and Angela Phillips, ‘Regulation of land access for resource development: A coal seam gas case study from Queensland’ (2012) 21 *APLJ* 110

Topic Area: Land Access

Jurisdiction: Australia

Introduction: Recent years have seen more comprehensive regulation of the environment, natural resources and cultural heritage, and a greater emphasis on achieving regulatory outcomes by negotiating agreements with landowners. Complementing these changes is a legislative trend to provide for new types of agreements which are given extended effect, meaning that they are deemed to bind not just the landowner who enters into the agreement, but also the landowner's successors (statutory agreements).

Aims & Research Methods: This article illustrates the difficulties and consequences of entry into land access agreements by a detailed examination of provisions in Queensland's Petroleum *and Gas (Production and Safety) Act 2004* (the Act). The Act authorises the undertaking of petroleum and gas projects upon private land, including **coal seam gas** projects.8 **Coal seam gas** exploration and extraction are conducted under an authority to prospect and a petroleum lease respectively (petroleum authority). A petroleum authority is issued to a 'petroleum authority holder' (PA holder) and authorises the holder to undertake 'authorised activities' within the area of the authority.

Scope: This article provides a detailed examination of the Queensland CSG legislative provisions and requires a layered analysis, in which we consider first, the enforceability of land access agreements under common law and equity, the operation of the statutory scheme, and finally the effect of the Land Title Act provisions.

Conclusions: The current statutory regime for land access agreements is fragmented and does not accord with any established legal rules. It will lead to significant uncertainty and transaction costs for subsequent holders of an interest in the relevant land. While the scope of a statutory covenant is necessarily limited, failure to specify the limits expressly leaves doubts as to whether particular types of terms in the agreements are binding on third parties, and which classes of third parties are bound. Rectification of this situation would ideally come in the form of a fundamental reconsideration of the use of land access agreements. In the absence of such reform, the abovementioned legislative amendments should be considered.

Citation: Danny Cameron, 'Coal Seam Gas' (2011) 40 *Engineers Australia Magazine* 1-7

Topic Area: Land Access Issues, Water Use and Management, Other Social Issues, Well Design, Construction and Abandonment

Jurisdiction: Australia

Introduction: Within the vast coal reserves in geological seams beneath Australia, a previously untapped gas reserve is being explored and developed, quickly emerging as the newest big resource market for the country. Coal has a long history in Australia and historically, some underground coal mines have had to deal with the danger of the methane generated and stored within the matrix of a coal seam. Following developments in the US and Canada, however, energy companies are realising the potential to tap into this methane.

Aims & Research Methods: This article provides a summary of coal seam gas development, land access regulation and issues in Australia, water treatment and management and processing of coal seam gas.

Conclusions: The management of all this coal seam gas production water is seen as the greatest challenge. The Queensland government said the primary purpose of its industry water management strategy was to "ensure that salt from coal seam gas activities does not contaminate the environment and to encourage beneficial reuse of water". In most of the current coal seam gas project *Environmental Impact Statements* it is envisaged that desalination plants will be set up through the gas fields to treat the coal seam gas production water by reverse osmosis (RO).

Citation: D Lloyd, H. Luke and W.E. Boyd, '*Community perspectives of natural resource extraction: coal-seam gas mining and social identity in Eastern Australia'* (2013) 10 *Collabah* 1-22

Topic Area: Social Impact Assessment

Jurisdiction: Australia

Introduction: This paper explores community perspectives of the coal-seam gas industry in affected communities of northeast New South Wales and southeast Queensland, Australia, as a case study of society-wide decision-making in the context of natural resource extraction. This case study focuses on a situation where public engagement is high, and is heightened through the contentious nature of the proposed resource extraction. As easily accessible sources of hydrocarbons have been exploited, the exploration industry has been forced to target unconventional reserves of oil and gas.

Aims & Research Methods: Using a recent case study of community reaction to proposed coal-seam gas mining in eastern Australia, this paper illustrates the role of community views in issues of natural resource use.

Scope: Drawing on interviews, observations and workshops, the paper explores the anti-coal-seam gas social movement from its stages of infancy through to being a national debate linking community groups across and beyond Australia.

Conclusions: A recurring message from affected communities is concern around perceived insufficient research and legislation for such rapid industrial expansion. A common citizen demand is the cessation of the industry until there is better understanding of underground water system interconnectivity and the methane extraction and processing life cycle. Improved scientific knowledge of the industry and its potential impacts will, in the popular view, enable better comparison of power generation efficiency with coal and renewable energy sources and better comprehension of the industry as a transition energy industry. It will also enable elected representatives and policy makers to make more informed decisions while developing appropriate legislation to ensure a sustainable future.

Citation: Thomas G. Measham , Fiona Haslam McKenzie , Kieren Moffat and Daniel M. Franks, 'An Expanded Role for the Mining Sector in Australian Society?' (2013) 22.2 *Rural Society* 184

Topic Area: Land Use, Other Social Issues

Jurisdiction: Australia

Introduction: Mining has always played a role in Australian society and economy. However, the role of mining in the economy has changed distinctly since the start of the most recent mining boom. The economic importance of mining is stronger than in previous mining booms, most visibly in the dominance of exports. This has led to unprecedented mining investment and the development of resource projects that are larger by an order of magnitude.

Aims & Research Methods: Our focus in this paper is to consider whether the current mining boom simply echoes past experiences, or if there is something distinct that differentiates the current boom. For the purposes of this paper, the mining sector comprises mineral and energy extraction including metals, coal and gas, in line with the definition used by the Australian Bureau of Statistics (ABS, 2011). The overarching disciplinary perspective presented in this paper is human geography. However, in line with this journal's goal of including papers with multidisciplinary perspectives, and the aim of complementing the disciplinary papers published in this special issue, we draw on a wider suite of disciplines to complement human geography.

Scope: The paper draws attention to four key areas. The first is the economics of mining, where a rise in commodity values has made mining more profitable. Mining now dominates Australian exports more than in previous booms. The second area is the scale of mining operations, which have grown substantially; reflecting unprecedented investment. The third area is the degree to which the diets of resource extraction extend to surrounding areas and distant urban centres through long distance commuting. Finally, we consider the centrality of the mining sector in public life: attention to mining in the media and encroachment on other land uses, and we look for evidence of changes in public acceptance of the sector.

Conclusions: In conclusion, we argue that the role of the mining sector in Australian society and economy has indeed changed The changes in terms of trade and the scale of mining have made the resource sector so important in Australia that increased impact in public lift is unavoidable.

Citation: Svetla Petrova and Dora Marinova, 'Social Impacts of Mining: Changes within the Local Social Landscape' (2013) 22.2 *Rural Society* 153

Topic Area: Land Access, Other Social Issues

Jurisdiction: Australia

Introduction: Defined as a process and a goal, social sustainability is a social construct related to different forms of social capital (both positive and negative), incorporating social mobility and cohesion, solidarity and tolerance and has long-term goals (Barron & Gawnlett, 2002; Dempsey et al., 2011; McKenzie, 2004). Social sustainability is also the foundation for diverse development paths depending on particular cultural, economic, political and/or ecological circumstances. Becker, Jahn, Stiess, and Wehling (1997, p. 19) argue that 'sustainability should not refer to the conservation of specific structures or to static qualities of societies or the natural environment, but, rather, should refer to stabilised and preserved patterns within social-ecological transformations'. In other words, sustainability offers a possibility for a conceptual shift from categories of remaining and preservation to categories of change and transformation (Becker et al., 1997). This is particularly important for understanding the role of mining.

Aims & Research Methods: This paper reflects on a community's perceptions and interpretation of these impacts as well as on the qualitative changes in the local social landscape and their implications for a sustainable future.

Scope: The findings are based on an exploratory research carried out in a small established settlement in Western Australia. Considered as an agricultural communities for decades, Boddington currently hosts two mining operations. Even though mining has been carried out there for decades, the recent opening of a large-scale mining operation is triggering significant demographic changes which result in a structural and functional transformation of the local social environment. Two new phenomena, namely transiency and a dependency culture are identified Maintaining existing levels of social and economic capital as well as mobilising the community's resources to capitalise on the opportunities associated with mining are identified as key challenges for the settlement's sustainability.

Conclusions: The social impacts of mining are not simply negative or positive; they are always inter-related, mutually dependent, cumulative and synergistic (Franks, Brereton, Moran, 2011; Vanclay, 2002). This exploratory case study revealed the emergence of two phenomena influenced by the presence of mining, namely: (1) transiency; and (2) dependency culture.

They are both closely associated with the dynamics within the local community. While the response to the second phenomenon could be the development of specific coping mechanisms through community 'owned' strategies, the first phenomenon poses much larger challenges to Boddington, WA and Australia. It includes personal choices and individual lifestyle strategies which require a more in-depth and serious attention. It also raises questions, such as: do we just accept this new culture or do we challenge the existing concept of community to allow for a different approach to planning and mitigating for the social impacts of mining?

Social sustainability is about change. The biggest challenge the Boddington community faces is how to mobilise its own resources and mechanisms in order to respond to the two new phenomena as part of the changing social landscape triggered by mining.

Citation: Stephen Hancock and Christian Wolkersdorfer, 'Renewed Demands for Mine Water Management' (2012) 31 *Mine Water Environment* 147-158

Topic Area: Water Use and Management

Jurisdiction: Australia

Introduction: The intensity and diversity of resource development projects has increased by orders of magnitude over the past two decades. At the same time, there has been an emphasis on environmental issues, decontamination of former industrial sites, a recognition of global warming issues, and a focus on the ability of project developers to initiate, operate, and close transient projects without ,compromising the land and water resource values that underpin existing and future land uses.

Aims & Research Methods: In the past, mine water related work for groundwater professionals has been subject to uncertainties because of the cyclical (''boom and bust'') nature of the mineral and energy industries. Those cycles have flattened and the continuous increase in membership numbers in the International Mine Water Association (IMWA) since 1997 proves this! This paper will mostly focus on the demand for groundwater professionals in Australia, but Australia is just a case study, since other regions in the world face similar issues. European and Canadian perspectives complement this Australian perception.

Scope: This article analyses the groundwater management and environmental planning relating to all mining activates.

Conclusions: The authors believe that there is an urgent need for groundwater managers to take up the learning opportunities and expand their skills by working even more internationally. This process should ensure cross fertilization of experience to the benefit of all the countries where groundwater issues are taken seriously.

Citation: Poh-Ling Tan, K.H Browmer and C Baldwin, 'Continued Challenges in the Policy and Legal Framework for Collaborative Water Planning' (2012) 474 *Journal of Hydrology* 84-91

Topic Area: Water Use and Management, Policy, Conflict Management

Jurisdiction: Australia

Introduction: As the pre-eminent statement of Australian water policy, the National Water Initiative sets out the basis on which 'freshwater resources are to be shared to support resilient and viable communities, healthy freshwater ecosystems and economic development' (Council of Australian Governments, 2004 and National Water Commission, 2011). Since water plans provide the mechanism for regional water sharing, planners have the daunting task of resolving tensions inherent in achieving a sustainable, nationally compatible allocation system that maintains social values. In 2004, when state and territory governments committed to the National Water Initiative, public participation was seen as important to the success of water reform. An assessment of the National Water Initiative's implementation in 2011 maintains that its provisions remain 'robust and relevant' but recognises lack of support in the reform agenda. Rural stakeholders, in particular, feel their trust in government processes is eroded and local knowledge ignored (National Water Commission, 2011).

Aims & Research Methods: The data on which this article is based was gathered through two predominant means. Firstly we carried out a desk-top analysis of published material and reviewed Australian water planning legislation and policy across the jurisdictions. In doing so we focused on the study areas in which we worked, that is Queensland, Northern Territory, South Australia, while drawing on relevant examples from New South Wales and Western Australia for a wider coverage. Secondly we base our observations on studies that were carried out using a participatory action research methodology (Mackenzie et al., this issue). Drawing upon the results of two major projects in water planning, the Collaborative Water Planning Project in Northern Australia, and the National Water Planning Tools project (WPT), we assess reform measures against the theoretical framework of collaboration. Empirical observations were compared with relevant literature, and further tested in a national workshop with 20 water planners from the above named jurisdictions and Victoria, with three representatives from federal agencies (Tan and Hoverman, 2010). Much of the data from which we draw observations and conclusions, is presented in earlier articles of this issue.

Scope: ► Fine-tuning of policy and legislation still needed after over 15 years of water reform. ► The active involvement of local communities in water planning can be sensitively carried out. ► Effective socio-economic analysis needs to incorporate cultural and community values. ► Deliberative processes are able to increase transparency of water planning. ► A key challenge remains: the role of planning for sustainable contraction.

Conclusions: With rapidly developing science, large probabilities around climate change and variability and new market-based approaches, over allocation has become increasingly apparent in three of our four study areas. Consumptive water users are often critical of the environmental benefit from environmental water allocation even though they may agree on the need for ecologically sustainable development. As noted earlier, water benefits accounting is a new approach that has not yet been fully developed. We propose that an adaptive management framework, as detailed in the first article of this issue, should underpin collaborative water planning. This approach can balance ecological and resource security with continuous improvement in accord with current stakeholder views that call for a more integrated and adaptive approach to environmental water management. Our research suggests that there is much to gain from implementing lessons from the collaboration literature. Where over allocation of water needs addressing, an adaptive approach to sustainable contraction should be a priority for future research collaboration with industry.

Citation: Avner Vengosh, Nathaniel Warner, Rob Jacksona, Tom Darrah, 'The effects of shale gas exploration and hydraulic fracturing on the quality of water resources in the United States' (2013) 7 *Procedia Earth and Planetary Science* 863-866

Topic Area: Water Use and Management, Fracking Activities

Jurisdiction: USA

Introduction: Advances in drilling technologies and production strategies such as horizontal drilling and hydraulic fracturing have significantly improved the production of natural gas by stimulating fluid flow from wells. Since 2008, these technological developments have spurred exponential growth of gas well drilling across the U.S. While the new drilling for shale gas and hydraulic fracturing technologies have dramatically changed the energy landscape in the U.S., recent scientific findings show evidence for contamination of water resources.

Aims & Research Methods: This paper provides key observations for the potential risks of shale gas drilling and hydraulic fracturing on the quality of water resources and include: (1) stray gas contamination of shallow groundwater overlying shale gas basins; (2) pathways and hydraulic connectivity between the deep shale gas formations and the overlying shallow drinking water aquifers; and (3) inadequate disposal of produced and flow back waters associated with shale gas exploration that causes contamination of surface waters and long-term ecological effects.

Scope: By using geochemical (e.g., Br/Cl) integrated with oxygen, hydrogen, strontium, radium, and boron isotopic tracers, this paper characterises the geochemical fingerprints of brines from several shale gas basins in the USA, including the Utica and Marcellus brines in the Appalachian Basin and the Fayetteville brines in Arkansas. We use these geochemical fingerprints to delineate the impact of shale gas associated fluids on the environment.

Conclusions: Overall, one of the direct unquestioned impacts of shale gas exploration on water quality is the issue of management and disposal of wastewater associated with the gas production. The increase use of hydraulic fracturing technology for enhancement and tapping of also conventional oil and gas wells is expected to increase the volume of these types of wastewaters in the U.S.

Citation: Geoffrey Lawrence, Carol Richards and Kristen Lyons, 'Food Security in Australia in an era of Neoliberalism, Productivism and Climate Change' (2013) 29 *Journal of Rural Studies* 30-39

Topic Area: Food Security, Land Access and Use

Jurisdiction: Australia

Introduction: For over 150 years Australia has exported bulk, undifferentiated, commodities such as wool, wheat, meat and sugar to the UK and more recently to Japan, Korea, and the Middle East. It is estimated that, each year, Australia's farming system feeds a domestic population of some 22 million people, while exporting enough food to feed another 40 million. With the Australian population expected to double in the next 40 years, and with the anticipated growth in the world's population to reach a level of some 9 billion (from its present level of 7 billion) in the same period, there are strong incentives for an expansion of food production in Australia.

Aims & Research Methods: This paper provides a brief overview of food insecurity among Australians, but its main purpose is to examine the unsustainable farm production system that has developed since the Second World War and has been strongly shaped, in the last three decades, by neoliberalism. There are signs that the neoliberal-based market solutions to food production and trade are leading, in a period of climate change, to increasing pressures on the environment and to the destruction of some sections of farming, both of which have the capacity to undermine future food production, and food security, in Australia. They will also place limitations on Australia's capacity to export food.

Scope: Drawing from current research into supermarkets and agri-food supply chains and into foreign direct investment in Australian farmlands, from government documents, and from materials produced by independent research bodies, this paper provides a case study of emerging food security issues facing Australia. The paper highlights the role of global neoliberalism in fostering productivist responses to the climate-change challenge, and to other challenges, faced by agriculture.

Conclusions: Australia's food-producing lands being used for biofuel production, coal seam gas extraction, or even as an 'off-shore farm' for oil-rich nations. The exposure of farmers to the 'get big or get out' doctrine of neoliberal capitalism has undermined the public good that can accrue from the traditional format of family-farm ownership. Under the current neoliberal political economy of domestic food production, farmers and consumers are increasingly vulnerable to a capricious global marketplace as well as the profit making desires of agribusiness corporations, the food retail sector, global finance companies and sovereign wealth funds. Yet, little change is likely. As Botterill (2005, p.216) has noted 'the agricultural policy community in Australia is virtually closed to those who disagree with the prevailing economic approach'. It seems that in the face of the need for Australia to fundamentally redesign its agriculture for the new century, the current productivist trajectory will continue to be pursued with vigor creating major concerns for food security into the future.

Citation: Rosemary Lyster, 'Coal Seam Gas in the Context of Global Energy and Climate Change Scenarios' (2013) 13/28 *Legal Studies Research Paper Sydney Law School* 1-13

Topic Area: Other Social Issues, Land Use, Food Security

Jurisdiction: Australia

Introduction: This article analyses CSG concerns relating to the impact of the exploration and production processes on farmland and food security. In November 2011, the Senate Rural Affairs and Transport References Committee's released its *Interim report: the impact of mining coal seam gas on the management of the Murray Darling Basin* (November 2011).51 A final report will be tabled in the Senate on 29 June 2012. The Committee found that much of the land affected by CSG is productive agricultural land and, properly managed, will remain a valuable resource for Australia and the world for many generations. This land should not be put at risk by a relatively short lived industry.

Aims & Research Methods: This article places the current controversy around coal seam gas production in Australia in the context of various global energy resources and climate change scenarios. It highlights the range of concerns that have arisen in Australia with regard to this resource including threats to water, farm land, and greenhouse gases. It also discusses the range of regulatory reviews being undertaken by the Commonwealth and State governments as they attempt to respond to community concerns and cast an effective regulatory net around the exploration for, and production of, coal seam gas.

Scope: This article is devoted to setting out in detail the regulatory responses of the Commonwealth, Queensland and New South Wales governments to concerns about CSG developments.

Conclusions: The article concludes that is likely that 2012 will see a great deal of regulatory activity and reform with respect to CSG developments. However, given the nature of the technology, developers can expect that regulatory agencies will be keeping a watching brief on the fitness for purpose of CSG regulation.

Citation: Barrie Hansen, 'Regulatory Analysis and Response to Potential Coal Seam Gas Groundwater Contamination in Queensland Australia' (2011)

Topic Area: Fracking Activities, Water Use and Management, Land Access

Jurisdiction: Australia

Introduction: Importantly, CSG groundwater contamination has not yet been litigated in Australia, but CSG groundwater pollution, and the damage caused by CSG hydraulic fracturing, has been litigated in the United States more than two hundred times.

Aims & Research Methods: The purpose of this article is to examine the statutory regime of the Queensland government; the obligations imposed in Queensland on CSG developers; and to suggest areas where the federal and state government may make changes to fill any regulatory lacuna which may to lead to damage to Queensland's groundwater, and to the tens of thousands of Queenslanders who rely on groundwater for drinking water, and the millions of Australians who rely on groundwater for the irrigation of crops, and the survival of livestock.

Conclusions: It is hoped this article will provide a foundation for further debate about groundwater environmental security, and the corollary, namely food and water security. Policy makers have it within their power to provide peace of mind to the thousands of Australians who are dependent on groundwater for their drinking water, and the millions of Australian who rely on groundwater for the food in their pantries. At the same time they can provide a sensible road map for the growth of the CSG industry in Australia, developed according to Australian standards.

Citation: Paula Dittrick, 'Canadian Provinces Follow US States in Hydraulic Fracturing Guidelines' (2012) 110 *Oil & Gas Journal* 36-38

Topic Area: Fracking Activities, Policy

Jurisdiction: Canada and USA

Introduction: Canadian provinces, like some US states, are forming hydraulic fracturing guidelines and regulations in an ongoing attempt to avoid controversy regarding groundwater and surface water safety. Industry suggests contamination likely stems from poor wellbore construction and surface spills than fracing.

Aims & Research Methods: This article provides an update on Canadian Shale Gas policy in relation to hydraulic fracturing.

Conclusions: British Columbia implemented mandatory public disclosure of chemicals used in hydraulic fracturing fluids, similar to what some US states already have done. Other Canadian provinces are expected to follow. The Canadian Association of Petroleum Producers (CAPP) recently announced Canada-wide operating practices for its members regarding shale and tight gas hydraulic fracturing. Effective January 1, British Columbia's mandatory disclosure rule requires companies to publicly disclose frac fluid ingredients via a Web site called FracFocus.ca. The online registry resembles a US version called FracFocus. CAFF Pres, Dave Collyer said gas producers developed CAPP's frac operating practices to ensure safe development of Canada's shale gas and to protect Canada's water.

Citation: Eleanor Stephenson, Alexander Doukas and Karena Shaw, 'Grennwashing Gas: Might a transition fuel label legitimise carbon intensive natural gas development' (2012) 46 *Energy Policy* 452-469

Topic Area: Fracking Activities, Canadian energy policy

Jurisdiction: Canada

Introduction: Natural gas is widely considered to be the crucial "bridging fuel" in the transition to the low-carbon energy systems necessary to mitigate climate change.

Aims & Research Methods: This paper develops a case study of the shale gas industry in British Columbia (BC), Canada to evaluate this assumption. We find that the transition fuel argument for gas development in BC is unsubstantiated by the best available evidence.

Scope: ► Transition fuel discourse may greenwash gas development. ► Gaps in research obscure emissions factors for LNG and shale gas. ► Climate solution label for shale gas and LNG development in BC is unsubstantiated.

Conclusions: Emissions factors for shale gas and LNG remain poorly characterized and contested in the academic literature, and context-specific factors have significant impacts on the lifecycle emissions of shale gas but have not been evaluated. Moreover, while the province has attempted to frame natural gas development within its ambitious climate change policy, this framing misrepresents substantive policy on gas production. The "transition fuel" and "climate solution" labels applied to development by the BC provincial government risk legitimizing carbon-intensive gas development. We argue that policy makers in BC and beyond should abandon the "transition fuel" characterization of natural gas. Instead, decision making about natural gas development should proceed through transparent engagement with the best available evidence to ensure that natural gas lives up to its best potential in supporting a transition to a low-carbon energy system.

Citation: Eleanor Stephenson and Karena Shaw, 'A Dilemma of Abundance: Governance Challenges of Reconciling Shale Gas Development and Climate Change Mitigation' (2013) 5 *Sustainability* 2210-2232

Topic Area: Energy Governance

Jurisdiction: Canada

Introduction: Shale gas proponents argue this unconventional fossil fuel offers a —bridge towards a cleaner energy system by offsetting higher-carbon fuels such as coal. The technical feasibility of reconciling shale gas development with climate action remains contested.

Aims & Research Methods: This paper argues that governance challenges are both more pressing and more profound. Reconciling shale gas and climate action requires institutions capable of responding effectively to uncertainty; intervening to mandate emissions reductions and internalize costs to industry; and managing the energy system strategically towards a lower carbon future.

Scope: The paper utilised a BC Canada case study as indicative of the constraints jurisdictions face both to reconcile gas development and climate action, and to manage the industry adequately to achieve social licence and minimize resistance. More broadly, the case attests to the magnitude of change required to transform our energy systems to mitigate climate change.

Conclusions: The BC case reveals that the emergence of abundant unconventional fossil fuels does not necessarily ease the challenges for states facing the need to mitigate climate change. Quite the contrary: abundant unconventional fossil fuels pose these challenges ever more intensely, revealing in particular the limitations of our current institutions of governance. While BC is an exceptional case, the challenges in BC speak to global conditions for jurisdictions developing shale gas. If BC cannot regulate the industry, we suggest it is likely other jurisdictions will face the same constraints when struggling with intersecting technical and governance challenges of reconciling gas development and climate change mitigation, and of managing the benefits and impacts of the industry adequately to minimize resistance. Based on this analysis, we find that governance challenges surpass technical challenges of rendering unconventional gas consistent with climate mitigation, with current governance institutions constrained or unwilling to impose costs, actively shape development, or plan strategically to integrate gas development into a low carbon energy system.

Citation: Desheng Hun, ShengqingXu, 'Opportunity, challenges and policy choices for China on the development of shale gas' (2013) 60 *Energy Policy* 21-26

Topic Area: Energy Policy

Jurisdiction: China

Introduction: With the highest shale gas reserves worldwide and huge need for energy, the Chinese government has introduced many incentives to accelerate the development of shale gas, including subsidies and reduction or waiver of the related fees or taxes. However, the challenges posed by a lack of advanced technologies, environmental protection, a shortage of water in quantity and a knowledge of how to develop a good industry–local community relationship are anticipated in the realization of the predicted golden age of the Chinese shale gas industry.

Aims & Research Methods: This paper focuses on the shale gas development policy of China. Based on an analysis of the opportunities and challenges facing the development of shale gas industry in China, as well as with reference to the experiences of countries with a developed shale gas industry and suggestions by the International Energy Agency, several policy choices, which may be beneficial for China to realize the golden age of the shale gas industry, are recommended.

Scope: Based on the particular situation and available resources in China, and with reference to the experiences in countries with a developed shale gas industry (such as the U.S.A.) and suggestions by the International Energy Agency, recommendations about the choices facing China can be summarized as follows: allowing foreign investors directly to hold exploration and mining rights in shale gas could facilitate the obtainment of advanced technologies; the improvement of the regulatory arrangements related to environmental protection could make developers more responsible; prompting developers to improve their water-use efficiency could help in not worsening the water supply to some extent; and SLO-based mechanism guidance could be helpful in developing a mutual-trust and -benefit relationship between the shale gas industry and the local community.

Conclusions: Despite the great opportunity for China to develop a shale gas industry, there are great challenges, technical and social, developmental and environmental, for the Chinese government and the developer to address. Without advanced technologies being employed, without the eco-environment being well protected, without water-use being well balanced, without a good relationship being established and maintained between the industry and the local community and/or its residents, the development of shale gas cannot bring China any benefits, but merely more serious environmental problems, a greater water shortage, and an unstable, unjust social situation in the development regions. There are several good choices facing China, but these choices are limited. Allowing a foreign investor with advanced technologies directly to hold exploration and/or mining rights in shale gas could open up the way to obtaining advanced technologies; improving the regulatory arrangements related to environmental protection could make the developer more responsible; prompting the developer to improve water-use efficiency could help in not worsening the water supply to some extent; and SLO-based mechanism guidance could help to develop a mutual-trust and -benefit relationship between the shale gas industry and the local community. Although China's policymakers have recognized the need to transform its energy policy and have taken measures to promote the development of a shale gas industry, to what extent these limited good choices can contribute to the realization of a possible golden age of shale gas resources in China relies on whether more detailed measures can be designed, enacted and implemented.

Citation: Tim Boersma and Corey Johnson, 'The Shale Gas Revolution: US and EU Policy and Research Agendas' (2012) 29 *Review of Policy Research* 570-576

Topic Area: Policy, Fracking Activities, Regulation

Jurisdiction: EU and USA

Introduction: The "shale gas revolution" raises a host of questions for policy makers and researchers on both sides of the Atlantic. We provide a brief overview of the regulatory environment as it relates to hydraulic fracturing for natural gas in the United States and the European Union. We then pose a set of open questions, which we believe should shape policy and research agendas surrounding shale gas wherever the development of this resource is being pursued or considered.

Aims & Research Methods: The forced release of shale gas, once thought a pipe dream, has turned into a piped reality: an economic boon for producers, a research bonanza, a massive headache for regulators, and a hotly debated political topic, which has pitted environmentalists against industry and those who see in shale the long-elusive goal of national energy security for the United States. "Marcellus shale," a once obscure geological reference, has entered the dinner table lexicon. Sleepy, struggling communities scattered by happenstance atop shale layers have experienced textbook hydrocarbon booms. In the European Union (EU), meanwhile, Poland's Lublin and Baltic basin are beginning to occupy similar places in the popular lexicon as the Marcellus shale in the United States, though developments there are still at the very early stages. This viewpoint assesses what all this means for policy and research agendas on both sides of the Atlantic

Scope: This article analyses fracking regulation in the US, the current US regulatory environment and Shale Gas regulation in the EU.

Conclusions: If large-scale shale gas exploitation can find its way in U.S. and EU energy markets in an environmentally acceptable fashion, both sides of the Atlantic can benefit in terms of affordable and secure energy supplies. However, many questions remain as to whether this is indeed possible.

Citation: Susan Sakmar, 'The Global Shale Gas Imitative: Will the United States be the role model for the development of Shale Gas around the world?' (2010-2011) 33 *Hous. J. International Law* 369-417

Topic Area: Policy, Regulatory Governance, Fracking Activities, Water Use and Management, Other Social Issues, Chemical Use and Disclosure

Jurisdiction: USA, Canada and a global outlook

Introduction: Thus far, the United States has been the undisputed leader in unlocking the vast tracts of gas-bearing shale found throughout the lower forty-eight states, but Canada is also emerging as a potential major source of shale gas. The so-called "shale gale," the strong wind blown by the technological advances in hydraulic fracturing and horizontal drilling, is not limited to North America. Because shale formations exist in almost every region of the world, the potential for shale gas development is enormous and global in scope.

Aims & Research Methods: To examine whether the GSGI will allow the United States to serve as a role model for the global shale industry, this Article addresses the legal, policy, and environmental challenges associated with shale gas development in the United States.

Scope: Part I provides an overview of the types of unconventional gas resources, including a discussion of the hydraulic fracturing and horizontal drilling technology that is crucial to shale gas development. Part II highlights the prevailing view that shale gas is an "energy game changer" that could dramatically impact global energy supplies, energy security, climate change mitigation, and geopolitics. This section also provides an overview of the major shale gas basins in the United States and Canada and a brief discussion of the potential shale gas reserves in the rest of the world. Part III discusses the GSGI as well as other U.S. efforts and initiatives to help countries around the world develop their own shale gas resources. Part IV addresses the various environmental concerns that have been raised related to the development of shale gas in the United States. Part V discusses the federal and state laws and regulations affecting shale gas development in the United States, including an analysis of proposed legislation to further regulate the industry and a recent EPA study into the potential impact of hydraulic fracturing on drinking water sources and other environmental effects. Finally, Part VI concludes that a careful analysis of the legal, policy, and environmental challenges associated with global shale gas development needs to be done before the full potential of this game-changing resource can be realized. With the exploration of shale gas resources being undertaken on nearly every continent, will the United States lead the way as a role model for environmental best practices in other countries? Though it may be too soon to tell, it is certainly a development worth watching.

Conclusions: The tremendous boom in shale gas production in the United States over the past five years has indeed been a game changer with potentially significant implications in terms of energy security and supply, climate change mitigation, and energy policy. While shale gas presents an enormous opportunity for the U.S. and perhaps the world, there are numerous legal, policy and environmental challenges that must be addressed before the full potential of shale gas can be realized. In the United States, this analysis is currently underway with the on-going EPA investigation and the recent re-introduction of the FRAC Act in the 112th Congress. While it is too soon to tell what the ultimate outcome will be, these developments should be closely watched as the world searches for the right energy policies for the 21st century.

Citation: Jeffrey R Ray, Shale Gas: Evolving Global Issue for the Environment, Regulation and Energy Security (2013) *Selected Works of Jeffrey R Ray*

Topic Area: Social Issues, Regulation

Jurisdiction: USA and EU

Introduction: Shale gas provides a significant step forward in energy security and climate change response for the European Union and the United States (US) that outweighs the issues that are uniquely manifested from acquiring Shale gas, including regulatory concerns from rapid advancements in technology and techniques.

Aims & Research Methods: This article, generally, uses a US lens when discussing shale gas as a logical point-of-view due to the recent extensive utilization, advancement in technology and methods of hydraulic fracturing techniques in the US. Regulatory concerns created from increasingly rapid advancements in technology and techniques require an additional inquiry into whether a special regulatory regime is needed with regard to hydraulic fracturing.

Scope: Acknowledgment of the global significance will be established in part II whilst emphasising the importance to the US and European Union. Part III will present the technical, legal and policy issues created by hydraulic fracturing in order to capture shale gas. Regulatory critique, particularly of the US, will be interwoven into the analysis of this article and linking together, or stating the correlation between, relatively low environmental impact results and concomitant positive attributes of the regulatory regime. Part IV includes observations, concluding remarks and suggestions.

Conclusions: This article proffers that a special regulatory regime is not necessarily needed regarding shale gas if the existing national regime properly addresses, or is capable of legislative amendment to address, the environmental, social and sustainable development issues that developing and producing shale gas has the potential to create. The US regulatory regime is used below to exemplify the above assertion. The US does not have a special regulatory regime for shale gas. Instead, the United States utilizes the generalized Environmental Protection Agency (EPA) in order to regulate the environmental effects that the industry may produce. The EPA is given power from the Clean Water Act, Energy Policy Act 2005, Clean Air Act and the Safe Water Drinking Act to regulate environmental concerns. Reliance is placed on legislative bodies and the industry to handle social issues surrounding shale gas.

Citation: Raphael J. Heffron, Angus Johnston, Darren McCauley, Kirsten Jenkins, 'Policy delivery for low carbon energy infrastructure in the UK, April 5th 2013: Conference overview' (2013) 61 *Energy Policy* 1367-1369

Topic Area: Policy

Jurisdiction: UK

Introduction: The main focus of the day was on new low-carbon electricity generation infrastructure and—as David Robson, Helen Cook, and Malcolm Keay stated—there is a need to view installation of such infrastructure within the evolving context of local, regional, national and international systems. An example of this was Jennifer McGuinn's presentation on the EU's TEN-E regulations.

Aims & Research Methods: The ambition of this conference was to deliver a first examination of how policy is delivered in the context of low-carbon energy infrastructure in the UK. The UK has been developing policy in this area since 2002 (Heffron, 2013). Finally, as the decade passed, in November 2012 an Energy Bill was put before the UK Parliament. One of the chief purposes of this Energy Bill is to establish the right environment for new electricity generation infrastructure in the low-carbon sector.

Scope: There is significant debate on how this will be achieved and, indeed, whether this piece of legislation will actually deliver this outcome. This conference aimed to examine the dynamics of policy delivery. Throughout the day, there was entertaining discussion as a variety of conference presenters provided interesting contributions on how to deliver such policy goals. In total, there were twelve speakers throughout the day representing the UK (University of Oxford, Pinsent Masons Law Firm, University of Stirling, University of Dundee and University of Aberdeen), and also those who provided lessons from abroad from the University of Copenhagen, Central European University, Milieu Ltd., Pillsbury Law Firm (Washington DC, US) and the Conservation Law Foundation (MA, US).

Conclusions: This conference is the first in series of planned events around the theme of policy delivery on energy policy, which will also address energy justice. There are significant lessons for achieving more effective policy delivery that emanate from this conference, and with the current flux over new energy infrastructure that is ongoing in the UK, this conference and the lessons generated are timely. What was contained in the presentations throughout the day was the importance of policy that demonstrates the government's commitment, and that it is consistent and stable. This will have a significant effect on the outcome of policy delivery. The conference also highlighted three central steps that lead to achieving effective policy delivery. Binding targets, contracts with government, and legislation that generates rights and entitlements which are protectable are central to securing policy delivery. Finally, the focus on policy delivery as a research topic is an area that requires more research, and on that is open to different academic disciplines, but in particular insights from law, economics, politics, geography and environmental sciences will prove important in addressing policy questions in an integrated and co-ordinated fashion.

Citation: Michelle Bamberger and Robert Oswald, 'Risk and Responsibility: Farming, Food and Unconventional Gas Drilling' (2012) Independent Science News <

http://independentsciencenews.org/health/risk-and-responsibility-farming-food-and-unconventional-gas-drilling/>

Topic Area: Other social issues, food security, regulation, chemical use and disclosure

Jurisdiction: USA

Introduction: Extraction of hydrocarbon gas from tight shale formations using horizontal drilling and hydraulic fracturing has been advertised as a path toward energy independence for the United States and is being promoted worldwide. This is tempered by environmental and societal concerns that have led to banning the practice in some countries (e.g., France), at least one state in the U.S. (Vermont), and numerous towns and cities in the United States. In the United States, the process itself is largely regulated at the state level, with exemptions from federal laws regulating air, drinking water and hazardous waste disposal. Regulation at the state level varies considerably among states with significant shale deposits, as does the level of enforcement of regulations. The argument often given to suggest that the process is safe cites the fact that in the sixty years since the first gas well was hydraulically fractured, the industry has not found proof it finds acceptable that drinking water has been contaminated.

Aims & Research Methods: This newspaper article argues the US can protect public health with greater certainty, unconventional shale gas extraction should be severely limited or banned, using the subsidies currently provided to support this industry to instead develop and deploy renewable forms of energy.

Scope: The article analyses US regulation and health issues in regards to chemical use.

Conclusions: The unconventional gas-drilling boom has swept across the globe in recent years without evidence that environmental and public health can be protected. In the United States, the industry enjoys extensive subsidies, which include, among many others, exemptions from federal laws regulating clean air, clean water, and the disposal of toxic substances. A patchwork of state regulations allow secrecy rather than disclosure of substances used in all steps of the process, and nondisclosure agreements have been used to block access to information on specific cases that could provide meaningful public health information. Without complete transparency (disclosure of all chemicals used and outlawing nondisclosure agreements in cases involving public health) and complete testing, science cannot proceed unimpeded. Without careful science demonstrating, not the absence of proof of harm, but rather the clear absence of harm to public health, neither state nor federal regulations can assure that the food supply and the health of individuals living near gas drilling and processing operations will be protected.

Citation: Daniel Cahoy, Joel Gehman, Zhen Lei, 'Fracking Patents: The Emergence of Patents as Information Containment Tools in Shale Drilling' (2012) 19 Michigan Telecommunications and Technology Law Review 279

Topic Area: Fracking Activities, Chemical Use and Disclosure

Jurisdiction: USA

Introduction: The advantages of new sources of energy must often be weighed against environmental, health and safety concerns related to new production technology. The rapid development of unconventional oil and gas fields, such as the Barnett and Marcellus Shales, are no exception. Information about extraction hazards is an extremely important issue. In general, patents are viewed as a positive force in this regard, providing a vehicle for disseminating information in exchange for a limited property right over an invention. However, there is an emerging recognition that patents can also be used to control the creation of new information by limiting the evaluation of an invention by third parties. Such control is more likely in situations where third-party use and assessment may produce information damaging to the patent owner.

Aims & Research Methods: This paper will explore the relationship between patents and information control in the context of natural gas extraction. It will describe the substantial growth of patents in hydraulic fracturing, the technology used to extract gas from the widely discussed Marcellus Shale in the eastern United States. The paper will then explain how patents on hydraulic fracturing fluids could potentially be used to prevent testing by third parties. Analogies in agricultural biotech and genetic treatments are used to support these claims. An understanding of the role of patents as information control mechanisms is critical to the safe employment of new technology. If patents substantially limit information creation or disclosure, government intervention to permit experimental use and environmental, health and safety testing may be necessary. However, options do exist under current law that should be considered before patent rights are encumbered.

Scope: This paper analyses the historical development of hydraulic fracturing and patents, information limitation in gas extraction and options for addressing information limitation in legislative revision and judicial reform.

Conclusions: The patent system has traditionally been viewed as a means for disseminating information as much as providing an incentive to innovate. Rapid information disclosure has traditionally been viewed as part of the bargain with the patentee. However, when reproduction or use of the patented invention is necessary to understand how it impacts the rest of the world, patent rights can actually serve as a barrier. This information limitation problem is particularly apparent in hydraulic fracturing technology. The great need for third party experimentation combined with the lack of an effective experimental use exception has resulted in the unexpected emergence of patents as a means to keep secrets. However, the problem is not limited to hydraulic fracturing and is worth considering as a general issue of patent policy. Before engaging in the wholesale reform of patent rights, policy makers should examine the relief options that already exist. Certain actors such as public universities possess greater flexibility in avoiding liability. Fully appreciating the intellectual property issues and prospectively planning a response may avoid many of the most negative impacts of information containment.

Citation: Barbara Warner and Jennifer Shapiro, ‘Fractured, Fragmented Federalism: A study in Fracking Regulatory Policy’ (2013) 12 *The Journal of Federalism Advance Access*

Topic Area: Fracking Activities, Regulation

Jurisdiction: USA

Introduction: Unlike the regulation of other heavy industries, fracking in which companies create cracks in shale rock to extract gas, oil, or other substances has been exempted from federal reach, leaving regulation to the states, which appear vulnerable to capture by energy interests. As fracking has expanded, become more complex, and generated considerable controversy, some states have sought to quash local government efforts to impose more stringent regulations. Citizens and activists have sought redress through the courts, and some states are fighting over the transport of waste disposal across state lines.

Aims & Research Methods: To better understand the choice of venue and its implications, we collected and collated our own data, based upon information from FracFocus,1 a national fracking chemical registry managed by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. This site is used by ten states. Furthermore, we spoke to state officials and attended a state fracking conference hosted by state officials and the fracking industry. We examined advocacy web sites and surveyed the State Review of Oil and Natural Gas Environmental Regulations (STRONGER) provisions for each state, creating our own online review of state STRONGER reviews (see Appendix I in supplementary data at Publius online). We also examined reputable news sites and industry news. Finally, we used the advocacy organization, Earth justice, to identify lawsuits involving fracking, researching the actual court opinions ourselves.

Scope: We begin with a brief regulatory history of fracking, including a recounting of the passage of the 2005 Energy Act that provided the critical federal exemption for fracking. We then examine local government regulatory challenges to their own states, followed by an examination of the state regulatory process regarding fracking. We end with a brief overview of some regulatory action on fracking and a summary discussion.

Conclusions: The prospects for major federal laws concerning fracking seem remote at this point, barring a high-profile accident or punctuated equilibrium (Spence 2010). As noted, gas producers did not support the FRAC Act, and the current Congress seems unlikely to take on the industry. Thus the states will likely continue to take the lead in the regulation of this potentially important energy source, and the industry interests are likely to continue to hold sway there.

Citation: Elizabeth Burleson, ‘Cooperative Federalism and Hydraulic Fracturing: A Human Right to a Clean Environment’ (2012) 22 *Cornell Journal of Law and Public Policy* 289

Topic Area: Fracking Activities, Other Social Issues, Public Policy, Human Rights

Jurisdiction: USA

Introduction: Hydraulic fracturing provisions are strikingly fragmented and have sparked a fierce debate about chemical disclosure, radioactive waste- water disposal, and greenhouse gas emissions. United States natural gas production may stunt the direction and intensity of renewable energy by up to two decades and will not provide a bridge to a sound energy policy if it "erode[s] efforts to prepare a landing at the other end of the bridge. " Unconventional natural gas extraction need not become a transition to a new addiction.

Aims & Research Methods: This Article argues that filling the energy governance gaps regarding unconventional natural gas can best be accomplished through collaborative governance that is genuinely adaptive and cooperative. Through cooperative federalism, combined with procedural rights for inclusive, innovative decision-making, state and non-state actors should design and implement the requisite safeguards before further natural gas development advances.

Scope: This Article analyses how cooperative federalism and inclusive decision-making can provide legitimacy and transparency when balancing property rights against police powers to regulate natural gas production.

Conclusions: No single layer of government consistently provides optimal public health and environmental integrity protections. At times, international, non-governmental, regional, federal, state, local, and individual players have provided sustainable development leadership. Some technologies and geographic realities may be better suited to a given kind of governance. Regional water-energy-climate collaborative governance may facilitate wave energy success along a coastline. Similarly, watershed management may benefit from regional trans boundary commissions. Yet such commissions will not, by definition, be insulated from persuasive and well-financed stakeholders seeking development permits that do not adequately take into account water quality and quantity needs of the watershed. Integrating the work of scholars conducting energy spectrum life-cycle analysis with the work of scholars analysing best practices in collaborative governance continues to unfold. The national academies and a wide range of public/private studies can further this crucial work. In the context of unconventional natural gas, engineering, geology, innovation, and governance are colliding, and better water-energy-climate co-ordination can further energy security.

Citation: Joe Stammers, ‘Coal Seam Gas: Issues for Consideration in the Illawarra Region, NSW, Australia’ (2012) *University of Wollongong Faculty of Science Honours Thesis*

Topic Area: Other Social Issues, Environmental Issues, Regulation, Fracking Activities

Jurisdiction: Australia

Introduction: Coal seam gas (CSG) is a naturally occurring gas, predominantly methane (CH_4) that can be used as a fuel to generate electricity. It is found within the pores and fractures of all sub-surface coal seams, typically at a depth of 300 to 1000 metres. Advances in drilling technology have made CSG extraction more economical, leading to a significant expansion in development, particularly in the eastern coal basins of Australia and parts of the US. This rapid expansion in development has created significant concern as to possible impacts on the environment, particularly issues relating to agriculture, groundwater, and water catchments.

Aims & Research Methods: The main environmental issues relating to CSG extraction are outlined in this thesis by analysing a range of literature relating to CSG development in the Illawarra region, south of Sydney, a region that has been extensively mined over the past 150 years and is an important water catchment for the Sydney metropolitan area. In addition to discussing exploration and production techniques such as hydraulic fracturing, an analysis of the geology and hydrogeology of the Southern Coalfield is undertaken, with particular reference to the potential impacts on groundwater and water catchments. The study also reviews the legislative framework, and looks at the global and domestic economic conditions currently driving CSG development in this country. This thesis forms an important basis for understanding the current issues relating to CSG in Australia, as well as proving local context for assessing potential impacts in the Illawarra region.

Scope: This paper analyses the global and local gas market, geology of the Sydney Basin, Coal Seam Gas regulation and a literature analysis.

Conclusions: CSG development in Australia has rapidly emerged over the past couple of years as one of the country's most highly contentious environmental issues. Concerns as to the possible impacts of CSG on agriculture, groundwater, and water catchments have generated considerable publicity and pressure on all levels of government to strike a balance between agriculture, the mining industry and the environment.

The overarching aim of this project was to objectively assess the current state of knowledge regarding CSG extraction and its potential environmental impacts so that local government can make informed decisions relating to future CSG developments. A critical review of available scientific, government and private company research formed the basis of this study, with gaps in knowledge relating to CSG developments in the Illawarra identified for further investigation.

Exploration and production techniques such as hydraulic fracturing were investigated, in addition to an analysis of the geology and hydrogeology of the Southern Coalfield, with particular reference to the potential impacts on groundwater and water catchments. A review of the current legislative framework was also undertaken, along with a discussion of the global and domestic economic conditions currently driving CSG development.

Citation: Francis Gradijan, 'State Regulations, Litigation and Hydraulic Fracturing' (2012) 7 *Environmental & Energy Law & Policy Journal*

Topic Area: Fracking Activities and Other Social Issues

Jurisdiction: USA

Introduction: Hydraulic fracturing is a process by which oil and gas operators can increase recovery of resources from otherwise unproductive, tight hydrocarbon bearing formations. After a well is drilled, it is encased in concrete and steel casing to prevent resource seepage into nearby rock formations. Holes, called perforations, are made in the casing over an interval in which hydrocarbons may be located. Hydraulic fracturing fluids, which are made of water and chemicals, are pumped under pressure through holes that are perforated in the casing until fractures are opened or enlarged in the shale formation's rocks. A 'propping agent', such as sand or ceramic beads, is pumped into the fractures to keep fractures from closing as the pumping pressure is released. The fracturing fluids are then returned back to the surface. If the hydraulic fracturing is successful, natural gas then flows from rock fractures into the well.

Aims & Research Methods: This article introduces the historical and the current regulatory structure for hydraulic fracturing, focusing on how the EPA's 2011–2014 investigation of fracking differs from a 2004 EPA study. Issues involving hydraulic fracturing-related litigation are discussed. Then several states' and model codes' hydraulic fracturing regulations are examined and categorized as disclosure-based, operational-based, economic-based, and regulatory-based. The article concludes with thoughts regarding the future of regulation.

Scope: This article analyses lawsuits and hydraulic fracking, regulatory structure and the history of hydraulic fracturing in the US, Model Regulations and Guidelines and State regulation of Hydraulic Fracturing.

Conclusions: State-based regulation of hydraulic fracturing has taken many different paths. New York's regulatory delays and increased requirements for environmental studies act as a curb on rapid development of hydraulically fractured wells. Pennsylvania focuses on disclosure and operational regulations. Texas and Wyoming took an early lead with disclosure-based regulations related to the composition of chemicals used in operations. West Virginia's state primacy over development precludes municipalities from enacting moratoria. West Virginia's experience demonstrates that people who seek to affect hydraulic fracturing in some locations must act at the state or federal level rather than through local ordinances. Regulation, rather than litigation, appears to lead to most reform in hydraulic fracturing activities. Successful litigation will likely focus on enforcement and the interpretation of regulations. Ultimately, the absence of significant hazards posed by the process of hydraulic fracturing means that fracking will provide an increasing percentage of America's oil and gas production

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Citation: John Furlow and John Hays, 'Disclosure with Protection of Trade Secrets comes to the Hydraulic Fracturing Revolution' (2011-2012) 7 *Texas Journal Oil Gas & Energy Law* 290-355

Topic Area: Fracking Activities, Regulation, Chemical Use and Disclosure, Other Social Issues

Jurisdiction: USA

Introduction: While there are risks inherent in all oil and gas production activities, opponents of fracing allege that it poses unique risks to human health and the environment. The "most contentious" issue is whether hydraulic fracturing fluids'8 ("frac fluids") injected into deep shale formations could escape into drinking water sources and cause contamination. Opponents are especially hostile to the use of chemicals in frac fluids. Companies have kept the identities of many of these chemicals secret because they consider their formulas to be proprietary trade secrets that confer competitive advantages in the market. As the industry has boomed over the past decade, some opponents of fracing exploited the lack of public information and veil of secrecy surrounding the chemical additives in frac fluids to spread unsupported allegations and misinformation about the risks posed by fracing. Citing a threat to groundwater contamination, many have called on federal, state, and local lawmakers to ban, limit, or circumscribe the process.

Aims & Research Methods: The passage of HB 3328 was a milestone. It marked the first hydraulic fracturing disclosure legislation in the country and the first regulation specific to the process in Texas history. The passage of HB 3328 in May 2011 was only the first step, however. The legislature required the RRC to adopt rules to implement the disclosure process outlined in the bill. In crafting the details of this process, the RRC faced the unique challenge of balancing two competing interests: (1) public disclosure of the potentially hazardous chemicals used in the process; and (2) effective and efficient protection of proprietary trade secrets. With the state's leadership in oil and gas, the Texas disclosure rule has and will likely continue to serve as a blueprint for disclosure policies nationwide. The science, law, and public perception driving the disclosure of chemical additives are central to this article.

Scope: This paper analyses the hydraulic fracturing revolution in the US at the federal and state level focusing on Texas. It provides an analysis of chemical additives and the drive for disclosure in relation to chemicals used in frac fluids, the federal regulatory environment, proprietary trade secrets and the controversy over groundwater contamination regarding social issues and the drive for disclosure.

Conclusions: Texas is leading the way on disclosure. While disclosure policies already exist in some other states, the expertise possessed by the RRC and sheer size of the Texas oil and gas industry means that the disclosure policy enacted by the Texas Legislature will likely set an important precedent for the future development of (and refinements in) state disclosure policies. Already, Colorado, Louisiana, Montana, New Mexico, and North Dakota have followed Texas's lead on the use of FracFocus website.4Other states are also following Texas's lead on the disclosure of MSDS *and* non-MSDS chemicals; use of CAS numbers for identification; disclosure on a well-by-well basis; and an open records based administrative process for determining the validity of trade secret claims.

Above all, HB 3328 and the disclosure rule should be lauded for the balance they bring to the issue of disclosure. The disclosures on FracFocus will provide the public with easy access to important information necessary for informed opinions about hydraulic fracturing. Presently, the most significant concerns about the use of frac fluids are the veil of secrecy surrounding the chemical additives and the general lack of public information on the process. Many opponents have exploited the secrecy issue to propagate misinformation and distrust, particularly in the Barnett Shale. Disclosure should remove the ability of opponents to freely exploit that issue to spread misinformation to the public, though the potential for manufactured hysteria should never be underestimated. The disclosure rule will also provide other benefits, including a continuous stream of public scientific data for analysis. In particular, the well-by-well disclosure requirement will allow for analysis on both a micro and macro level. Additionally, the disclosures should serve as another useful tool for determining the validity of alleged cases of groundwater contamination.

Citation: Jason Obold, ‘Leading by Example: The Fracturing Responsibility and Awareness of Chemicals Act of 2011 as a Catalyst for International Drilling Reform’ (2012) 23 *Colorado Journal of International Environmental Law and Policy* 474-500

Topic Area: Fracking Activities, Chemical Use and Disclosure, Other Environmental Issues

Jurisdiction: USA

Introduction: This boom has brought fracking closer to populated areas and generated numerous questions concerning its effects on people and the environment." Because fracking was removed from regulation under the Safe Drinking Water Act ("SDWA") by the United States Congress in 2005, many of these questions remain unanswered, and fracking continues nation-wide with scattered and inconsistent regulation at the state level. However, both the

House and Senate have offered to repeal the exemption for hydraulic fracturing in the SDWA and finally bring fracking back under federal regulation.' The Fracturing Responsibility and Awareness of Chemicals Act of 2011 ("FRAC Act") would establish the regulatory framework necessary to efficiently monitor the environmental impacts of fracking, facilitate the expansion of scientific inquiry into fracking's effects on humans, and bring greater transparency and accountability to the fracking industry in the United States.

Aims & Research Methods: This note argues the importance of fracking regulation cannot be understated. Fracking catastrophes abroad could devastate densely populated regions, which would inevitably impact the United States because of the interconnected global economy. Now, with the global unconventional hydrocarbon boom in its infancy, the United States must act to prevent fracking from contaminating its domestic environment and to avoid an environmental catastrophe abroad that might cripple the U.S. economy. The FRAC Act establishes a regulatory foundation the United States can take to the international community to begin discussing the adoption of serious reforms in fracking regulation worldwide.

Scope: This Note begins by discussing the history and procedure of fracking. Part II focuses on the unintended side effects of fracking and the resulting personal and environmental injuries. Part III outlines the history of fracking regulation in the United States and its role in mitigating the consequences of fracking. This history moves chronologically from federal fracking regulation under the SDWA to the express removal of fracking from the SDWA and the creation of today's inconsistent and unchecked system of state control. Part III concludes by offering insight into the prospects of Congress bringing fracking back under federal regulatory control in the near future and by explaining why doing so is in the best interests of the United States. Part IV examines the global community and analyses the state of fracking and the environment internationally by focusing on what is happening in China and India. Finally, this Note explains why fracking that results in environmental degradation in other nations is a threat to the United States' national interests, offering insight into how the United States may use its technological prowess and the regulatory foundation of the FRAC Act to spark change in less developed nations that are looking to fracking to solve their energy demands.

Conclusions: This Note concludes that the United States should pass the FRAC Act to ensure safe and sustainable fracking practices domestically, and that the United States should use the FRAC Act as the foundation for better domestic regulation and building a cooperative international understanding of safe and sustainable fracking practices.

Citation: Jason Schumacher, Jennifer Morrissey, ‘The Legal Landscape of “Fracking” The Oil and Gas Industry’s Game Changing Technique is its Biggest Hurdle’ (2013) 17.2 Texas Review of Law & Policy 239-303

Topic Area: Fracking Activities, Chemical Disclosure and Use

Jurisdiction: USA

Introduction: By the end of this decade, the United States will surpass Saudi Arabia as the world's largest oil producer, and will be nearly energy independent by 2035. This was the astonishing prediction made by the International Energy Agency in its latest World Energy Outlook report. The forecast is all the more surprising when one recalls that just a decade ago, the U.S. was thought to be running out of domestic natural gas and oil and was looking at becoming a long-term net importer.

Aims & Research Methods: This article briefly describes the types of regulatory structures being developed for hydraulic fracturing at the state and federal level in the United States to protect public health, safety, and the environment. It also describes the current public dialogue that is driving many of the changes being proposed or made. Finally, we suggest what may lay ahead for the industry in the future.

Scope: This article provides an overview of fracking issues, water quality, water use issues, emissions issues, land access issues, induced seismic activity and federal regulation

Conclusions: It is clear that natural gas will hold a prominent position in the nation's fuel mix for the foreseeable future. The U.S. energy mix is driven by fuel availability, policy, and regulatory decisions. None of the issues discussed herein is simple to address. However, as gas becomes more widely accepted in the U.S., in its own right as a cheap and abundant fuel and as a bridge fuel in the transition to more widespread use of renewable energy, the states and federal government will continue to craft a regulatory scheme that allows the industry to meet growing demand while protecting critical water supplies. The reach of the federal government will be of particular interest to observers in the energy industry. Will regulation be left primarily to states, as at present? Will the federal government instead step in to create a national policy? Or will technological developments in the industry continue to rapidly outpace regulation, both federal and state, leaving lawmakers scrambling to sort through what is science and what is myth in an ongoing game of regulatory catch-up?

Citation: Terence Centner, 'Oversight of Shale Gas Production in the US and the Disclosure of Toxic Substances' (2013) 38 *Resources Policy* 233-240

Topic Area: Fracking Activities, Chemical Use and Disclosure

Jurisdiction: USA

Introduction: With the encouragement of shale gas production in the United States, governments have considered a range of legislative and regulatory proposals to manage health and environmental damages that may accompany extraction activities. Exceptions adopted by Congress to major federal environmental legislation have meant that individual US states have deemed it necessary to provide oversight through regulations to protect people and safeguard environmental quality. In responding, states have legal structures under which drilling firms may not need to disclose the toxic substances used in fracturing wells. Yet, with increasing numbers of drilling sites, more people are at risk from accidents and exposure to harmful substances used at fractured wells. To provide for meaningful health and safety protection, governments may need to revaluate legal provisions offering trade secret protection for toxic substances used in fracturing.

Aims & Research Methods: This article argues The United States has rapidly expanded its natural gas production by drilling in its shale gas plays. Because drilling often involves the use of toxic substances, the public is concerned about risks of health damages and environmental contamination. Due to exceptions in federal law, shale gas development activities are being conducted without complete oversight by several major federal environmental laws that offer safeguards to protect people and the environment. Given health and environmental concerns, states have developed laws and regulations to provide for public safety and protect their water, air, and land resources from contaminants.

Scope: This article analyses federal and state environmental and health regulations relating to disclosure of toxic substances, proprietary information and trade secrets.

Conclusions: The efforts by many states have not fully responded to the risks accompanying shale gas production because they fail to provide information of hazards to injured and potentially-injured persons. By allowing information of chemicals used on a site to qualify for trade secret protection, governments are enabling drilling operators to use dangerous chemicals in shale gas production in communities without disclosing what chemicals are present. Persons residing near well sites who are exposed to toxic constituents accompanying production activities have no idea what chemicals are being used. The secrecy of chemicals used in fracturing suggests that public interests are not fully being considered. This situation may be contrasted with the rights of people to learn about the presence of other hazardous substances in their communities under the Emergency Planning and Community Right-to-Know Act.

Because accidents happen and shale gas production activities involve releases of toxic chemicals, fuller disclosure of the chemicals being used offers a number of benefits. Exceptions for trade secrets are burdening health care providers and frustrating timely responses to harmful exposures of chemicals from fractured wells. Disclosure would support faster and more effective clean-up efforts where spills occur. Information is also important to individuals who believe they are suffering injuries from exposure to toxic constituents and in allowing individuals to make choices about exposure to risks. Disclosure of chemicals used at well sites may also encourage drilling companies to find combinations of safer fracturing fluids as well as develop new technology and processes to minimize risks and damages. While balancing the secrecy of proprietary information, economic performance, injuries to humans, and environmental damages is difficult, legislators charged with promoting public welfare may be neglecting their duties by supporting nondisclosure exceptions that increase uses of toxic chemicals and sacrifice public health.

Citation: Travis Van Ort, ‘Hydraulic Fracturing Additives: A Solution to the Tension between Trade Secret Protection and Demands for Public Disclosure’ (2012) 2 *Ky. J. Equine Agric. & Nat. Resources L.* 439

Topic Area: Fracking Activities, Chemical Use and Disclosure

Jurisdiction: USA

Introduction: The increasing use of hydraulic fracturing as a method for extracting energy supplies, however, has led to tension between private companies and the general public. Companies that are making and using the additives for hydraulic fracturing are seeking to protect their additive formulas as trade secrets while the general public is demanding disclosure of the chemicals used as additives. Currently, states regulate disclosure, and a number of states have promulgated new rules or updated their old rules on this issue in the last two years.' To resolve the aforementioned tension, however, disclosure should be promulgated at the federal level to ensure one uniform standard. Relying on state standards could destroy companies' trade secret protection if any one state requires too much information to be publicly disclosed. While regulation should be at the federal level, enforcement should be left to the states because state enforcement agencies are closest both to the general public and the sites where these chemicals are used.

Aims & Research Methods: This paper argues it is almost axiomatic that businesses will resist new regulations. However, if industry advocates are correct, the proposal outlined above will not add any substantial burden to energy extraction companies. Advocates claim that these companies disclose, at least to some extent, the composition of their hydrofracking additives on sites such as FracFocus.org. Indeed, these companies should welcome the proposal herein because having one promulgator of these regulations, the EPA, would simplify regulations on disclosure. States wouldn't promulgate their own regulations; they would just be empowered to enforce the federal regulations.

Scope: Part II will give a brief overview of the hydraulic fracturing process and will explain the public concern over the composition of the additive products used in the fracking. After defining the problem, the paper will continue by examining how some states have attempted to address the issue and some possible solutions. The first possibility, examined in Part III, would be to use an alternative form of intellectual property right protection to resolve this tension. Upon finding the other types of intellectual property will not work, Part IV examines the state level regulations to find best practices and explain the hazards of piecemeal regulations. Lastly, Part V explains the proposed federal/state regulatory scheme and its superiority to the other proposed solutions.

Conclusions: Energy formations, such as shale gas plays, recognize no state boundary. Thus, a company currently drilling for gas on both sides of a state border has to be aware of, and comply with, two different disclosure regulations. This proposal would protect existing trade secrets by creating one law on disclosure, uniform across the U.S. Companies would have to disclose the composition, by volume, of the trade secret protected formulas to state agencies, such as the state health department and the agency enforcing public disclosure, but would only have to publicly disclose any toxic or hazardous chemicals, such as those regulated under the Safe Drinking Water Act, that are being injected into the wells. The companies would, of course, have the freedom to publicly disclose more information, on FracFocus.org or in some other manner, should they so choose. The key difference between voluntary public disclosure and public disclosure imposed by regulation, even if the information disclosed is the same, is that the imposed disclosure has the weight of law behind it, and entities that fail to disclose or only partly disclose will face legal sanctions. Voluntary disclosure is an admirable first step in this area, but it is not enough to dispel public concerns about hydrofracking and build the public's trust. Regulated disclosure is necessary to accomplish those goals.

Citation: Hannah Wiseman, ‘The Private Role in Public Fracturing Disclosure and Regulation’ (2012) 3 *Harvard Business Law Review Online* 49

Topic Area: Fracking Activities, Chemical Use and Disclosure

Jurisdiction: USA

Introduction: Recent domestic growth in oil and gas natural gas production from shales and sandstones called “tight” formations—largely enabled by a modified technology called slickwater hydraulic fracturing—has driven both economic growth and environmental concerns. Public concerns have often focused on the chemicals used in the fracturing process, yet federal regulations requiring disclosure of chemicals are weak. In the midst of initial "threats" of federal intervention, industry—along with state regulators—developed a website that enabled chemical disclosure. State regulations later mandated disclosure through this website, or allowed it as one option within a mandatory disclosure regime. Independently, gas companies also have begun to experiment with less toxic fracturing chemicals and to take other substantive efforts toward identifying and limiting the risks of tight oil and gas development. This example of a public-private effort to enhance informational access in fracturing, and to make limited substantive changes, may offer important lessons for other oil and gas regulation moving forward. Agencies and policymakers must make independent assessments of risks and avoid directly adopting industry solutions if those solutions are incomplete or avoid needed change. But oil and gas operators have shown how public action, combined with industry coordination and innovation, can sometimes inspire productive responses to the risks of unconventional oil and gas production.

Aims & Research Methods: In response to public concerns about the known and unknown risks of drilling and fracturing, a growing number of states have required operators to disclose the type and quantity of chemicals used at fractured well sites. Industry's involvement in driving and shaping these state regulations offers interesting initial lessons in public-private efforts at regulatory reform in drilling and fracturing, and this Essay briefly explores this trend.

Scope: Part I describes weak federal disclosure requirements, which, in part, drove public demands for change. Part II identifies public-private efforts to form a voluntary chemical disclosure website and explores state laws mandating disclosure—many of which require or allow disclosure through the website. Having identified this core public-private development, Part III describes other efforts, often instigated by coalitions of state regulators and industry members, to identify and respond to the risks of shale gas and oil development. Finally, Part IV draws from the literatures of new governance and voluntary industry behaviour to analyse how industry might both inspire and constrain future substantive regulatory change, identifying both positive and negative lessons from the public-private experiment so far.

Conclusions: As tight oil and gas development continues its rapid march toward domination of the U.S. energy market, both industry and government actors—often working in concert—are responding in a variety of ways. This Essay has introduced several of the private and public-private efforts to address the risks of this development and appease public concerns. One of the most successful efforts to date has involved the expansion of chemical disclosure, with voluntary industry efforts morphing into state regulations that require disclosure through a public-private website.

Similar initiatives have emerged in more substantive areas. Private and public-private efforts to disseminate information about the content of state oil and gas regulations have provided useful, although incomplete, means of comparing regulatory content. Similar efforts to identify risk and propose improved regulation—although not always implemented—also appear to be somewhat successful. And finally, private best practices provide some industry self-regulation of risks.

More action, both at the public and private levels and the grayer areas between them, will be needed to address the range of impacts introduced by a rapidly growing industrial practice. Local, state, and federal agencies implementing further change must account for and in some cases formalize the private progress already occurring, while recognizing that such action could disincentives future industry efforts. At the same time, private actors seeking public acceptance of tight oil and gas would be wise to further improve information dissemination and show the extent to which industry actors follow the many best practices that already have been developed. Disclosure is a very important start, but much more collaborative work remains to be done.

Citation: Fatemah Bagheri, 'Regulation of Hydraulic Fracturing of Shale Gas Formations in the US' (2031)6 Pepperdine Policy Review

Topic Area: Fracking Activities and Chemical Use and Disclosure

Jurisdiction: USA

Introduction: According to the Environmental Working Group, since the year 2000, approximately 120,000 wells were drilled by oil and gas companies and 270,000 wells were drilled since the 1980s. According to the publication 'Rocky Mountain States Natural Gas: Resource Potential and Prerequisites to Expanded Production' the energy resources of the Mountain West are significant to meeting the nation's energy challenge, which is a resource problem, but encompasses underlying economic challenges (American Petroleum Institute, 2011).1 B. Costs Some of the direct costs associated with the practice of hydraulic fracturing are the regulation of the practice including compliance, knowledge, and monitoring.

Aims & Research Methods: This paper argues the patchwork of policies that exist primarily on a state to state basis is no longer the way hydraulic fracturing should be regulated because it is not effective, especially when some states have no regulation on some of the procedures involved in the process.

Scope: This article analyses hydraulic fracturing in terms of economic aspects, environmental impacts, social and health impacts and politics, government agencies and legislation

Conclusions: This paper concludes that given the amount of time the practice has been in existence, the federal government had plenty of time to conduct studies in order to protect not only the constituents of the United States, but to also protect the environment. However, a reasonable time frame needs to be offered to the industry in order to ensure appropriate technologies are implemented properly to mitigate risks and to ensure maintenance of facilities is kept to stringent standards.

Citation: Paula Dittrick, 'Canadian Provinces Follow US States in Hydraulic Fracking Guidelines, Rules' (2012) 110.3 *Oil & Gas Journal* 36-38

Topic Area: Fracking Activities, Chemical Use and Disclosure

Jurisdiction: USA and Canada

Introduction: Canadian provinces, like some US states, are forming hydraulic fracturing guidelines and regulations in an ongoing attempt to avoid controversy regarding groundwater and surface water safety. Industry suggests contamination likely stems from poor wellbore construction and surface spills than fracing. British Columbia implemented mandatory public disclosure of chemicals used in hydraulic fracturing fluids, similar to what some US states already have done. Other Canadian provinces are expected to follow. The Canadian Association of Petroleum Producers (CAPP) recently announced Canada-wide operating practices for its members regarding shale and tight gas hydraulic fracturing. Effective January 1, British Columbia's mandatory disclosure rule requires companies to publicly disclose frac fluid ingredients via a Web site called FracFocus.ca. The online registry resembles a US version called FracFocus. CAFF Pres, Dave Collyer said gas producers developed CAPP's frac operating practices to ensure safe development of Canada's shale gas and to protect Canada's water.

Aims & Research Methods: This article provides a short summary of Canadian Fracking Legislation including Alberta, Quebec, Saskatchewan, New Brunswick, and Nova Scotia

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Citation: Ross Schweitzer and Ilkin Bigesu, 'Developing US Shale Plays: Marcellus Economics of Marcellus Shale well and fracture design completions' (2010) 231 *World Oil*

Topic Area: Well Design and Construction

Jurisdiction: USA

Introduction: Information on well and completion designs for the Marcellus Shale is rather vague and kept close to the chest by operators. This information plays a key role in the production of these shale wells and can determine whether or not they are economical.

Aims & Research Methods: In this study, simulations have been conducted with several wellbore configurations for gas production from the Marcellus Shale. Parameters included lateral wellbore length, propped half-length and the number of fracture stages. Economic evaluations were performed to determine the most cost-efficient configuration. The average present-day completion costs and projected sale price of gas were used in the calculation process.

Scope: This paper analyses well design and reservoir modelling, drilling and completion costs for wells in the Marcellus Shale.

Conclusions: Horizontal wells were found to be more economic when compared to vertical wells. Vertical wells were found to be economic in the higher gas pricing scenario. In general, the optimal designs had a fractured half-length of 1,000 ft and the maximum number of fracture stages (nine in this study). As far as the lateral length was concerned, it was not cost-efficient to drill longer laterals if the number of fracture stages was not going to be increased, but it was cost-efficient if more fracture stages were added.

As expected, much higher IRRs were found with the higher gas pricing. Higher gas prices allow more exploration in vertical wells or smaller-scale horizontal wells due to the lower initial cost. There was no direct trend, but some IRRs and NPVs increased dramatically due to the gas price change. Ultimately, in the Marcellus Shale, the more money spent up front with larger fracture jobs, the more economical the results appear to be.

Citation: Carlos R. Romo and J. Scott Janoe, 'Regulatory Regimes for Recycling Produced and Frac Flowback Water' (Paper presented at 105th Air & Waste Management Association Annual Conference, San Antonio, Texas, June 2012) Working Paper 2012-A-453-AWMA

Topic Area: Fracking Activities, Flow back water, waste water treatment and use

Jurisdiction: USA

Introduction: Despite promising new water treatment services that can help oil and gas operators conserve freshwater and recycle produced and hydraulic fracturing flow back water, there is little consistency across jurisdictions as to how produced water recycling operations are regulated. Some jurisdictions differentiate between commercial and non-commercial operations. Others treat water recycling like solid waste recycling.

Aims & Research Methods: The goal of this paper is to present information on the various state regulatory schemes that exist for the recycling of produced water and the permitting issues associated with these regimes.

Scope: The presentation will cover basic regulatory considerations in recycling oil and gas wastes and will briefly detail how specific high-growth shale field states such as Texas, Colorado, Louisiana, New Mexico, Pennsylvania, and Wyoming manage the permitting process for produced water recycling. A particular focus will be on issues affecting water scarce areas like the Eagle Ford Shale. The presentation highlights potential changes in the near future regarding oil and gas regulatory exemptions that may affect produced water recycling and advocates for states to examine ways to reduce regulatory obstacles to encourage recycling.

Conclusions: The technologies and regulation of recycling produced and frac flow back water are constantly evolving. Because of new emerging technologies to recycle and reuse oil and gas wastewaters, states have been prompted to review relevant regulations to encourage these promising new methods to reduce water consumption and oilfield wastes. 41 Still, significant uncertainty and inconsistency exists in many states. The DOE's Shale Gas Subcommittee recently made three recommendations related to water use, including the need to estimate volumes of water flows throughout the hydraulic fracturing process and minimize water use. While this paper attempts to provide some general considerations and key information regarding the current state of regulation of recycling produced water, states should continue to review their regulations to evaluate whether obstacles exist to recycling produced water and whether changes could be made to facilitate promising new recycling technologies.

Citation: Katherine Owens, 'Strategic Regional Land Use Plans: Presenting the future for coal seam gas projects in New South Wales?' (2012) 29(2) *Environmental and Planning Law Journal* 113, 118-120

Topic Area: Other Social Issues, Land Use, Hydraulic Fracturing, Regulatory Frameworks

Jurisdiction: Australia (NSW)

Introduction: In New South Wales, as elsewhere in Australia, there has been little attempt to plan for the spatial distribution of coal seam gas (CSG) projects at a strategic level, and regulatory frameworks are not considered to be sufficiently robust to manage the cumulative environmental effects of CSG activities on aquifer integrity. The New South Wales State government has pledged to resolve some of the problems associated with CSG mining through its Strategic Regional Land Use Policy, in which Strategic Regional Land Use Plans are to play a key coordinating role. However, a "spatial fix" of this nature is likely to constitute a dangerous shortcut in planning regulation in the particular context of CSG development, which may do very little to resolve the concerns expressed by environmental, farming and community groups, or the concerns of the CSG industry itself in resolving the emerging land-use conflicts.

Aims & Research Methods: This paper argues that strategic planning can only provide an enduring solution to the land-use conflicts at play if the New South Wales government and stakeholders commit to a more integrated and reflexive process, which involves an explicit acknowledgement of, and provision for, doubt.

Scope: This article outlines a number of factors that are likely to limit the effectiveness of SRLUPs over time, and argues that strategic planning can only provide an enduring solution to the land-use conflicts at play if the New South Wales government and stakeholders commit to a more integrated and reflexive process, which involves an explicit acknowledgement of and provision for doubt.

Conclusions: If these guiding principles are ignored then strategic planning, as practiced through SRLUPs, is likely to fall short of what is required to guide ecologically sustainable development of CSG in New South Wales. At this point in time, the New South Wales government has an opportunity to intervene and guide CSG development along more sustainable pathways. However, the government's regulatory and policy response suggests it has either underestimated the potential risks involved or is simply not prepared to interfere in any substantial or meaningful way with an industry that is likely to generate significant royalties and revenue for the State over the next 25 years. SRLUPs have created an opportunity for the government to engage the public in strategic choices concerning both the coordination of land-uses and the management of our natural resources. However, the essential shortcuts that are likely to be taken in addressing and outlining the relevant environmental choices at stake, and the reductionist approach the government is likely to take to analysing the various land-use mix options, may mean that land-use conflict will give way to more fundamental and irreversible concerns about our essential groundwater systems.

Citation: Peter Green and Ross Randall, 'Queensland's Coal Seam Gas Industry continues to Brighten' (2011) 40 *Queensland Government Mining Journal*

Topic Area: Coal Seam Gas Production Basins

Jurisdiction: Australia (Qld)

Aims & Research Methods: This report outlines the active coal seam gas Basins in Queensland and provides general information regarding their production and reserve activities.

The report states the future for the coal seam gas industry in Queensland is bright.
By 2010, about 70 per cent of Queensland's gas market will be supplied from coal seam gas. Gas-fired power generation, with around half the carbon dioxide emissions of conventional coal-fired generators, is likely to significantly increase in eastern Australia.

On 3 June 2007, the Queensland Government released the Climate Smart 2050–Queensland Climate Change Strategy to reduce carbon dioxide emissions. The coal seam gas industry has additional advantages in that incremental development can more readily occur for relatively small financial outlays, enabling coal seam gas companies to more readily increase production to meet growing demand. The potential for LNG exports provides additional opportunities for coal seam gas producers to further expand their operations.

Exploration opportunities Land for petroleum, including coal seam gas exploration is made available by the Queensland Department of Mines and Energy in a call for tenders process. A call for tenders is generally made at least once a year.

Citation: Anne Lenz and Petrina Prowse, 'Incident Reporting for Coal Seam Gas Activities under the *Environmental Protection Act 1994'* (Qld) (2012) 97 *Australian Environment Review*

Topic Area: Incident Reporting

Jurisdiction: Australia (Qld)

Aims & Research Methods: This paper argues early notification of environmental incidents plays an important role in environmental regulation. Reporting environmental incidents to the relevant authorities as soon as practicable means that necessary action can be taken to prevent or mitigate the extent or severity of any subsequent environmental harm. There is a statutory obligation to report environmental in the *Environmental Protection Act (1994)* (Qld) that creates legal obligations and corresponding offences around the duty to notify. DERM also considers reporting to be an important issue and lists disclosure and cooperation as specific considerations for enforcement decisions.

Conclusions: The paper concludes that timely compliance with statutory and voluntary incident reporting requirements is a critical consideration in DERMS enforcement response. The above discussion highlights the importance of practitioners ensuring their client is aware of the full range of legal obligations that may arise in relation to environmental incident reporting under the EPA Act. It is also important that the practitioner emphasises that the legal onus for incident reporting tests with the client themselves, rather than with the practitioner.

Citation: James Plumb and Laura Letts, 'Land Access and Compensation in Queensland' (2011) 30 *ARELJ*

Topic Area: Land Use and Compensation

Jurisdiction: Australia (Qld)

Introduction: Both the resources and the agricultural industries play an integral role in the Queensland economy, injecting billions of dollars into the economy and supporting tens of thousands of Queensland jobs.

Essential to both industries is the use of Queensland's land resources. The competing nature of the resources' and agricultural industries' land needs is recognised by the Queensland Government, which is committed to the implementation of the land access code and standard compensation agreement so that land access issues are equitably managed.

Aims & Research Methods: This article examines the shortcomings of the old land access regime and the changes introduced by the Geothermal Energy Act 2010 (Qld), as well as industry responses to the changes.

Conclusions: The land access provisions as they relate to permits under the P&G Act, 1923 Act, GHG Act and Geothermal Exploration Act, have been in force for over five months and in relation to EPs and MDLs under the MRA for close to four months. Early indications from Resource Authority holders are that the introduction of the new land access regime presented an opportunity to develop and strengthen relationships with landholders. Resource Authority holders have been able to work: closely with landholders helping them to understand the changes and how they work in practice. Resource Authority holders also report that the negotiation and dispute resolution process is working well and providing greater certainty with respect to project time frames.

Early indications are that landholders have more confidence in the new regime as it is transparent, logical and clearly sets out the parties' rights and time frames. Landholder representative groups such as AgF orce and the Queensland Fanners' Federation have noted that, while the new land access regime is a step in the right direction and provides some security to landholders, "there are still challenges to maintaining a level playing field".60 Drew Wagner of AgForce considers that the next step is for LAWG to be fe-formed to focus on the production side of the resources industry.61 It is clear that both the resources and agricultural industries are vital to the Queensland economy. The two industries often compete for Queensland's land resources and it is imperative that land access issues are equitably managed in a timely manner. The new land access regime addresses a number of the key deficiencies identified in the old access regime and while early reports indicate the new regime is working well, however, it is clear that the agricultural industry perceives the need for further reform to level the playing field. Time will tell whether the new regime is acceptable to both industries and whether further reform is warranted.

Citation: James Fund Chern Foo, 'Testing Uncharted Waters: The Precautionary Principle and the Protection of Groundwater in Coal Seam Gas operations in Queensland' (June 2012) (Project submitted in partial fulfilment of the requirements for the degree ofMSc (Energy and Resources) UCL School of Energy and Resources, Australia)

Topic Area: Water Use and Distribution, Groundwater Contamination

Jurisdiction: Australia (Qld)

Aims & Research Methods: The nature of modern-day society is such that there is an insatiable need for energy and resources to support our lifestyles. This has led to the production of resources from increasingly unconventional sources. Coal seam gas is one such resource and its abundance in Queensland has created a booming industry that is now seeking to export the resource internationally. However, there are significant concerns about the uncertainties of coal seam gas production, especially in relation their potential impacts on Queensland's groundwater resources. One of the most prominent principles underlying environmental law is the precautionary principle and at its core lies the idea that decision-makers should be taking steps to address the threat of serious and irreversible harm before scientific evidence has been established to prove that the harm will occur. Its application is especially aimed at containing the potential impacts of new technologies, as the full impacts on society may not be fully appreciated. Its application to the coal seam gas industry is especially pertinent, given the introduction of relatively new production techniques into new environments. However, as will be demonstrated by this thesis, its implementation in the energy and resources industry in Australia produces inconsistent results. Furthermore, in Queensland, its implementation through adaptive management may not necessarily protect Queensland's groundwater resources.

Scope: In the context of the CSG industry, it is the argument of this dissertation that the precautionary principle introduces an element of uncertainty into the decision-making process. As can be seen in Chapter V, the implementation of the precautionary principle may lead to multiple outcomes, especially for the energy and resources sectors. While the Queensland government has introduced an adaptive management framework to manage the uncertainties of CSG production, there are still questions over how stringent the requirements for adaptive management will be, as well as whether adaptive management will be appropriate in all scenarios. Through the discussion in Chapter V, it will also be argued that the efficacy of the precautionary principle in protecting Queensland's groundwater resources is dependent upon the willingness and ability of the Queensland government to impose suitable measures. Furthermore, despite the ability of the courts to act as a check on administrative discretion, Chapter VI will illustrate that the judiciary has generally played a limited role in utilising the precautionary principle to challenge the administrative decisions of decision-makers. Lastly, Chapter VII will provide some recommendations on how the government can ensure that the precautionary principle can be used to secure environmental protection in a more effective and transparent manner. It is the aim of this multi-disciplinary study on the precautionary principle to highlight the difficulties in its use to securing environmental protection.

Conclusions: There is no doubt that the precautionary principle has an important role to play in environmental management. Due to the history of how science has previously failed society from unintended consequences, there is growing recognition of a need for measures to address the limits of science. Indeed, the call by certain community groups to halt CSG production is based upon the distrust of the industry's claims that their operations will have little to no impact on Queensland's groundwater resources, resources which have been the lifeblood of these agricultural and regional communities. However, part of the confusion as to how the precautionary will apply is due to the wide range of precautionary measures that are available. In particular, when looking at how the precautionary principle has impacted energy and resources projects in Australia, there are concerns about the consistency of decision-making outcomes, due to the uncertain nature of how much weighting that will be given to environmental considerations. This is due to the fact that in its adoption in government policy and legislation, multiple goals, such as economic development are concurrently being pursued.

The ability to pursue economic and development objectives calls into question the suitability of measures that have been implemented to address uncertainty in Queensland. Indeed, in contrast to NSW, where a moratorium was imposed to allow for the government to develop more stringent guidelines, Queensland has adopted an adaptive management framework to deal with the uncertainties surrounding the impacts of CSG production on groundwater. Queensland's approach has been beneficial for the industry in that it allows the industry to proceed without first undertaking prohibitive amounts of research. Furthermore, formal acknowledgement of the adaptive management framework provides some guidance as to what the outcome of an application for an EA or water licence might be. Nevertheless, there are questions over the suitability of adaptive management to protect groundwater resources and its appropriateness in all environments.

While the courts are able to play a role in enforcing the precautionary principle, it is clear that governments (and decision-makers) will be more crucial to enforcing and implementing the precautionary principle. Decision-makers are now facing greater calls to take into account wider considerations, such as community perceptions of risk, when assessing applications for EAs or water licences, beyond merely assessing whether the project has satisfied an environmental checklist. In addition, the complex nature of CSG production also requires decision-makers to be cognisant of multiple disciplines, such as law, engineering, economics, geology (to name but a few). It is therefore crucial for governments to possess the appropriate expertise to be able to satisfy the increasing demands being placed on them. Furthermore, given the interaction between these disciplines, the government should also consider developing a set to guidelines to allow the industry greater insight into how decision-makers will take into account the precautionary principle.

The greater entrenchment of the precautionary principle within environmental law in Australia can be seen in the shifting of the debate from whether it is to be applied in the environmental decision-making process to how it will actually be applied. However, to be able to translate the hype surrounding the precautionary principle into substantive measures that will protect Queensland's groundwater resources, the government must be willing and able to pursue such environmental goals.

Citation: Bumb, A.C., In-Situ Inc.; McKee, C.R., In-Situ Inc., 'Gas-Well Testing in the Presence of Desorption for Coalbed Methane and Devonian Shale' (1988) 3 *SPE Formation Evaluation*

Topic Area: Gas Well Testing in the Presence of Desorption

Jurisdiction: Global

Aims & Research Methods: Very large potential gas reserves are present in both coal beds and Devonian shales. In both formation types, long-term gas production is the result of gas desorption from the matrix. Experiments on core samples show that the desorption obeys a Langmuir isotherm.

An approximate analytic solution is derived for single-phase gas flow when gas is present as both free gas and gas adsorbed on the matrix. The solution was verified against a finite-difference solution; the agreement between the two methods is excellent.

The analysis of test data is simplest if the test is conducted at a constant mass flow rate. It is shown that the effect of desorption cannot be detected in production testing; therefore, analysis can be performed to obtain permeability as if the desorption effect is absent. The procedure to obtain desorption parameters is also given. The effect of desorption shows up in an increased compressibility, of the form , which can be much larger than the gas compressibility. The effect of desorption on total production is substantial. When gases are adsorbed total production over the life of a well can be an order of magnitude higher.

Conclusions: In recent years, coal beds and Devonian shales have been looked to as potential unconventional sources of gas. These sources of gas differ from conventional sources in that gas (methane) is present as free gas and is also held within the porous matrix by an adsorption mechanism that is controlled by the reservoir pressure. Fig. 1 shows methane sorption isotherms at 82 deg. F [28 deg. C] for shale samples from the Illinois basin. The solid curves measure only adsorbed gas as a function of pressure (adsorption isotherm). While the dashed curves measure the total gas content (free and adsorbed gas). Figs. 2 and 3 show sorption isotherms for coal. It is evident from the curves presented in these figures that in coal beds as well as Devonian shales, long-term gas production is the result of gas desorption from the matrix.

These figures also demonstrate that adsorption isotherms are highly nonlinear. Consider, for example, a reservoir with an initial reservoir pressure of 870 psi [6000 kPa] and a sorption isotherm given by Fig. 3. If the pressure is lowered to 435 psi [3000 kPa], the amount of methane adsorbed on the coal changes from 18.47 to 16.18 cm/g, a mere 12.4% decrease. The pressure must be reduced to 260 psi [1790 kPa] (a 70% reduction in external pressure) before one-fourth of the adsorbed methane can be released. The remaining three-fourths of the methane can be released only when the pressure is reduced the remaining 260 psi [1790 kPa]. This demonstrates that desorption phenomena play a key role in releasing as, and thus, in gas production. Hence, gas content is not the only factor to consider in estimating reserves. Desorption will ultimately affect current assessment of recoverable gas from both coal and Devonian shale. While gas production decreases with time for conventional sandstone reservoirs, it can increase with time when gas is present as adsorbed gas in unconventional gas reservoirs as a result of desorption phenomena.

Some coal bed methane reservoirs and most Devonian shale reservoirs have low or no water content. This paper therefore focuses on single-phase gas flow when any water present is immobile. Flow equations and an approximate analytic solution are developed for gas flow in gas reservoirs where gas is present as both free gas and adsorbed gas. This analytic solution is then compared with a numerical solution. The analytic solution is then used to develop testing procedures for obtaining information on reservoir properties, and to show the effects of desorption on gas production.

The adsorption data that describe the volume of gas adsorbed as a function of pressure at constant temperature are known as the adsorption isotherm. Many functional forms have been proposed in the literature. Two popular forms are the Langmuir and Freundlich isotherms. The Freundlich isotherm is a power-law relationship between adsorbed volume and pressure, and thus it does not limit the total volume adsorbed. Figs. 1 through 3 shows that the adsorbed volume reaches a limit at high pressure: therefore, the Freundlich isotherm may be unsuitable when the reservoir pressure is high.

Citation: Mutchler, Norman E., Berger Assocs. Inc.; Sachse, Harry R., Sonosky, Chambers and Sachse, 'Legal Aspects of Coalbed Gas' (1981) 33 *Journal of Petroleum Technology*

Topic Area: Coalbed Gas Regulation and Litigation

Jurisdiction: USA

Introduction: Methane gas released in connection with mining of coal traditionally has been considered a costly and hazardous liability rather than an asset. Methane gas is a hydrocarbon gas formed in the process of peat turning into coal. It has roughly the same Btu (J) content and is in the same chemical family as "natural gases" found in connection with petroleum. In this sense it is a natural gas, but it is not necessarily natural gas in the conventional sense of this term. Methane gas released during coat mining may accumulate in mined-out areas (gob gas) and may migrate into coal mines from adjacent areas. If the coal seam does not have a relatively impermeable caprock, methane gas may be present in the overburden as well, and it is believed by many that this gas migrated upward from the coal seam. It is now technically and, many believe, economically feasible in certain coal beds to produce and market methane gas. Methane drainage (the earlier term) has been practiced in the U.S. since 1920; however, with certain exceptions, recovery is generally a more recent occurrence. The OPEC oil embargo of 1973 and subsequent shifts in national policies emphasized utilization in 1974. However, one private recovery effort is known to date from 1931 and a USBM cost-shared project recovered methane gas in 1972. Recovery of methane gas before, during, and after mining (gob gas) may contribute to the safety of mining, increase coal mining productivity, reduce ventilation costs, and conserve a valuable energy resource. Many coal operators vent methane gas to the atmosphere, but an insignificant amount is recovered for use.

It is well established in common law and under West Virginia law that the landowner begins owning every resource of value, and even of no current value, on and underneath his land. In West Virginia, the breadth of this ownership is indicated in the definition of minerals mentioned in Horse Creek Land and Mining Co. v. Midkiff: "every inorganic substance which can be extracted from the earth for profit, whether it be solid as stone ... and coal, or liquid, as, for example, salt and other mineral waters and petroleum oil, or gaseous..." The theory in some states is that oil and gas, unlike solid minerals, are fugacious like wild animals and are not susceptible to private ownership until they are reduced to possession by extraction. In contrast, oil and gas in West Virginia are considered susceptible to absolute ownership in place (see Robinson v. Milam and Williamson v. Jones). There is little practical difference in the two theories. West Virginia considers, as a corollary to ownership in place, that any person may drill on his land and extract such oil and gas as he can, regardless of its origin, unless he already has disposed of that right.

Aims & Research Methods: The major institutional problem in production of gas from coal beds is the legal question of who owns the gas. In this study, related judicial decisions in West Virginia are examined along with U.S. federal and state regulations, and a limited overview of Pennsylvania law is given. The problem could be resolved by litigation, legislation, or cooperation. An outline for a model legislative solution is given. However, it is recognized that cooperation may be a viable solution for near-term development of this unconventional gas source.

Berger Associates Inc. completed a comprehensive technical, economic, and institutional study for the Appalachian Regional Commission on Appalachian unconventional gas sources that included a special legal study of coal bed gas ownership. A single judicial decision exists on the subject: a Greene County, PA, judge recently held that rights to coal bed gas are not conveyed through a coal mining lease. That decision currently is pending appeal before the Pennsylvania Superior Court. Another dormant case was found in Virginia. Hence, research and analysis must rest primarily on related cases. The legal ownership problem must be solved if this gas source is to make the contribution many have predicted. The risk of expensive lawsuits is a major deterrent to utilization of the gas.

Citation: James A. Beckstrom, SPE, Amoco Production Co., and David G. Boyer, New Mexico Oil Conservation Div., 'Aquifer-Protection Considerations of Coalbed Methane Development in the San Juan Basin' (1993) 8 *SPE Formation Evaluation*

Topic Area: Aquifer Protection

Jurisdiction: USA

Introduction: The San Juan Basin is located in Northwestern New Mexico and Southwestern Colorado (see figure 1). It is a large oil and gas producing basin covering roughly 9,000 square miles. Natural producing basin covering roughly 9,000 square miles. Natural gas has been produced commercially in the basin since 1911 and interstate transportation of basin gas started in the early 1950's (ref. 2 and 3). Installation of the interstate gas line spurred active drilling in the basin and by 1960 over 4,700 gas wells had been drilled in the New Mexico portion of the basin (ref. 4). Infill drilling started in the mid 1970's as a result of a spacing change from 320 to 160 acres for several of the producing formations in New Mexico's portion of the basin. By the end of 1980, about 6,000 more gas wells had been drilled, bringing the total on the New Mexico side to almost 12,000 (ref. 5).

Prior to the development of oil and gas, the basin's primary Prior to the development of oil and gas, the basin's primary industry was agriculture. The climate is arid and population centres are located along the rivers to take advantage of the water available there. Domestic water wells are primarily for household use and livestock watering. Some of the wells in the river valleys are hand dug and completed in the alluvial fill. Drilled wells are completed in the alluvial fill or in the shallow Tertiary section, the San Jose or Nacimiento formations.

Since the early 1950's, oil and gas has been a major industry in the San Juan Basin. Population density along the rivers has complicated recent oil and gas development because the public and industry want to minimize the impact of oil and gas operations on local residents. Minimizing impact is difficult in many cases because homes have been constructed adjacent to well locations after the wells were drilled. The increase in population near and adjacent to producing areas has increased population near and adjacent to producing areas has increased the number of people being affected by day to day producing operations.

Today there are over fourteen thousand gas wells in the New Mexico portion of the basin that are producing from at least ten different gas productive formations, eight of which are presented in the stratigraphic and facies chart in figure 2 (ref. 6).

Aims & Research Methods: Coalbed methane development in the San Juan Basin has caused concern about several environmental issues with respect to health, safety and remediation This paper describes and presents the findings of four groundwater sampling programs, a presents the findings of four groundwater sampling programs, a unique water sampling device, and aquifer protection work on producing wells and deep cathodic protection groundbeds. producing wells and deep cathodic protection groundbeds. Conclusions of the study stress the importance of water sampling techniques, the financial significance of aquifer protection work and the importance of information flow between protection work and the importance of information flow between industry, agencies and the public.

Drilling and production of Fruitland Coal gas has raised concerns about aquifer protection in the San Juan Basin and has resulted in some operational reviews and changes. Issues of concern have Included natural gas migration into groundwater, water and gas charged cathodic protection groundbeds, produced water disposal wells, produced water evaporation pits produced water disposal wells, produced water evaporation pits and hydraulic fracturing into shallow aquifers. The majority of the public concern has been geographically cantered around the Bondad, Colorado and Cedar Hill, New Mexico areas and for that reason water sampling programs, bradenhead testing, fracture treatment tracing, and groundbed testing have been conducted in those areas.

Results of those studies have led to remedial work on producing wells, well plugging and abandonments, and deep producing wells, well plugging and abandonments, and deep cathodic groundbed abandonments.

This paper provides a historical perspective and discusses the findings of the sampling and testing programs in the study area which runs along the Animas river valley in and near the community of Cedar Hill, New Mexico (figure 1).

Citation: R.S. Taylor, Halliburton; P. Tertzakian, ARC Financial Corporation; T. Wall, Apache Canada Limited; M. Graham, Encana Corporation; P.J. Young, DYAD Consulting Limited; and S. Harbinson, Halliburton, 'Natural Gas: The Green Fuel of the Future' (2012) 51 *Journal of Canadian Petroleum Technology* pp 163-175

Topic Area: Sustainability/Social Responsibility

Jurisdiction: Global

Aims & Research Methods: As populations and economies continue to grow globally, energy demand will grow proportionally. Extensive work by Tertzakian (2007, 2009) has shown crude-oil supplies may not keep pace with this increased demand. The shortfall must be met by other energy sources.

Only two current energy sources have the global capacity to, by themselves, address increased energy demand in a timely manner. These are natural gas and coal.

Traditionally, the major use of crude oil has been for processing into transportation fuels, with lesser amounts being used for petrochemicals and home heating. Natural gas and coal have been used primarily for electrical generation and heating.

A pivotal transition will likely occur in which natural gas and coal begin to see increased use as transportation fuels. A battle for market share between primary fuels will likely ensue.

The objective of this paper is to present data comparing the environmental impact of using methane vs. coal. A compelling case for the use of natural gas as the future "green fuel" emerges.

Citation: A.N. Martin, Baker Hughes, 'The Potential Pitfalls of Using North American Tight and Shale Gas Development Techniques in the North African and Middle Eastern Environments' (2012) 4 *SPE Economics & Management* pp. 147-157

Topic Area: Tight and Shale Gas Development Techniques

Jurisdiction: Global

Introduction: Many companies operating in the upstream gas industry in the Middle East and North Africa (MENA) are interested in the outstanding technical successes achieved by the US and Canadian tight and shale gas producers. It seems almost miraculous that companies can obtain significant gas-production rates from rocks with permeabilities measured in nanodarcies--so low, in fact, that permeability becomes almost impossible to assess accurately. In North America, the main factor now constraining shale gas production is the historically low gas price. Operators in MENA, who are accustomed to working in formations with permeabilities five or six orders of magnitude greater, have realized recently that they may be sitting on top of huge untapped gas reserves that had been evaluated previously as sub economic.

In recent years, several major MENA-based operating companies have bought interests in US and Canadian tight and shale gas operations, with the objective of acquiring experience and technology that can be applied to similar formations in MENA and elsewhere. This seems to be an obvious and wise strategy; unfortunately, the problem is not the strategy, it is the tactics ("the devil is in the details"). In many instances, operating companies have been disappointed to discover that they cannot simply transplant an American-style development into MENA. Similarly, many North American independents have viewed the untapped low-permeability gas reserves of MENA as a natural territory for expansion, only to find themselves frustrated at almost every turn.

Aims & Research Methods: This paper seeks to highlight the potential pitfalls of trying to use North American development techniques in MENA, and to promote strategies and tactics that are more suitable. In addition, this paper will suggest structural changes that could have a significant positive impact on low-permeability gas developments in MENA.

Citation: Ruud Weijermars, Alboran Energy Strategy Consultants and Delft University of Technology, 'Jumps in Proved Unconventional Gas Reserves Present Challenges to Reserves Auditing' (2012) 4 *SPE Economics & Management* pp. 131-146

Topic Area: Reserves Replacement and Booking, Economic Analysis Guidelines, Field Development Optimization and Planning, Benchmarking and Performance Indicators and Unconventional Resources

Jurisdiction: USA

Aims & Research Methods: This study analyses the typical challenges and opportunities related to unconventional-gas-reserves maturation and asset performance. Volatility in natural-gas prices may lead to downgrading of formerly proved reserves when the marginal cost of production cannot be sustained by the wellhead prices realized. New US Security and Exchange Commission (SEC) rules have accelerated the growth of unconventional-gas reserves, which in a way is an additional but unintended source of volatility and hence risk. Concerns about security of investments in unconventional-gas assets are driven by the effects of volatile natural-gas prices on production economics and by uncertainty about stability of reported reserves. This concern is exacerbated by an unprecedented rise in proved undeveloped gas reserves (PUDs) reported by unconventional-gas operators, arguably effectuated by favourable interpretations of PUDs when applying the new SEC accounting rules. This study includes a benchmark of proved reserves reported by two peer groups, each comprising four representative companies. The peer group of conventional companies includes Exxon, Chevron, Shell, and BP, and the unconventional peer group is made up of Chesapeake, Petrohawk, Devon, and EOG. Possible sources of undue uncertainty in reported reserves are highlighted, and recommendations are given to improve the reliability of reported reserves, especially from unconventional field assets.

Citation: R. Stefik and K. Paulson, British Columbia Oil and Gas Commission, 'When Unconventional Becomes Conventional' (2011) 50 *Journal of Canadian Petroleum Technology* pp. 68-70

Topic Area: Unconventional Resources and Energy Policy and Regulation

Jurisdiction: Canada

Introduction: British Columbia (B.C.) has seen near-exponential growth in the areas of the Horn River and Montney unconventional shale-gas plays situated in northeastern B.C. (Fig. 1). The original-gas-in-place volume for the Montney and Horn River basins has not been formally calculated, but it has been estimated at greater than 500 Tcf and continues to be revised upwardly as new and more-refined information is obtained and development takes place. The Cordova embayment and Liard basin, east and west (respectively) of the Horn River basin, are at early stages of assessment but promise additional massive gas-in-place values.

Approximately 5 years ago, industry experts were predicting a dramatic reduction in viable gas production from the western Canada sedimentary basin, and from North America in general. Market predictions were favouring investment in import terminals for liquefied natural gas (LNG), in which gas from offshore suppliers could be imported and moved through the North American transportation grid to market. Regulators were anticipating an influx of LNG-facility applications and myriad infrastructure modifications to handle the resulting new flow regime.

In 5 short years, this dire future has been reversed completely because of the advent of economically viable methods to access gas trapped in shales and similar tight formations. At the current rates of production and exploration, there are more than 20 years of gas reserves in B.C., reversing a previous decline, as shown in Fig. 2.

B.C. is ideally positioned to provide gas to North America with ready access to a number of major gas-transportation pipelines, including systems operated by TransCanada Pipelines, Spectra Energy Gas Transmission, and the Alliance Pipeline. Many of these systems are undergoing significant capacity expansions to accommodate the influx of gas from these new plays.

Aims & Research Methods: This paper will explore the challenges posed to regulators in rapidly moving from conventional vertical-well developments to unconventional multiwall pads consisting of multiple fracture-stimulated horizontal wells.

Citation: Richard Olawoyin, John Y. Wang, SPE, and Samuel A. Oyewole, Pennsylvania State University, 'Environmental Safety Assessment of Drilling Operations in the Marcellus-Shale Gas Development' (2013) 28 *SPE Drilling & Completion* pp. 212-220

Topic Area: Environmental Safety Assessment of Drilling Operations

Jurisdiction: USA

Introduction: The process of gas development is intensive and involves risk to the environment. Statistics confirm that 0.5 to 1% of wells drilled result in a blowout. Causes of these exploration risks are identified as violations of environmental laws enforced by the Pennsylvania Department of Environmental Protections (DEP), operational pollution (accidental spills and leaks), and operator's policy. In addressing this concern, a risk-assessment methodology was used to evaluate all violations by operators in the State of Pennsylvania from January 2008 to November 2010, by use of Statistical Analysis Software (SAS). The most significant causes of environmental damage and risk were determined by use of the doubly repeated measure analysis of covariance (ANCOVA). The category effect and interaction effect were used to prove the usefulness of the developed model, which helps explain the safety level of the locality. There were a total of 2,601 violations between 2008 and 2010 committed by 65 different operators in the Marcellus Shale, out of which only 27 of the operators showed significance difference based on environmentally damaging violations (ranked 5 to 10). A statistical comparison was made to understand the difference between the operators based on the 2,601 total violations. The most significant incidents are ranked [on the basis of Borda count (Saari 1985)] 3, 5, 9, 10, which accounts for 67% of all the violations. These data reflect several environmental concerns that are currently prevalent in the Marcellus-shale area.

Aims & Research Methods: This research identifies environmental incidents, causes and effects of exploration risk, and safety impediments in the Marcellus gas play. It also presents guidelines for feasible options to minimize environmental risks and consequently increase the degree of safety in the area. Recommendations on how to mitigate these impending problems are presented.

Citation: A.N. Martin, Baker Hughes, 'The Potential Pitfalls of Using North American Tight and Shale Gas Development Techniques in the North African and Middle Eastern Environments' (2012) 4 *SPE Economics & Management* pp. 147-157

Topic Area: Environmental Safety Assessment of Drilling Operations

Jurisdiction: Global

Introduction: Many companies operating in the upstream gas industry in the Middle East and North Africa (MENA) are interested in the outstanding technical successes achieved by the US and Canadian tight and shale gas producers. It seems almost miraculous that companies can obtain significant gas-production rates from rocks with permeabilities measured in nanodarcies--so low, in fact, that permeability becomes almost impossible to assess accurately. In North America, the main factor now constraining shale gas production is the historically low gas price. Operators in MENA, who are accustomed to working in formations with permeabilities five or six orders of magnitude greater, have realized recently that they may be sitting on top of huge untapped gas reserves that had been evaluated previously as sub economic.

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Aims & Research Methods: This paper seeks to highlight the potential pitfalls of trying to use North American development techniques in MENA, and to promote strategies and tactics that are more suitable. In addition, this paper will suggest structural changes that could have a significant positive impact on low-permeability gas developments in MENA.

Citation: Woljciech Baginksi, ‘Shale Gas in Poland- The Legal Framework for Granting Concessions for Prospecting and Exploration of Hydrocarbons’ (2011) 32 *Energy Law Journal* 145 - 155

Topic Area: Shale Gas Regulation

Jurisdiction: Poland

Introduction: The following outline presents a step-by-step guide for obtaining concession for prospecting and exploration of hydrocarbons in Poland.

The steps are as follows:

1. Obtain a mining usufruct right – an agreement with the State Treasury.

2. Apply for the concession for the prospecting and exploration of hydrocarbons.

The application should include:

- the designation of the applicant (address, number in the register of entrepreneurs or official business record);
- designation of the type and scope of business activities that are going to be included in the concession;
- designation of the applicants rights to the plot on which the activities are going to be performed or the designation of the right that the applicant is applying for;
- designation of the time period for which the concession should be granted along with the date from which the activities are going to be performed;
- designation of resources available to the applicant to effectively carry out the activities that are in the scope of the application; geological work programme.

3. Compensate the State for the mining usufruct right and the concession.

Aims & Research Methods: The article explains from the practical point of view the procedure for the acquisition of a concession for prospecting and exploration of hydrocarbons in Poland. Based on this analysis arguments are presented in support of a thesis that the current legal framework in Poland concerning the prospecting and exploration of hydrocarbons strongly protects the energy interests of the country.

Scope: Several arguments are presented in support of a thesis that the current legal framework in Poland concerning the exploration and prospecting of hydrocarbons strongly protects the energy interests of the country. From the analysis of the regulatory structure it may be inferred that its drafters had the foresight to develop a system that will protect from and reduce the potential adverse effects of intensified interest in the State‟s strategic resources. This potentially may be attributed to vast reserves of coal that exist in Poland.

To enhance the readability of this article a brief outline of the procedure for the acquisition of a concession for the exploration and prospecting of hydrocarbons in Poland will be presented first.

Conclusions: Currently, due to the increased interest in potential gas deposits in Europe, there are several companies prospecting and exploring vast territories of Poland. The prize for the successful prospector is the right to apply for a preferential mining usufruct. This in turn means potential benefits and proceeds. The race has just begun, and if the expert predictions are true, there is still room for more mining companies taking its share of the pie.

Citation: Edyta Materka, ‘Poland’s Quiet Revolution: Of Shale Gas Exploration and its Discontents in Pomerania’ (2012) 1 *CEJISS*

Topic Area: Gas Exploration

Jurisdiction: Poland

Aims & Research Methods: This research highlights the unravelling of Poland’s shale gas revolution and analyses the structural problems faced by villagers who oppose testing, drilling, wildcatting, and the production of shale gas in their rural communities in northern Poland.

Scope: I argue that the bed-fellowship between global energy (oil and gas) companies and the Polish government have ignored villagers’ complaints and excluded the public from discussions on shale gas exploration and its ecological effects. Due to the lack government-sanctioned legal protections against shale gas exploration granted to villagers, the rural poor have been burdened with the task of reaching out to international organisations and the academic community to establish alliances and leverage influence in order to be heard by their own government. Lastly, I argue that the “transition” into the market economy for these villagers is over as they now have to fight for the very private property rights they fought for during Solidarity and are now entering into the larger, rural struggles on the global level against global companies’ intrusion and dispossessing them of their natural environments, private property, and rural livelihoods. I urge post-socialist scholars, ethnographers, citizens, activists with access to such rural communities to help amplify their voices in the international sphere.

Conclusions: The international campaign for 'alternative' fuel sources and green energy does not necessarily mean that the environmental, economic, and political issues faced by villagers faced with its production in their backyards will be any less filled with injustice, frustration, silencing, and sense of powerlessness. Villages' complaints are countered with public relations representatives simply stating that the villagers' comments have no merit, are 'backwards,' or based on assumptions due to lack of knowledge about the 'routine process' of shale gas exploration. Rather than the burden being on the companies to demonstrate that hydraulic fractuation is bad for the environment, the burden is on the villagers to muster up the international attention, academic studies to produce the evidence against the shale gas revolution. Villagers' complaints about what they see in their environments where they have dwelled for decades holds no value or legitimacy in the public sphere dominated by proshale gas exploration coverage sponsored by the government and the exploration companies. In other to be heard, these villagers will have to build strong, multi-scalar alliances on the local, regional, national and international spheres of government and civil society in order to gain political leverage on the local level. It is a steep and dangerous mountain to climb. As the last section demonstrated, the youth are key in bridging the gap between villagers and the international audience.

These sets of encounters between prospecting companies and the villagers demonstrate post-socialist subjects are no longer focusing on the 'transition' between socialism and the market economy, but are rather much more complexly implicated in the sets of relations that come with the territory of globalisation. In this new position as a multi-scalar actor, the villager of today no longer fits into the category of 'post-socialist subject.' The encounter places villagers into the global dialogue with at least people in other rapidly- developing countries. This is the case for why we as scholars need to look beyond post socialism by focusing on the transition to a global market economy, and to zoom in on villager's voices and transformation in this new encounter with the global. It is in that way we can truly amplify their voices.

Citation: Marta Duraj, 'Legal Aspects of the Hydraulic Fracturing Method' 1:2 *Wroclaw Review of Law, Administration and Economincs* 109- 120

Topic Area: Hydraulic Fracturing

Jurisdiction: Poland

Introduction: In order to understand the legal issues connected with the hydraulic fracturing method it is necessary to understand some basic technical information about the method itself. According to the materials presented by the Polish Geological Institute, National Research Institute3 the main concern with extracting shale gas is the fact that it occurs in rocks with very low permeability and, in consequence, it is necessary not only to drill a well, but also to procure a flow. The hydraulic fracturing method improves permeability, but only within an area of several dozen meters from the borehole. Consequently, the effectiveness of this method requires a dense arrangement of boreholes and a territory of 0.5 to 3 ha. Such an investment also requires proper infrastructure for heave vehicles and gas transmission, as well as reservoirs for technological fluids.

Aims & Research Methods: This article is aimed at showing Polish regulations, both planned and currently in force, as well as the relevant EU law in respect of shale gas extraction. The author would like to emphasize the need to create one coherent legislative regime which would enable entrepreneurs to commence extraction by way of hydraulic fracturing without creating a danger for the environment.

Conclusions: At the moment the European Union is faced with the problem of future energy resources. Nuclear energy is an important element of every discussion regarding energy supplies. On the other hand, the emerging perspective of shale gas extraction has shown that there are also other sources within the territory of the EU that could be exploited. According to recent studies, Poland has one of the largest deposits of shale gas in Europe, which could provide a chance to become independent from foreign gas suppliers. New technologies could be a chance for a better future for Europe, but on the other hand the European legislators must not lose sight of other principles, such as environmental protection. Shale gas extraction may become a threat for the environment if it is conducted without proper technical capacities. It could be stated that new technologies require new legislation. The author has presented the technical issues connected with the hydraulic fracturing method in order to illuminate the potential threat.

In the EU there is no comprehensive legal framework for shale gas extraction. At the moment, the same situation is visible in Poland. The new act presented above is supposed to change this situation. The Polish legislator has decided that natural gas extraction requires special regulations. Nevertheless, the new law is not perfect and from the beginning gives rise to several problematic issues, such as the lack of an obligation of the Minister of the Environment to grant a concession for natural gas extraction to an entity disposing a pre-emption right. It should be also noted that tender processes in Poland are widely criticized in conjunction with inappropriate criteria, which lead to the result that in most cases the winning tenderer is the one who presents the cheapest offer. Often the smallest amounts offered by the tenderers are not sufficient, and the planned project cannot be performed properly or even finished at all.

In the case of shale gas extraction, the main criterion should be the technical capabilities and experience of the applicant. The costs should not be artificially lowered, as this may lead to an environmental disaster. In consequence, the criterion of the proposed amount of the remuneration for the mining usufruct is already alarming. Shale gas extraction is regarded as a great opportunity for Polish business and such a chance should not be destroyed by improper legislation. Time will tell if the new regulations ensure proper protection for entrepreneurs as well as for the environment.

Citation: Jonas Teusch, 'Shale Gas and the EU Internal Gas Market: Beyond the hype and hysteria' (September 2012) (EPS Working Document No. 369) 1-12

Topic Area: Shale gas and the EU internal gas market

Jurisdiction: Global

Introduction: Since the so-called silent energy revolution in the US, shale gas has sparked considerable debate in many parts of the world and has often been described as a geopolitical gamechanger. 1 At the same time, shale gas has sparked fears of negative environmental externalities such as water and air pollution and resource costs, especially in water-scarce regions. The climate impact of shale gas is also far from clear. 2 This paper does not aim to contribute to the debate on the negative environmental externalities of shale gas, nor does it inform the debate on the implications of shale gas for climate change. Rather, it aims to assess what shale gas development in Europe and the world mean for the European gas market. Two key dimensions are discussed: first, in an optimistic scenario, how much could shale gas change the structure of European gas supplies? Second, to what extent do shale gas developments depend on a well-functioning European energy market and, conversely, would shale gas complement or run counter to the EU's efforts to complete the internal gas market? Having clarified how shale gas interacts with the EU's agenda to complete the internal gas market, the paper looks at the implications of this analysis for stakeholders. What key requirements do European and international companies with a stake in the shale gas business need to fulfil to do business in Europe? Here, the emphasis is not so much on what regulatory framework is necessary for economically and environmentally viable shale gas development, which is discussed elsewhere,3 but rather on the challenges business and industry would face if they intend to develop shale gas in Europe.

This paper makes a sober assessment of the contribution that global shale gas development could make to securing Europe's energy supplies and aims to outline the real challenges that lie ahead. It attempts to take some of the emotion out of a debate that is still characterised by hype about a 'shale gas revolution' or hysteria about shale gas leading to 'the end of the world as we know it'.

Aims & Research Methods: This paper analyses the interplay between shale gas and the EU internal gas market. Drawing on data presented in the 2012 International Energy Agency's report on unconventional gas and additional scenario analyses performed by the Joint Research Centre, the paper is based on the assumption that shale gas will not fundamentally change the EU's dependence on foreign gas supplies. It argues that attention should be shifted away from hyping shale gas to completing the internal gas market. Two main reasons are given for this. First, the internal gas market is needed to enable shale gas development in countries where there is political support for shale gas extraction. And second, a well-functioning internal gas market would, arguably, contribute much more to Europe's security of supply than domestic shale gas exploitation. This has important implications for the shale gas industry. As it is hard to see how subsidies or exemptions from environmental legislation could be justified, shale gas development in Europe will only go ahead if it proves to be both economically and environmentally viable. It is thus up to the energy industry to demonstrate that this is the case.

Conclusions: It seems unlikely that subsidies or exemptions from environmental legislation will be justified to enable shale gas exploitation in the EU, so shale gas developments will only go ahead if they turn out to be both economically and environmentally viable in Europe. It is up to enterprises to demonstrate that this is indeed possible, for example by developing "less environmentally hazardous drilling and fracturing fluids." (AEA, 2012a). It is challenges such as these that could also represent a business opportunity for European enterprises undertaking shale gas development. They could develop the technology that would allow the extraction of shale gas in a way consistent with Europe's environmental standards. These technologies could then also be applied elsewhere, providing both an export opportunity for European businesses and a potential European contribution to more sustainable shale gas exploration in other parts of the world. To enhance the trust between the general public, the energy industry and the companies in charge of shale gas exploitation in Europe, a step-by-step approach may be needed. One idea would be to evaluate the environmental sustainability of shale gas by conducting a pilot project in a transparent and participatory manner. If such a project, under the close supervision of trustworthy and disinterested expert organisations could prove that the risks to European citizens are manageable, shale gas developers may be able to (re)gain the confidence of citizens and investors. The most likely country to host such a project would seem to be Poland, which has been described as the EU's "shale gas lab" (Wyciszkiewicz et al., 2011). However, as the success of such a pilot project would also depend on the idiosyncratic characteristics of the selected site (e.g. local geological conditions), the extent to which one may derive general conclusions from just one case may well be questioned. Transparency and the involvement of affected citizens early on should thus not be limited to pilot projects, but would need to become general practice.

To conclude, this paper has argued that a fully functioning European gas market is a key strategic priority. Making the internal gas market work may also increase the prospects of shale gas development in Europe. Only if companies believe in the existence of a stable and sufficiently large European market will they invest in the technology that could make shale gas exploitation both economically and environmentally viable in Europe.

Citation: Mark Harvey and Sarah Pilgrim, 'The new competition for land: Food, energy, and climate change' (2011) 36 *Food Policy* 540-551

Topic Area: Food and Energy Security

Jurisdiction: Australia

Introduction: During the 21st century, land as a global resource is likely to become the focus of intensified competition from a variety of uses. Moreover, the competing uses are likely to become subject to increasing controversy, in terms of the claims made by those promoting those uses, and in terms of potentially conflicting national, regional and global interests. The main focus of this paper is to consider these developments in the light of two underlying drivers for increased competition for land: the increasing demand for energy, particularly with respect to transport (terrestrial and air); and the increasing demand for food, both to meet growing world population and in meeting changes to, and improvements in, nutrition and quality of food. Some recent debate has staked a primacy of claim over land use for production of food (World Bank, 2008; FAO, 2008; OECD-FAO, 2008). However, failure to address the demand for energy and materials, in particular to develop alternatives to counter the depletion of petro-chemical resources, will inevitably result in major economic and social disruption on a global scale. We restrict ourselves here to considering the implications for demand for land arising from developing alternatives to oil, rather than energy demand overall. Enhanced and sustainable social welfare will depend on developing new forms of agricultural production of both energy and food, highlighting the significance of 'the sustainable intensification of global agriculture' (Royal Society, 2009; Pretty, 2008; Godfray et al., 2010). We focus on issues raised by the new competition for land1, particularly in relation to food, energy, and climate change, rather than the increasing demands for the production of food as such.

Aims & Research Methods: The paper addresses the new competition for land arising from growing and changing demand for food when combined with increasing global demand for transport energy, under conditions of declining petrochemical resources and the urgent need to reduce greenhouse gas emissions. The paper starts from the premise of a 'food, energy and environment dilemma' (Tilman et al., 2009), where all demands to expand the area of cultivated land present high risks of increasing the carbon footprint of agriculture. Having reviewed the main drivers of demand for food and for liquid transport fuels, the paper weighs the controversies surrounding biofuels arising from food-price spikes, the demand for land, and consequent direct and indirect land-use change. It suggests that we need a more complex, and geographically differentiated, analysis of the interactions between direct and indirect land-use change. The paper then reviews evidence of land availability, and suggests that in addition to technical availability in terms of soil, water, and climate, political, social, and technological factors have significantly shaped the competition for land in different global regions, particularly the three major biofuel producing ones of the USA, Brazil and Europe. This point is further developed by reviewing the different innovation pathways for biofuels in these three regions. The main conclusion of this review is firstly that any analysis requires an integrated approach to the food-energy-environment dilemma, and secondly that strategic political direction of innovation and sustainability regulation are required to bring about major shifts in agriculture leading to sustainable intensification of cultivation (Royal Society, 2009), rather than the continued expansion of cultivated area. The consequent perspective is one of considerable global variety in technologies, agricultural productive systems, and use of natural resources. This contrasts sharply with the world of a dominant global and integrated technology platform based on petro-chemicals to which we have become accustomed.

Conclusions: We have attempted to explore the dynamics of competition for land, and identify some of the principal issues at stake for future sustainability of land use. Based on the model represented in Fig. 1, competition for land use in the coming decades was seen as being driven by two major objectives in achieving sustainable economic growth: the delivery of food and energy/materials in a post-fossil carbon economy. The paper has systematically attended to each of the elements of a complex interaction: growing and changing demand for food; demand for energy and materials derived from biomass in the context of oil depletion; GHG emissions from current agricultural practices and land-use change; and climate change itself as a constraint on land available for cultivation at high levels of productivity. The scale of the challenges was examined, as was the significance of current patterns of land-use in contributing to global warming. The growth of agricultural production cannot continue on current lines and practices without risking major crises, given its significance as a source of greenhouse gases. A key element of future development will be to meet increasing demands on land by intensification of low-carbon gas emitting agriculture, by all technological means possible. The growth in demand for food (arising from the need to ‘feed the 9 billion’ and improve standards of nutrition) has been taken as given, resting on arguments and analysis more thoroughly developed elsewhere (IAASTD, 2009; Royal Society, 2009; Godfray et al., 2010; DEFRA, 2009b). In exploring the demand for land driven by biofuels and biomaterials, evidence was presented that suggests the need for a major shift in policy understanding of innovation. The shift to bioeconomy alternatives to petro-chemical technologies requires a pro-active, long-term, strategic political direction, promoting innovation from the basic science through to the delivery of goods. The broader challenge to deliver both food and energy calls for a combined new green and bioeconomy revolution. The political shaping of this process will require both sustainability regulation and strongly directed innovation, delivering the means to achieve the ends. The shift to a bioeconomy and sustainable agriculture involves a paradigm change from the petro-chemical technological model of the world that has characterised the previous epoch. Land, water and climate as a global resource provides different regions with widely contrasted agricultural potentials. The shift to sustainable agriculture for food and energy is likely to re-shape the geopolitical environment of the world. Flows of food and energy/materials will be re-drawn, and different regions will pursue different innovation pathways as a consequence of their diverse political objectives and natural endowments.

In sum, two broad conclusions can be drawn from this paper.

Firstly, however uncomfortable and challenging, mitigating the competition for land can only occur provided that the complexity of the dynamics is fully addressed. Each of the contributing factors explored above (energy and food demand; petro-chemical depletion; the various sources of anthropogenic climate change involved in land use) cannot be treated in isolation. Secondly, recent history and current developments strongly underscore the importance of long term political strategy driving forward the shift to a sustainable intensification of land use, combining regulation with effective long term, but urgent, promotion of science and innovation to deliver the goals of sustainability.

Citation: Timothy Fitzgerald, 'Frackonomics: Some Economics of Hydraulic Fracturing' (2013) 63 *Case Western Reserve Law Review* 1337- 1362

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: The United States has experienced an oil and gas renaissance thanks to technological innovations that have propelled unconventional resources to the forefront of energy policy discussions. Hydraulic fracturing is part of the suite of technologies that have transformed the energy industry and outlook over the past fifteen years. Commonly called "fracking,"1 the process has been a lightning rod for public and environmental concerns about the expansion of oil and gas development.

Aims & Research Methods: This Article introduces the economic factors behind hydraulic fracturing. These effects cut across three different scales. First is the minute scale at which microfractures in unconventional reservoirs allow large productivity increases in well investments. The second is an aggregate scale where the market supply of hydrocarbons has changed due to application of the new technology, with implications for global environmental issues. The third and final scale is a human scale, as trade-offs between additional wells and environmental impacts are considered.

Conclusions: In combination with other technologies, hydraulic fracturing has helped revolutionize the domestic oil and gas supply outlook in the United States. Although a precise accounting of the benefit-cost ratio is not feasible, the source of the gains starts with the massive increase in reservoir contact that properly designed and implemented fractures provide. This in turn increases initial production rates and the ultimate recovery of unconventional wells. But fracking is still imperfectly understood, which provides both opportunities and risks. The opportunities for reducing the variance in well performance suggest that the technology can still be fine-tuned and productivity gains can be recognized. The environmental risks associated with an evolving technology are nontrivial. There has been particularly strong grassroots resistance to unconventional oil and gas development. That popular discontent has led to calls for increased regulatory oversight. Demonstrable and verified links between fracking and environmental harm are still lacking. The events in Pavillion, Wyoming, indicate that the burden of proof is quite high and that definitive evidence of harm will likely be required before regulations are created. Given the widespread benefits of increased domestic oil and gas production and the bundle of technologies that have helped give rise to those gains, one might consider why the resistance has coalesced around fracking and not some other aspect of development. The most convincing answer to that question might be one of political convenience. In creating thousands of good-paying jobs, the industry does not offer very promising villains in the form of roughnecks and other blue-collar beneficiaries. But the handful of corporations that have been the key to the propagation of hydraulic fracturing are more conspicuous and sufficiently anonymous to demonize. Halliburton makes a convenient foil.

A final thought about fracking provides some context for debate. A return to an earlier technology that was less productive and potentially more environmentally harmful is even less appealing than fracking. In 1969, a forty-three kiloton nuclear bomb was detonated underground near Rulison, Colorado, in an attempt to free trapped natural gas. The explosion was not successful in freeing large amounts of gas, and what gas was freed was too radioactive to market. The area remains off-limits to drilling today due to radioactivity concerns, despite active drilling in the surrounding area.84 Another failed experiment in 1973 in nearby Rio Blanco County, Colorado, led energy firms to experiment again with hydraulic fracturing. It is no coincidence that some of the advances made in fracking were made in the same area of western Colorado. The unconventional resources are there, and the ingenuity of engineers will be constantly applied to unlock those valuable resources. Hopefully that ingenuity can be married to wisdom of other specialists to produce a workable regulatory framework for hydraulic fracturing and unconventional oil and gas development more broadly. If not, and fracking bans are more widely adopted, consideration may be needed for the appropriate regulatory framework for improved nuclear fracturing.

Citation: Kalyani Robbins, 'Awakening the Slumbering Giant: How Horizontal Drilling Technology brought the Endangered Species Act to bear on Hydraulic Fracturing' (2013) 63 *Case Western Reserve Law Review* 1143- 1166

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: Hydraulic fracturing (also known as "fracking") is nothing new. It dates back to the 1940s and drew little environmental attention or concern for most of its existence. It is a form of natural gas extraction that involves pumping water, chemicals, and sand slurry into a well at extremely high pressure in order to fracture the surrounding rock formation and prop open passages. This frees up the trapped natural gas to flow from the resulting rock fractures to the production well for capture. Fracking operations have evolved from using a range of 20,000 to 80,000 gallons of water per well to using up to 8 million gallons of water and 75,000 to 320,000 pounds of sand (proppant) per well.1 Much of this advancement happened in the last two decades, thanks largely to the development of dramatically more advanced drilling technology that allows for horizontal drilling deep under the ground. After drilling downward from the point of entry, the drill turns roughly ninety degrees once deep underground, thereafter traveling parallel to the surface. To visualize this process, imagine a very tall "L" with the long side horizontal underground and the short side's tip at the surface. While the downward drilling goes a substantial distance, the drill goes much further after it turns horizontally, and is thus able to get at exponentially more of the shale rock. This new technology has not only rendered the method far more productive and profitable but has also increased the environmental impact.

Aims & Research Methods: The recent development of utility-scale hydraulic fracturing, which has taken place at a gold-rush pace and with a corresponding level of excitement, has raised many new environmental concerns. The issues are quite serious, ranging from drinking water contamination to earthquakes, so it is not surprising that wildlife has not been at the forefront of the alarms. But as it turns out the wildlife problem, and not the contamination of the human water supply, may well be the most ominous for the industry. This seemingly anomalous circumstance stems from the array of regulatory exemptions granted to the industry in the statutes designed to protect human health and the complete absence of such exceptions in the Endangered Species Act (ESA). Indeed, the ESA tends to be the least flexible of environmental statutes. It may not get its due in implementation, but when it is applied, it is fierce and unbending. We are just now gradually learning that the new scale of hydraulic fracturing technology is fraught with potential ESA violations, and early signs suggest that the wildlife agencies and NGOs are poised to halt the activity.

Conclusions: Hydraulic fracturing has been hailed as a solution to many of our problems. Not only is it lowering the cost of energy because it is such an efficient method of extraction, but the natural gas it extracts is slightly cleaner burning than other fossil fuels. The current boom is thus no surprise, and many people are thrilled to see it happening. But there are many downsides to fracking, with some very serious examples that are beyond the scope of this Article. Given the stubbornness of the ESA, the ecosystem downside may wind up being the single most formidable hurdle for the industry to leap over. The giant is heading in fast, and could prevent fracking from getting nearly as pervasive as the industry imagines.

Citation: Thomas W. Merrill, 'Four Questions about Fracking' (2013) 63 *Case Western Reserve Law Review*

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: The recent innovation, which is responsible for all the stir, consists of combining hydraulic fracturing with a relatively new technology, horizontal drilling. This consists, as the name suggests, of drilling down vertically and then, at some point, turning the drill bit and moving horizontally through a seam of rock. Much of the oil and gas in the ground that is trapped in no permeable rock is found in relatively thin seams of coal or shale. A couple dozen years ago, a number of independent gas producers started fiddling around with the idea that you could combine horizontal drilling with hydraulic fracturing, and this might be a way to extract gas from these thin seams of coal or shale. They would drill down to the seam, turn the pipe horizontally and thread it through the seam, and then inject the seam with fracturing fluid. After a long period of trial and error, an independent gas producer named George Mitchell, working in the Barnett Shale field near Fort Worth, Texas, figured out the right combination of horizontal drilling, pressure, and proppants to get the gas flowing out of shale.6 Mitchell's breakthrough came in 1998. His success was observed by other producers, and they quickly emulated his methods.

Aims & Research Methods: As a startling and unforeseen development, the fracking revolution presents a number of interesting questions. I will address four. These are not the only significant questions presented by this surprise. But they are ones that resonate particularly with me, a property and environmental law teacher. Here, in brief summary, are the four questions. First, why did fracking technology, perhaps the most important innovation in energy technology in a generation, emerge in the United States rather than somewhere else? Answering this question may provide some clues about the conditions that promote innovation in developing new sources of energy more generally. Second, are there any novel environmental risks presented by fracking? Fracking undoubtedly poses environmental risks, but we need to ascertain whether they are the kinds of risks that can be addressed by racketing up existing regulatory regimes, or if something entirely new is needed. Third, if there are novel risks, what is the best regulatory strategy for addressing those risks? Fourth and finally, what should a concerned citizen anxious about the prospect of global warming think about fracking? Is fracking something to be opposed in order to promote a transition to alternative energy, or is it something to be embraced as a bridge to a greener future?

Conclusions: I would conclude that a conscientious citizen concerned about global warming should support the fracking revolution. Cheap gas will upend nuclear and renewables at least temporarily, but more importantly it will displace coal. If this can be done on a global basis, big progress will have been made against global warming. Cheap gas and potentially cheaper oil also make it more likely that legislatures will agree to adopt a carbon tax, which could help stimulate innovation in renewables over the long term. Cheap gas is thus probably the best strategy on the horizon for reducing greenhouse gases, until we see a technological breakthrough in renewables. And the only way to get cheap gas is to support fracking.

Citation: Susan L. Sakmar, 'The Global Shale Gas Initiative: Will the US be the Role Model for the Development of Shale Gas Around the World?' (2011) 33 *Houston Journal of International Law*

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: Global

Introduction: One of the most promising recent developments in the energy sector has been the dramatic increase in the production of natural gas from shale formations, or shale gas. Although experts have known for years about the vast deposits of shale gas found throughout the world, technological difficulties and the high costs of producing shale gas made it impractical to consider as a serious energy source. However, recent technological innovations combining hydraulic fracturing (also *371 known as "fracing") and horizontal drilling technologies have resulted in a tremendous increase in shale gas production in the United States over the past five years. [FN4] This boom seems likely to continue with leading energy experts proclaiming shale gas as an energy "game changer" that will "revolutionize" global gas markets and help bridge the gap between conventional resources and the development of renewable energy sources.

Aims & Research Methods: To examine whether the GSGI will allow the United States to serve as a role model for the global shale industry, this Article addresses the legal, policy, and environmental challenges associated with shale gas development in the United States. Part I provides an overview of the types of unconventional gas resources, including a discussion of the hydraulic fracturing and horizontal drilling technology that is crucial to shale gas development.

Part II highlights the prevailing view that shale gas is an “energy game changer” that could dramatically impact global energy supplies, energy security, climate change mitigation, and geopolitics. This section also provides an overview of the major shale gas basins in the United States and Canada and a brief discussion of the potential shale gas reserves in the rest of the world.

Part III discusses the GSGI as well as other U.S. efforts and initiatives to help countries around the world develop their own shale gas resources. Part IV addresses the various environmental concerns that have been raised related to the development of shale gas in the United States. Part V discusses the federal and state laws and regulations affecting shale gas development in the United States, including an analysis of proposed legislation to further regulate the industry and a recent EPA study into the potential impact of hydraulic fracturing on drinking water sources and other environmental effects.

Finally, Part VI concludes that a careful analysis of the legal, policy, and environmental challenges associated with global shale gas development needs to be done before the full potential of this game-changing resource can be realized. With the exploration of shale gas resources being undertaken on nearly every continent, will the United States lead the way as a role model for environmental best practices in other countries? Though it may be too soon to tell, it is certainly a development worth watching.

Conclusions: The tremendous boom in shale gas production in the United States over the past five years has indeed been a game changer with potentially significant implications in terms of energy security and supply, climate change mitigation, and energy policy. While shale gas presents an enormous opportunity for the U.S. and perhaps the world, there are numerous legal, policy and environmental challenges that must be addressed before the full potential of shale gas can be realized. In the United States, this analysis is currently underway with the on-going EPA investigation and the recent re-introduction of the FRAC Act in the 112th Congress. While it is too soon to tell what the ultimate outcome will be, these developments should be closely watched as the world searches for the right energy policies for the 21st century.

Citation: John Deutch, ‘The Good News About Gas’ (2011) 90 *Foreign Aff*

Topic Area: Gas Development

Jurisdiction: Global

Introduction: Good News about energy is rare. Energy use and its cost are rising worldwide, most countries remain dependent on oil imports, and little progress has been made toward curbing climate change. So the world should take notice of the recent dramatic increase in estimates of unconventional sources of natural gas in North America and elsewhere, perhaps the greatest shift in energy-reserve estimates in the last half century. In the past few years, thanks to technological advances, vast amounts of natural gas-particularly gas trapped in underground shale basins-have become economically viable.

Aims & Research Methods: This paper argues Countries that import natural gas should anticipate more competing sources of it, which will lower prices and reduce concerns about the security of the gas supply. No longer, it seems, will the world be dependent on a few nations-Iran, Qatar, Russia, Saudi Arabia, and Turkmenistan-that control the bulk of conventional natural gas reserves. Countries that produce natural gas will need to adjust to lower revenues from natural gas exports; for some of them, the adjustment may be quite severe and potentially destabilizing. As gas acts as a substitute for oil, demand for oil will fall, putting downward pressure on oil prices. This will lessen, but certainly not eliminate, the geopolitical influence that major oil-exporting countries enjoy today. It is perhaps a permissible exaggeration to claim a natural gas revolution. But like all revolutions, whether and to what extent the benefits are realized will depend on how rapidly the economic and political systems adapt to the change.

Conclusions: In addition to affecting natural gas markets, the increased supply of natural gas will dramatically change the outlook for oil markets. As natural gas edges out oil in the power, transportation, and chemical sectors, oil prices will fall and the price disparity between oil and gas will close. The major oil-producing countries, of course, will need to readjust their expectations. Most of them operate through national oil companies that serve their government's political and economic. Interests. The newfound natural gas reserves, dispersed around the world, will reduce the market power these companies have enjoyed. There will be difficult negotiations between natural gas suppliers and consumers over new contract terms. Accordingly, past concerns that the Gas Exporting Countries Forum, an OPEc-like cartel formed by major natural gas producers, could control supplies and prices of gas the way oil producers have with oil appear far less serious. International oil companies caught with major investments in the exploration and production of natural gas in the Arctic and deep offshore are quickly shifting their exploration and production activities to shale and other forms of unconventional gas that are cheaper to produce. Nobody knows how significant this prospective shift from oil to natural gas might become. But two points deserve emphasis. First, although the explosion of shale gas production will lead to gas substituting for oil and erode the market and political power of today's major oil- and gas-exporting countries, this market penetration will not be so large that the security concerns of the United States and other oil importers about dependence on foreign oil will disappear. And second, in the long run, the world will need to transition from fossil fuels to carbon-free sources of energy, such as wind, solar, geothermal, and nuclear energy. In this sense, shale gas is a way station en route to a new energy future-not a permanent solution to the problem. None of these changes will occur rapidly. There are significant uncertainties about how much shale gas around the world can be produced economically, the environmental implications of widespread production, and the economics of substituting natural gas for other sources. The large investments required for natural gas exploration, production, and distribution depend on financing supported by long-term contracts. Established industry practices change slowly. There will continue to be fierce competition over pipeline routes, LNG projects, and supply contracts-which means that there will continue to be difficult commercial, financing, and political negotiations between supplier and consuming nations. The countries and international oil companies that are large producers of conventional natural gas will resist delinking the price of the gas they sell from the price of oil. But at the end of the day, economic reality should prevail, and a global market for gas will develop just as it did for oil. Eventually, there will be a transparent and integrated global gas market with diverse supplies that is governed by economic considerations and is free of subsidies. And gas consumers everywhere will be better off.

Citation: Michael Weir and Tina Hunter, 'Property rights and coal seam gas extraction: The modern property law conundrum' (2012) 2 *Property Law Review* 1-13

Topic Area: Land Access and Land Use

Jurisdiction: Australia

Introduction: Recent years have seen a burgeoning in extraction of unconventional gas resources in parts of Australia. As this process requires access by petroleum titleholders to a publicly-owned asset (petroleum) found on privately-owned rural land, this has revealed a structural conflict between the interests of landholders and titleholders. This conflict may be based partly upon a misunderstanding of what is the nature of property rights granted to a fee simple owner or Crown leaseholder.

Aims & Research Methods: This article discusses the legislative background to this conflict, the changes in perception which are needed for landholders and titleholders to deal with this inherent conflict and the adjustment required to the statutory regulatory system to maintain an equilibrium between private and public property rights and the protection of productive rural land.

Scope: This article will first outline the geographical distribution of CSG in Queensland and New South Wales and examine the practical impact of CSG extraction on land, examining the property law issues for landholders as they are perceived by landholders. It will then deal with what is the reality of the nature of property rights related to the extraction of CSG. Finally, in order to address the issues relating to access to land for CSG extraction, this article examines the way forward and what is being implemented or proposed to address some of these property issues.

Conclusions: This article has addressed the land access issues pertaining to CSG activities in Australia. The Australian system of land and concomitant property rights that arise as a consequence of the system of private land tenure and Crown ownership of petroleum presents challenges for regulators, landholders and titleholders as government and titleholders seek to develop CSG resources in eastern Australia. An understanding of fundamental property rights, and their relationship to CSG activities, provides an insight into how land access issues might be addressed. This article seeks to clarify the property rights and interests of stakeholders. Most property disputes relating to CSG activities raise significant conflicts that go beyond a simple dispute between owners of separate interests in land. Rather, CSG activity raises complex conflicts between private owners of land (i.e. pastoralists and agriculturalist landholders) and those who have been granted statutory rights by the Crown. This mirrors the conflict that arises between the public interest and the rights of landholders in planning and land acquisition decisions. Property rights often involve a determination of rights at a particular period of time based upon known legal rights and obligations. This article provides some clarity on the legal entitlements of landholders and titleholders and the legal context in which this debate will continue. It is suggested that ultimately the balancing of private and public interest requires an internalised acceptance by landholders of the limits on their property rights to aid dispute resolution of access and compensation issues. In addition, government and titleholders should acknowledge that the exploitation of a public right should be sensitive to the economic, social and environmental impacts of that exploitation to avoid costly and ultimately disruptive conflict and litigation where no stakeholder obtains the outcome they desire.

Citation: Kate Galloway, 'Landowners vs. Miner's Property Interests: The Unsustainability of Property as Dominion' (2012) *James Cook University, Cairns*

Topic Area: Land Access and Land Use

Jurisdiction: Australia

Introduction: Since the 2010 release of the film *Garlands* in the US, community opposition to coal seam gas ('CSG') mining activities has gained considerable momentum in Australia. The grounds of opposition rest on environmental concerns and associated risks to the health of those living nearby, as well as economic and social impacts through destruction of food-producing land and local communities. These issues are being taken to governments across Australia — particularly by the community-based lobby group, Lock the Gate Alliance Inc ('Lock the Gate'), but also by the Australian Greens. Farmers' groups have highlighted the threat to food production nationally, where exploration and mining occur in agriculturally viable areas.

Opposition to CSG activities has included calls for environmental safeguards, moratoria on CSG extraction processes pending further research on their impacts, and protection of food production. The Environmental Defender's Office (NSW) has written a comprehensive submission on how to address many of these issues — and others — within a framework of sustainability principles, but focussing on planning law and approvals.1

In addition to these grounds, much opposition involves a vocal assertion of private property rights by freehold landowners against private property rights of miners to explore and extract.2 This has resulted in an alliance between green (environmental) interests and farmers' groups, which together appeal for recognition and protection of freeholders' private property. Disputes between land-owners and miners over access to private land for the purpose of exploiting CSG have thus highlighted the inadequacy of the Australian framework of property law, which centres on individual private rights, to cater for much deeper interests representing com-munity and ecology.

As a landholding system founded in feudalism, and perfected in the individualism of Enlightenment thinking, the common law understanding of land and property more generally remains predicated on individualism and classical utilitarianism in a world that can no longer afford to operate on these assumptions. What the CSG issue highlights is the centrality of a competition between *private* interests, in what is more sensibly categorised as a *public* interest debate. In the private sphere, however, there appears to be no room for the deeper public concerns that underlie the present debate over CSG exploration and extraction.

Aims & Research Methods: This article highlights the inadequacies of considering interests in land (property) in terms of individualistic private interests, in light of the ecological issues facing society at large. It does so using the CSG debate as an example of the limitations inherent in our system of private land holding. It first provides a background to Australian law's understanding of the nature of private property and its attendant rights, then examines how this framework is unable to accommodate deeper community concerns such as food security and ecological sustainability. Finally, it assesses whether the issue to be addressed in the CSG debate is one of competing private property interests, or rather one of re-thinking the very nature of private property to reflect a more sustainable ecological framework.

Conclusions: While pressure needs to be maintained over the reform and effective enactment of laws to protect the environment, so too do we need to reconsider the law's approach to concepts that underpin our relationship with the environment — not as a legally constructed resource, but rather as a holistic, networked, global ecosystem.

The CSG conflict between private property interests of 'land'-owners and miners reveals the inadequacy of property law to conceptualise what is at stake, other than in terms of pure economic interests.

There is a way to go in re-thinking the terms of granting CSG mining interests. The terms need to be cast according to true sustainability rather than in terms of developing a petroleum industry. So long as the focus is on environmental management, CSG interests would exist in a system that is superimposed on an out-dated justification for, and expression of, private property interests. Instead, what is called for is a re-thinking of the very foundation of property so that it encompasses concepts of connection of eco-logical systems, of communities and people with the environment.

Citation: Jonathan Remey Nash, 'Property Frames' (2010) 87 *Washington University Law Review* 449- 504

Topic Area: Land Use and Land Access

Jurisdiction: USA

Introduction: Property law confronts circumstances where owners' excessive perceptions of their ownership rights impose social costs, frustrate policy goals, and hamper the very institutions meant to support private property. Ground-breaking research in cognitive framing suggests an answer to the question of how to selectively attenuate (or strengthen) ownership perceptions.

Aims & Research Methods: In a novel application of this research, we contend that property law may ―set frames for individual owners. Specifically, we hypothesize that framing property as bundles of rights and forewarning of limitations weakens perceptions of ownership and decreases resistance to subsequent restrictions. We conducted experiments to evaluate these claims and found that both bundle-of-rights/discrete-asset framing and forewarning framing affect perceptions of ownership, rights infringement, valuation, and satisfaction. Our study shows that ―layering‖ both of these conditions (bundle framing and forewarning) have a stronger, synergistic impact than the sum of each effect alone. The potential applications of this research to property theory are numerous. Legislators, judges, and regulatory agencies craft legal measures that respond to, or even capitalize on, strong, pre-existing frames of citizen-owners. These institutional players also endeavour to limit spill overs and other social harms by reframing property as a limited set of use rights in areas of law including pollution rights, intellectual property, and common interest communities. The goal of this Article is to investigate how law can employ ―property frames‖ systematically to alter ownership perceptions and expectations regarding regulation. If there are no effects from framing, this suggests that the tremendous academic debate over the proper conception of property may have limited utility on the ground in affecting how people think about their property. If, as we hypothesize, framing property to convey a sense of limitation and cognitively prime restrictions weakens ownership perceptions, then property law may serve to ―set frames‖ in complex legal and social contexts. To clarify our analytical parameters, our aim is not to endorse a normative conception of weak property rights universally or to dispute the utility of private property. In many circumstances, strong property rights perceptions (and even misperceptions) promote individually and socially valuable investment. Rather, we contend that in certain contexts excessively strong rights expectations impose steep social costs in the various currencies of efficiency, fairness, and social responsibility—and may stymie the very property institutions they purport to extend.

Scope: This Article proceeds as follows. Part I describes the problem of excessive property perceptions. We then review the framing research in cognitive psychology and examine the bundle of rights/discrete asset dichotomy in legal theory. We contend that discrete-asset and bundle paradigms may serve as framing devices that attenuate property perceptions and decision making. In Part II, we discuss the two experiments we conducted and report the statistical analyses and results. Part III examines the relevance and import of our findings for property theory. Our findings challenge fundamental conceptions of property law, including assumptions about the endogeneity of property perceptions and the futility of liberating laypeople from the discrete-asset or dominion paradigm of ownership. In Part IV, we suggest areas where reframing might appropriately be used to realign owners' understandings of their property rights. We focus primarily on areas of law where bundle-of-rights framing can attenuate or refine rights perceptions. However, our research is equally applicable to contexts that call for strengthening property perceptions; we demonstrate the effectiveness of discrete-asset framing for that purpose. In this Part, we consider regulatory framing of conservation measures and market-based pollution trading permits. We also examine the legal and quasi-legal framing of rights in common interest communities and copyrighted intellectual property.

Conclusions: In this Article, we have evaluated empirically the question of whether it is possible to ―reframe‖ people's perceptions of property interests. Contrary to the implicit assumptions of many commentators, we have provided evidence of successful reframing of ownership perceptions and reactions to regulation. In particular, we have identified two factors that tend to reduce people's expectations about the strength of their property rights: (i) framing the property rights under the ―bundle-of-rights‖ as opposed to the ―discrete-asset‖ paradigm; and (ii) including a forewarning about limitations in the property rights. The reduction in people's expectation is largest when both factors are employed. Certainly, reframing has its costs—especially uniform and predictable reframing. This suggests the need to employ reframing selectively. Reframing may not be desirable in all circumstances and there may be conflicts in particular instances as to whether framing should be used to weaken or strengthen property rights. Many normative issues attend the question of how strong people's expectations about their property rights ought to be.

Citation: Matthew Austin and Lauren Kirkwood, 'Queensland's Strategic Cropping Land Act 2011 and the extractive industries: Let's look beyond the borders' (2011*) Australian Environmental Review* 75-79

Topic Area: Land Access and Land Use

Jurisdiction: Australia (Qld)

Introduction: The impact of Australia's extractive industries, especially coal mining and coal seam gas developments, on agricultural land is under greater scrutiny than ever before. This is clear from the inquiries announced at the Commonwealth and state levels of government and from the legislative responses to date.

Aims & Research Methods: While this article focuses on Queensland's Strategic Cropping Land Act 2011 (Qld), concerns about Australia's agricultural land should also be seen in the context of global food security risks.

Conclusions: The SCL Act represents another major reform to the assessment of gas production and mining in Queensland. It is likely that 2012 will see a great deal of regulatory activity nationally. Further reforms to the regulation of extractive industries are expected, particularly around impacts to agricultural land. Refinements to the SCL regime are likely to be made over the next few years as practical implications become apparent. However, the short term political and media commentary on the regulation of extractive industries in general should not completely distract from the broader global food security context. The decreased food production capability of high-quality cropping land (whether as a result of extractive industries or of global warming) remains a critical issue on the world stage. The SCL Act is, at the very least, an attempt to reconcile these concerns at a local level.

Citation: Carolyn Bergner, 'Regulating Hydraulic Fracturing in Natural Gas Development: A Policy Analysis' *United States Environmental Protection Agency Office of Research & Development Office of Science Policy* (2011)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: Hydraulic fracturing is a method of oil and natural gas extraction used in shale plays, tight sands, and other unconventional oil- and gas-containing formations. Recently this method has become instrumental in domestic energy production, and its use is only expected to increase in the next several decades. However, along with the growth of domestic energy development have come concerns about the potential environmental and public health effects of hydraulic fracturing, which involves the high-pressure injection of water and chemicals into underground formations. Consequently, states are reassessing their oil and gas regulations, the federal government and other researchers are conducting studies of hydraulic fracturing, and two sides of the public are emerging— those in favour of and those opposed to hydraulic fracturing.

Aims & Research Methods: This paper will present an overview of the current state of hydraulic fracturing regulations related to natural gas extraction and evaluate policy alternatives for regulating this practice. The analysis will consider political feasibility, impacts on production, and environmental effects of each alternative. After analysing the outcomes of the alternatives, a policy will be recommended that combines mandatory disclosure of hydraulic fracturing chemicals, regulation under the Safe Drinking Water Act, and state enforcement of the use of best practices related to hydraulic fracturing. These actions can help protect the environment and public health while enabling the U.S. to take advantage of its vast domestic energy resources.

Conclusions: Given the current political climate and public concern, this paper recommends a policy combining alternatives 2 and 4. Passing the FRAC Act is a reasonable political action given the amount of current public support for stronger regulations. SDWA would require permit applicants to show that the proposed underground injection would not endanger sources of drinking water, which according to operators is normally the case (Wiseman, 2009). Additionally, disclosure of chemicals would ease public concern and encourage companies to develop environmentally friendly drilling fluids. Policy 4 would ensure that gas operators use the best practices available. A feasible means for implementing this policy might be a review and revision of current best practice standards by American Petroleum Institute, EPA's Natural Gas STAR, or another multi-stakeholder organization, followed by state adoption of these practices into their regulations. While these policies might potentially result in a decrease in domestic natural gas production, public concern calls for some action to ensure the protection of public health and the environment.

Citation: Leonie Reins, 'The Shale Gas Extraction Process and its Impacts on Water Resources' (2011) 20 (3) *RECIEL* 300- 312

Topic Area: Water Distribution and Use

Jurisdiction: Global

Introduction: The 'Shale Gas Revolution' has been hailed as an answer to the worldwide security of energy supply problem and as a means to meet energy demand.1 Increasing natural gas prices and advances in hydraulic fracturing and horizontal drilling have made shale gas profitable over the past decade in the United States.2 However, as of the present, there are still no commercial shale gas undertakings outside North America.3 In the European Union (EU), for example, Member States, especially Poland, are assessing 'Europe's potential for sustainable extraction and use of conventional and unconventional (shale gas and oil shale) fossil fuel resources'4 in order to enhance its security of supply. Furthermore, the European Energy Strategy 2020 addresses the need for a non-conventional gas policy: 'The potential for further development of EU indigenous fossil fuel resources, including unconventional gas, exists and the role they will play must be assessed in all objectivity.'5 Cooperation and knowledge transfer are exercised on mutual levels: efforts such as the European Unconventional Gas Summit 2011 in Paris tried to bring experts and stakeholders from the United States and Europe together to discuss and investigate extraction techniques and potential. Also United States President Obama has met with Polish President Komorowski in Warsaw to discuss further cooperation and assistance in terms of shale gas extraction.

Aims & Research Methods: The emerging trend of shale gas extraction poses some new challenges to existing regulatory regimes worldwide, with most of the applicable regulatory regimes not explicitly covering unconventional gas resources. Particularly regarding water resources, there are some serious negative impacts and a lack of regulation concerning shale gas extraction. This article analyses and compares some of the existing legal regimes in the United States and the European Union on water resources, and their abilities to cope with the impacts of shale gas extraction.

Conclusions: This analysis of the American and EU regimes regulating the shale gas extraction process serves to demonstrate that there is not yet suitable regulation for governing the impacts of the shale gas extraction process on water resources. The existing regimes lack focused regulations that address the drilling processes and the wastewater disposal challenges posed by shale gas extraction. Neither of the jurisdictions provides sufficient protection of underground, surface or drinking waters. Furthermore, in both jurisdictions the regulation of unconventional gas extraction falls under general, conventional oil and gas legislation, even as the framework and the extraction conditions of unconventional gas resources are often more difficult and dangerous than conventional gas resources and require distinct regulatory controls. Moreover, both grant exemptions to the oil and gas industry in general, which results in weaker environmental protection standards.

An effective regulatory regime to address shale gas extraction activities must include several key attributes. As the proposed components of such a regime show, there is no point in reinventing the wheel. However, some specific requirements and characteristics in the shale gas extraction process, like the hydraulic fracturing and drilling resulting in wastewaters and the impacts on surface, drinking and groundwater, as well as the regulation of the fracking fluids require the establishment of a specific regime, containing strong provisions as noted above. An alternative way of governing the individual shale gas exploitation sites would be governance through 'shale gas basin committees' similar to the DRBC approach. This would enable coherent governing of shale formations which are spread out among several States or jurisdictions. The regulation would not just be on a State level, but on a regional level and therefore better suited to the challenges and conditions of the applicable shale formation. Consequently, an effective regime regulating the trans boundary aspects of shale gas could be composed, on the one hand, of overarching provisions that effectively regulate the less specific aspects of the 'shale gas value chain' and, on the other hand, of specialized provisions and regulations that mold the regime to the specific character of the shale formation at hand.

Citation: LoValerie Mullins, 'The Equity Illusion of Surface Ownership in Coalbed Methane Gas, The Rise of Mutual Simultaneous Rights in Mineral Law and the resulting need for Dispute Resolution in Split Estate Relations' (2009) 90 *Missouri Environmental Law & Policy Review*

Topic Area: Land Access and Land Use, Alternative Dispute Resolution

Jurisdiction: USA

Introduction: The push for alternative energy resources in America has caused a phenomenon in American jurisprudence: the dichotomizing of legal approaches to interpreting mineral law. Analysis of the small collection of landmark coal bed methane gas (CBM) ownership cases reveals a chaotic trend in the interpretation of mineral law as a movement from traditional judicial reverence for property rights toward a growing preference for contract theory. Problematically, this trend is redefining mineral law in a manner foreign to traditional interpretations of mineral theory and in contravention to historical practices of mineral conveyancing. Much of the problem lies in courts' collective resistance to addressing specific extraction issues of a new group of split estate mineral owners who now share *mutual simultaneous rights* to CBM. As a result, coal bed methane case law resembles the practice of ad hoc interventions in equity, wholly lacking in consistent principles of mineral theory. Moreover, the property rights of split estate surface owners have suffered from the chaos, as functional solutions to diminished rights of quiet enjoyment and environmental protection have not been forthcoming.

Aims & Research Methods: This article is an effort to scrutinize the coal bed methane phenomenon and its effect on a new class of split estate surface owners. Analysis will include my assessment of historical conflicts between contract theory and property law which have come to disturb the continuity of modern mineral law. As a centrepiece to understanding these historical conflicts, I explore the issue of equitable intervention on the part of the courts in mineral production issues. In concluding my analysis, I illustrate why alternative dispute resolution is the single best alternative to the pandemic of legal uncertainty in mineral law as it trends away from property rights protections.

Scope: In accomplishing these goals, Part I of this article addresses the physical properties of CBM and describes its new mineral value. Part II analyses the chaos behind CBM case law as it involves the Virginia Supreme Court Case *Harrison- Wyatt, LLC v. Donald Ratliff, et al*. [FN1] Part III considers the “interface” [FN2] issues between contract theory and property law, which disturb the continuity and predictability of mineral law. Part IV retraces the historical conflict between contract theory and property law. Part V looks at the big picture in coal bed methane production as it affects the nation. Part VI reviews the nature of equitable intervention on the part of recent courts in the treatment of split estate issues. Part VII explains why there exists the equity illusion of just intervention in CBM ownership cases. Part VIII suggests the best practice in managing CBM issues is a focus on extraction rights. Part IX advocates for the use of alternative dispute resolution to mitigate the chaos of CBM extraction issues.

Conclusions: There is nothing *plain* in the language of Virginia's ruling on the plain language of intent of predecessors in interest, dead 100 years before coal bed methane gas became a valuable fuel resource. The real truth of the matter is that no jurisprudential tool exists for deciding the ownership of coal bed methane gas in the vacuum of time and place, except the tool of equity. Potentially, the decision in *Harrison-Wyatt* could have been the result of a court's granting of equity to surface estate owners, bearing on the history of marked inequity in mineral production of the Appalachian Basin. Virginia, however, used the wrong jurisprudential tools in its effort. The Court diminished property law in favour of a new contract approach to mineral conveyancing which argues ownership instead of extraction. Further, it ballooned the difficult work of managing mineral issues by perpetuating a case by case analysis with diminished evidentiary *200 tools available under the contract approach. Finally, the Court invoked a higher burden of proof for equitable relief by utilizing contract theory instead of relational equity in fairness. Equity, therefore, is less of what the state Supreme Court achieved than chaos. Essentially, in re-contractualizing Virginia's mineral law, the Virginia Supreme Court has prompted the deterioration of equity in mineral law. The question becomes therefore, “How can the practice of equity survive Virginia's new common law approach to mineral ownership?” The answer is that it most likely cannot. A systemic tool with greater reach is needed. That tool is alternative means of dispute resolution. The alternative to judicial equity lies in the collaborative efforts of dispute resolution, particularly as alternative fuel production expands to new reaches, and into new communities of surface owners.

Citation: J. Daniel Arthur, P. E., ALL Consulting; Bruce Langhus, P. G., Ph.D., ALL Consulting; David Alleman, ALL Consulting, ‘An Overview of Modern Shale Gas Development in the United States’ (2008) *ALL Consulting Paper*

Topic Area: Modern Shale Gas Development

Jurisdiction: USA

Introduction: Natural gas production from tight shale formations, known as "shale gas", is one of the most rapidly expanding trends in onshore domestic oil and gas exploration and production today. In some cases, this has included bringing drilling and production to regions of the country that have seen little or no activity in the past. New oil and gas developments bring change to the environmental and socio-economic landscape, particularly in those areas where gas development is new. With these changes have come questions about the nature of shale gas development, the potential environmental impacts, and the ability of the current regulatory structure to deal with this development. Both regulators and policy makers need objective sources of information upon which to base answers to these questions and to make decisions about how to manage the challenges that may accompany shale gas development.

Aims & Research Methods: This paper responds to these needs by describing the importance of shale gas in meeting the future energy needs of the United States (U.S.) and providing an overview of modern shale gas development. It also presents a summary of regulations applicable to the natural gas production industry, and details the environmental considerations related to shale gas development.

Conclusions: A variety of waste fluids are generated on site at shale gas wells. During drilling, used mud and saturated cuttings are produced and must be managed. The volume of mud roughly correlates with the size of the well drilled, so a horizontal Marcellus well may generate twice as much drilling waste as a single vertical well; however, as discussed above, it will replace four such holes. Drilling wastes can be managed onsite either in pits or in steel tanks. Each pit is designed to keep liquids from infiltrating vulnerable water resources. On-site pits are a standard in the oil and gas industry but are not appropriate everywhere; they can be large and they disturb the land for an extended period of time. Steel tanks may be required to store drilling mud in some environments to minimize the size of the well site "footprint" or to provide extra protection for a sensitive environment. Steel tanks are not, of course, appropriate in every setting either. In rural areas or pits or ponds, steel tanks are usually not needed.

Where space is available at the well site horizontal drilling development has the power to reduce the number of well sites and to group them so that management facilities such as storage ponds can be used for several wells. Make-up water is used throughout the development process to drill the well and to form the basis of the hydraulic fracturing fluid. Large volumes of water may be needed and are often stored at the well site in pits or tanks. For example, surface water can be piped into the pit during high-water runoff periods and used during the year for drilling and fracture treatments in nearby wells. Exhibit 14 shows one of these large storage ponds servicing the Marcellus development in Pennsylvania. Storage ponds are not suitable everywhere in the shale gas play; like steel tanks, they are appropriate in some locations and not in others. The water-based fracturing fluids begin to flow back through the well casing to the wellhead. This water is referred to as flow back water and consists of spent fracturing fluids and, in some cases, dissolved constituents from the formation itself (minerals present in the shales as well as brine waters that may be present within any natural pore space contained in the shale). The majority of flow back water is produced in a range of time from several hours to a couple of weeks. In various basins and shale gas plays, the extent of this volume of flow back water may account for less than 30 recent to more than 70 precent of the original fracture fluid volume.65 In some cases, production of flow back water can continue for several months after gas production has begun.66 Natural formation waters that flow to the well are known as produced water. Regardless of the source of water, flow back or formation water, these waters that are produced back through the wellhead with the gas represent a production stream that must be managed and are collectively referred to as produced water. Gas shale operators manage produced water through a variety of mechanisms including: underground injection, treatment and discharge, and recycling. Underground injection is not possible in every play area as suitable injection zones may not be available. Similar to a producing reservoir, there must be a porous and permeable formation capable of receiving injected fluids near the play area. If such is not locally available, it may be possible to transport the produced water to a more distant injection site. Treatment of produced waters may be feasible through either self-contained systems at well sites or fields or through municipal waste water treatment plants or commercial treatment facilities. The availability of municipal or commercial treatment plants may be limited to larger urban areas where treatment facilities with sufficient available capacity already exist; as in underground injection, transportation to treatment facilities may or may not be practical.

Citation: John R. Nolon & Steven E. Gavin, 'Hydrofracking: State Preemptino, Local Power and Cooperative Governance' (2013) 63 *Case Western Reserve Law Review* 995- 1039

Topic Area: Hydraulic Fracturing Activities and Regulation

Jurisdiction: USA

Introduction: Advocates for the gas drilling technology known as hydraulic fracturing, or hydrofracking, argue that it will bring significant economic benefits to the private and public sectors. Its opponents dispute these claims and point to significant environmental and public health risks associated with hydrofracking—risks that must be considered in adopting government regulations needed to protect the public interest. One of the many issues raised by hydrofracking is which level of government should regulate which aspects of the practice. This debate is complicated by the fact that the risks associated with hydrofracking raise concerns of federal, state, and local importance and fit within existing regulatory regimes of each of these levels of government.

Aims & Research Methods: This Article begins by describing the limited aspects of hydrofracking that are currently regulated by the federal government, which leaves many of the risks unaddressed, opening the door for state and local regulation. This Article describes the legal tension between state and local governments in regulating hydrofracking in the four states that contain the immense Marcellus shale formation. Its particular focus is on court decisions that determine whether local land use regulation, which typically regulates local industrial activity, has been pre-empted by state statutes that historically regulate gas drilling operations. This investigation suggests that the broad scope and durability of local land use power as a key feature of municipal governance tends to make courts reluctant to usurp local prerogatives in the absence of extraordinarily clear and express language of pre-emption in state statutes that regulate gas drilling. The Article concludes with an examination of how the legitimate interests and legal authority of all three levels of government can be integrated in a system of cooperative governance.

Conclusions: One model for state-local cooperative governance is New York's law on siting major electric generating facilities, which pre-empts local control of utility siting but accommodates the local interest in the permitting system it created. This law reauthorized and revised article X of the Public Service Law, establishing an electric generation siting board to review and approve the siting of electric utility generators of twenty-five megawatts or greater. This board is empowered to override local land use laws that it believes are unreasonably burdensome, but it includes two members who are residents of the affected community. Prior to the adoption of this law and following the expiration of a previous version of article X, localities governed this land use and often opposed or significantly delayed the approval of generation plants vitally needed by the state's power grid. In establishing a state-controlled siting system, the legislature largely pre-empted local control but allowed for the input of the affected locality and local stakeholders. In addition to requiring local residents to sit on the siting board, the revised article X requires applicants to set up a fund that will enable affected local governments, environmental groups, and the community at large to hire experts, lawyers, and other consultants to participate in the process of creating a scope of review for the proposed utility. Applicants are encouraged to enter into agreements with these parties regarding the scope of review and a hearing examiner is appointed to resolve any disputes that arise over the scoping. While it does not impose a collaborative decision-making process on affected agencies, governments, and private actors, this legislative approach sets the table and provides significant resources so that one can occur. There are many more such techniques that could be agreed upon if states pursued the intentional policy of including and working with local governments in the regulation of hydrofracking, followed by serious negotiations to create a framework and practices for working together. Such a policy would avoid the uncertainty and vagaries of pre-emption debates and litigation, respect the critical role of local governments in controlling land uses within their jurisdictions, offer them the technical assistance they need to determine where hydrofracking can occur and how to guard against its adverse impacts, and avoid simplistic solutions such as complete proscriptions that may be inimical to larger state interests.

Citation: Joseph P. 'Tomain, Shale Gas and Clean Energy Policy' (2013) 63 *Case Western Reserve Law Review* 1187- 1215

Topic Area: Shale Gas and Clean Energy Policy

Jurisdiction: USA

Introduction: A recent report from the International Energy Agency (IEA) makes claims similar to those expressed by Daniel Yergin. Both commentators argue that new fossil fuel discoveries in the United States are having a profound impact on domestic and global energy policies. According to the IEA, "[t]he global energy map is changing" and "is being redrawn by the resurgence in oil and gas production in the United States." Industry observers project that by 2020, the United States will produce more oil than Saudi Arabia and more natural gas than Russia. In addition, the IEA reports that the global energy map is changing as countries retreat from nuclear power and replace it with rapidly growing wind and solar technologies. Other commentators, like Professor Richard Pierce, claim that shale gas addresses *all* of our major energy problems, while still others treat this natural gas resource as a bridge fuel to the future. Indeed, in his 2012 State of the Union Address, President Obama cited experts who predicted that the natural gas industry will create 600,000 jobs by the end of the decade. As remarkable as these claims are, the United States is not scheduled to be energy independent without a robust clean energy economy, even in the brightest projections. To be sure, these new finds of natural gas have much to recommend them. First, recent discoveries reveal abundant reserves and, following abundance, consumers enjoy lower natural gas prices.8 second, natural gas emits about half of the carbon dioxide released by coal. As a result of these lower prices and less drastic environmental effects, natural gas is beginning to displace coal for electricity generation. Fourth, the increase in domestic production adds jobs to the economy. Fifth, the United States is beginning to reduce imports and increase exports, thus reducing the trade deficit as the United States grows more energy independent. Not only are we less reliant on imports, natural gas can be adopted for use in the transportation sector—further reducing our reliance on oil. And, sixth, new discoveries have the effect of smoothing out the price volatility experienced by the natural gas sector for the last two decades. There is other good news for the U.S. energy economy. In addition to developing our own resources, U.S. energy consumption has been declining in recent years. According to Worldwatch Institute measurements, energy use in 2012 was 7% below the 2007 level and that decline constituted the steepest five-year decrease in approximately sixty years. Additionally, renewable resources, particularly wind, are increasing their share of the country's energy portfolio. Most notably, we are beginning to witness a decline in carbon dioxide emissions as well as reductions in other greenhouse gas emissions such as sulphur dioxide.

Aims & Research Methods: But open questions remain. If we look behind the numbers on energy consumption, how much of that declining consumption is attributable to increases in energy efficiency and how much is attributable to a poor economy? If we look more closely at shale gas production, particularly when we consider hydraulic fracturing, what environmental costs are associated with developing this domestic resource? And, from a broader perspective, what role should natural gas, including shale gas, play in the country's clean energy future? Will we continue to favour fossil-fuel incumbents at the expense of new entrants in renewable resources and energy efficiency?

This Article will address these questions by first describing the clean energy transition in Parts I–III. Next, in Part IV, the Article will describe the role of natural gas and shale gas in our contemporary energy picture. Finally, in Part V, the Article will identify some of the costs attributable to shale gas production, including the possibility that our current focus on shale gas will simply result in a new hydrocarbon future at the expense of a vibrant and productive clean energy economy. The Article concludes in Part VI with some recommendations for future shale gas regulation. While acknowledging the reality that shale gas will play an increasingly larger role in our energy portfolio, the Article argues that natural gas should not be considered a clean energy resource.

Conclusions: From the above analysis, I conclude that natural gas, particularly shale gas, should not be included in the definition of clean energy. For all its environmental improvements and economic benefits, shale gas continues our traditional fossil fuel energy model. For most of the twentieth century that model yielded great benefits, including a robust economy and the construction of a national infrastructure, and it served as the backbone of U.S. world leadership, particularly during the two world wars.

But that model benefited from a series of government supports, including tax breaks and other subsidies; under enforcement of royalty, environmental, and safety obligations; and an energy bureaucracy that has played an intentionally supportive role that has buoyed domestic oil and gas producers to phenomenal levels of wealth. In short, the playing field between fossil fuels and clean energy is not level regardless of the increasing, but too often episodic, financial supports afforded new and cleaner technologies. Today, the natural gas industry is highly competitive as prices continue to fall, sometimes to the dismay of gas exploration companies and those that finance them. But the fact that some explorers cannot turn a profit is indicative of competition rather than a market failure. Neither oil nor gas producers need the helping hand of government. Additionally, as natural gas displaces coal for electricity generation, we will witness a lowering of carbon dioxide emissions, particularly as natural gas continues to serve that sector.

In short, we are substituting a cleaner burning fuel in the electric sector but we are not using a clean fuel. If the clean energy transition is to be successful, then the United States, and indeed the world, must move away from fossil fuels. In the United States, we can improve national security, reduce economic threats, and reduce environmental degradation through clean energy. We must continue a commitment to a clean transition by expanding the use of renewal resources and energy efficiencies. Shale gas plays no role in that picture.

By concentrating on natural gas development we run the risk of diminishing the importance of our concentration on clean energy activities. As a realist, I recognize that natural gas will play a large role in our energy economy. Further, I do not dismiss its positive environmental and economic benefits. Nevertheless, even though natural gas has been a major component of our hydrocarbon economy and even though it will continue to play significant role, as a matter of a sound future energy policy, we cannot allow it to distract us from a more important and economically promising clean energy future.

Citation: Christopher S. Kulander, 'Shale Oil and Gas State Regulatory Issues and Trends' (2013) 63*Case Western Reserve Law Review* 1101-1141

Topic Area: Shale Gas Regulation

Jurisdiction: USA

Introduction: Development of hydrocarbons from shale has dramatically changed the picture of American reserves. Advancements in directional drilling and hydraulic fracturing have made possible widespread development of oil and gas in rock formations previously believed to be too impermeable for commercial development. In a time of economic want, this American boom employs tens of thousands in tough but lucrative work and significantly reduces the United States' dependence on hydrocarbons imported from unstable and unfriendly countries. Moreover, unlike past booms (and busts) that repeatedly inflated (and deflated) only the economies of the traditional oil patch, the shale gas boom has rippled everywhere prospective shale formations are found, including the long-moribund Northeast. While New York watches, Ohio, Pennsylvania, and West Virginia have embraced a thriving new industry. But it is in Texas, where the shale craze started, that the most frantic activity continues today. Since the curtain rose on the Barnett Shale in the early 2000s, bringing production onto the grounds of DFW Airport and into the city of Fort Worth, shale gas production has blasted off in the Eagle Ford Shale of South Texas, leaving a brightly lit footprint caused by production that can be seen from orbit. Twenty active Eagle Ford Shale fields produce "over 900 million cubic feet *per day* of natural gas." Producers have stampeded into the Haynesville Shale along the Texas-Louisiana line. The newest target, the Cline Shale in West Texas, is thought to have an isopach thickness of 200 to 550 feet—"the equivalent of ten Eagle Ford shales stacked on each other." The Cline Shale joins other West Texas shale targets, like the Bend and Avalon shale formations, and other shale formations thought to be analogous to the Barnett and Woodford shale formations. This latest rush has the downsides of harming environmental assets if the related machinery is not correctly deployed and definitely foisting inconvenience, delay, and nuisances on various surface parties through truck traffic, pulverized roads, noise, foul smells, surface degradation, and more onto parties that may not be directly benefitting from shale development. Therefore, the states wherein shale hydrocarbon development is now blossoming are scrambling to craft regulations that promote environmentally responsible development.

Aims & Research Methods: This Article surveys proposed and existing state laws and regulations to describe the most common statutory and regulatory issues associated with hydraulic fracturing—the drilling-completion technique necessary to make recovering hydrocarbons from shale economic. It includes discussion of individual state laws and regulations as well as general trends and policies among the states regarding state regulation of well drilling and hydraulic fracturing. Laws and regulations affecting both groundwater and surface water supplies and acquisition, fracturing fluid ingredient disclosure, and drilling completion and monitoring standards will be compared across the states wherein hydraulic fracturing is common. Finally, a few thoughts on whether federal agencies, mainly the EPA, should seek to pre-empt or direct state action regarding fracturing regulation on private and state lands will be provided. This Article also includes an appendix that briefly describes both horizontal drilling techniques and the hydraulic fracturing process. This appendix further contains information explaining how hydraulic fracturing may detrimentally affect surface and groundwater. Finally, an explanation of the terminology used in this Article is necessary. The issue of hydraulic fracturing is so prickly that no consensus exists as to even the spelling of the informal terms used for it. “Fracing,” “fracing,” and “fracking” have all been used in media outlets as a substitute for “hydraulic fracturing.” This Article uses “fracing.” Similarly, a “fracked well” is a well that has undergone hydraulic fracturing. Also, in the oil and gas context, “operator” is used to describe any mineral developer, whether it be a self-developing mineral owner or a mineral owner’s lessee.

Conclusions: Should the federal government or the individual states regulate hydraulic fracturing? A fixture in the debate over fracing is whether the regulation of the process is rightfully the province of the federal agencies or individual states. The state law and regulatory framework in states most affected by fracing (Texas, Louisiana, Oklahoma, North Dakota, West Virginia, Pennsylvania, and New York) potentially may face pre-emption by federal legislation. The Bureau of Land Management, an agency of the Department of Interior, has already announced its intention to formulate rules requiring disclosure of chemicals used in the drilling process and to adopt well-integrity standards as part of the permit process. The EPA is still in the midst of a multiyear study of hydraulic fracturing, producing a prolonged debate over the regulatory role of the EPA versus individual states. Despite the extensive expertise of state regulatory agencies and their responsiveness to their own states’ unique challenges, some commentators still desire federal oversight of hydraulic fracturing.

State primacy for regulation on hydraulic fracturing has been disparaged as being “uneven” and a “patchwork.” This author submits that what is being derided as a weakness is actually a strength: each state can rapidly respond to its unique blend of economic, political, hydrological, and geological realities to achieve realistic and functional regulatory oversight. A further weakness alleged by those favouring federal primacy, that states are “rushing” to create law regulating fracing, is also strength: the necessary regulations are made in a timely manner, in response to industry activity, and by those more familiar with the challenges faced by an individual state. In contrast, the federal government’s record regarding the proposal of realistic bills and quick action on those bills is lacking. For example, it took the EPA over three years to promulgate UIC regulations for a new category of injection wells. If it takes over three years to establish federal regulatory oversight for a relatively uncontroversial program, how responsive can the federal government be expected to be to the demands for formulating a much larger and controversial regulatory system covering all the facets of fracing? State regulation *is* uneven and results in a patchwork of laws across the states. Sometimes this results in circumstances where federal intervention and oversight have been required, as in cases where individual civil rights have not been protected or where interstate commerce is threatened with disruption. Sometimes, however, federal intervention is merely clumsy unnecessary, and unresponsive.

Citation: Peter M. Gerhart & Robert D. Cheren, 'Recognising the Shared Ownership of Subsurface Resource Pools' (2013) 63*Case Western Reserve Law Review* 1041- 1100

Topic Area: Shared Ownership of Subsurface Resource Pools

Jurisdiction: USA

Introduction: An important function of legal theory is to provide a framework for understanding the common law and its regulatory substitutes. Now that horizontal slickwater fracturing has renewed popular and academic interest in the governance of subsurface resource pools, it is helpful to apply property theory to understand the law's response to issues concerning resources that lie under, or can be extracted only by going under, more than one piece of property. If property theory is to be helpful, it ought to sharpen our ability to correctly diagnose the social problems addressed by the law and to identify the coherence of, and justification for, the law's response to those problems. By this measure, property theory has underserved our understanding of both the problem of subsurface resource pools and the law's response to that problem. Property theory was ill-equipped to address the problem of subsurface resource pools because it had only two paradigms for identifying and addressing the problem: a paradigm of private property and a paradigm of commons property. Because neither paradigm adequately addresses the problem of subsurface resource pools, the law applicable to water, oil, and gas has been misunderstood and mischaracterized.

Aims & Research Methods: In this Article, we argue that property theory, appropriately understood; show that subsurface water, oil, and gas ought to be treated as shared property that can be exploited, if it is to be exploited at all, by the coordinating agreements of owners of the surface property, or their licensees, supervised by common law courts. We therefore offer the paradigm of shared property as the appropriate analysis for thinking about the law's approach to rights in oil and natural gas. We also argue that the shared property paradigm is largely consistent with the common law's approach to subsurface resource pools, even though conventional understanding of the law vacillates between the private property and commons property paradigms. Much of this Article is revisionist. We argue, unconventionally, that the common law embraced the paradigm of shared property in much of its regulation of subsurface resource pools because it essentially treated those resources as owned by tenants in common, as modified by the common law nuisance exception for injuries to subsurface resource pools. Under this reading, the special common law rules regarding subsurface resource pools have been misunderstood either as providing for (1) commons property treatment of subsurface resource pools underground followed by private property treatment after the resources are extracted from the subsurface pools or (2) private property treatment of the resources even while underground but subject to loss of title if the resources crossed property boundaries. Under our reading of the cases, when interpreted against the paradigm of shared property, the common law consistently recognized shared ownership of subsurface resource pools yet limited surface owner's rights to quiet enjoyment of subsurface resource pools based solely on courts' own perceived incapacity, because the resources are hidden, to understand the causal relationship between land use and disruption of enjoyment of subsurface resource pools. But this limit did not prevent courts from coordinating the exploitation of subsurface resource pools between surface owners by recognizing causes of action for malicious interference, waste, and unreasonable exploitation. This analysis supports our claim that the property issues inherent in today's concerns over horizontal slickwater fracturing can be addressed under private agreements that are subject to judicial supervision. Moreover, because we now have the seismic technology to understand resource location and flows, the common law's reluctance to provide common owners of shared property with an accounting should dissipate.

Scope: Part I examines in detail the common law of subsurface resource pools. Part II demonstrates this common law of subsurface resource pools is an application of the shared property paradigm. Part III suggests that judicially supervised private governance regimes can ensure that subsurface resource pools are exploited efficiently and fairly.

Conclusions: The law's need to accommodate the particular and the general— to understand the outcome in particular cases in terms of general directions that others can follow—requires legal theory to move easily between the pieces of a mosaic and the overall picture the pieces portray. This requires theory that can move beyond general principles whose content is unexplored and undefined, while simultaneously capturing the relationship between the details in a way that binds them together into a coherent pattern. For this reason, successful theory depends on a framework or paradigm that captures the relevant variables and their relationships to each other. When formed at too diffuse a level or when focused on too many particulars, theory provides insufficient guidance; when focused on too few particulars, theory distorts reality. The theory applicable to subsurface resource pools has never presented a comfortable picture because it has continually vacillated between theories of individual ownership and common ownership that has left the law's imprint smudged and confused. Attempts to bring the law into focus by espousing theories that focus on one feature over others—such as capture or location—or by giving up on theory and allowing resource exploitation to be understood as a race (the "Drill, baby, drill!" v) have given the law applicable to subsurface resource pools a vacillating, uneven, and opaque character. Because the widespread deployment of horizontal slickwater fracturing has threatened traditional property interests by requiring the driller to cross surface boundaries, in this Article we have taken a fresh look at the cases that determine rights and responsibilities to subsurface resource pools. What we have found is that common law courts have implicitly applied a theory of shared ownership to controversies arising from the exploitation of subsurface resource pools, one that they modified only to accommodate the difficulty of tracing the flow of hidden resources. This finding ought to change the way we understand the law applicable to subsurface resource pools, for it allows us to integrate into a single theory—a theory of shared resources—that actualizes a legal approach to the many controversies that such resources generate. Under the theory of shared resources, owners of surface property over a subsurface pool have a unity of interest in the exploitation of the pool that requires each surface owner to act as if she were part of unified ownership, but each surface owner has an individual interest in the portion of the pool underlying her property. This is the paradigm that common law courts have largely applied, and it is the theory that should govern our understanding of, and legal approach to, horizontal slickwater fracturing. Moreover, now that seismic technology has largely removed the hidden nature of resource pools, courts can move to fully implement the shared resources paradigm, for now the individual shares of the resource pool can be determined with a fair degree of accuracy. Significantly, the shared property theory can largely be implemented through private agreements, rather than legislative or regulatory commission dictates. Because surface owners have a unity of interest and neither their number nor their idiosyncratic interests are great, most of the issues relating to unified exploitation can be worked out by negotiations between surface owners acting reasonably and in good faith, and subject only to judicial review to evaluate the reasonableness of the agreements and to address controversies that cannot be resolved by the owners themselves.

Citation: NPC Global Oil & Gas Study, 'Unconventional Gas' (Working Document of the NPC Global Oil & Gas Study Topic paper No 29, NPC, Made Available July 18, 2007)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Aims & Research Methods: On July 18, 2007, The National Petroleum Council (NPC) in approving its report, *Facking the Hard Truths about Energy*, also approved the making available of certain materials used in the study process, including detailed, specific subject matter papers prepared or used by the Task Groups and their Subgroups. These Topic Papers were working documents that were part of the analyses that led to development of the summary results presented in the report's Executive Summary and Chapters. These Topic Papers represent the views and conclusions of the authors. The National Petroleum Council has not endorsed or approved the statements and conclusions contained in these documents but approved the publication of these materials as part of the study process.

The NPC believes that these papers will be of interest to the readers of the report and will help them better understand the results. These materials are being made available in the interest of transparency. The attached Topic Paper is one of 38 such working documents used in the study analyses. Also included is a roster of the Subgroup that developed or submitted this paper. Appendix E of the final NPC report provides a complete list of the 38 Topic Papers and an abstract for each. The printed final report volume contains a CD that includes pdf files of all papers. These papers also can be viewed and downloaded from the report section of the NPC website (www.npc.org).

Citation: Thomas W. Merrill1 & David M. Schizer, 'The Shale Oil and Gas Revolution, Hydraulic Fracturing, and Water Contamination: A Regulatory Strategy' (March 13 2013) (Draft)

Topic Area: Hydraulic Fracturing and Water Contamination

Jurisdiction: USA

Introduction: In the past decade, energy companies have learned to tap previously inaccessible oil and gas in shale with "hydraulic fracturing" ("fracturing" or "fracking"), pumping fluid at high pressure to crack the shale and release gas and oil trapped inside. This "shale revolution" has created millions of jobs, enhanced our energy independence, and reduced U.S. greenhouse gas emissions by substituting natural gas for coal. Fracturing is controversial, however, because it presents a number of environmental risks. It may undercut the renewable energy industry, exacerbate air pollution and congestion, and use significant amounts of water. The most unique risk, which is the focus of this Article, is the potential contamination of groundwater. The fluid used in fracturing contains toxic chemicals. There is little evidence so far that subterranean fracturing can directly contaminate groundwater, and this risk may never materialize. But there are other ways in which fracturing might contaminate groundwater, including surface spills of fracturing fluid, improper handling of waste, and the migration of natural gas into water wells. Some of these risks are familiar from decades of conventional oil and gas production, while others are new.

Aims & Research Methods: In response, this Article proposes a strategy for regulating water contamination from fracturing. For issues that are already well understood, we would rely on best practices regulations. For issues that are unique to fracturing and are not yet well understood, we would rely on liability rules – and, specifically, a hybrid of negligence per se, res ipsa loquitur, and a regulatory compliance defence – to motivate industry to take precautions, develop risk-reducing innovations, and cooperate in the development of best practices regulations. To facilitate more accurate determinations of causation, we recommend information-forcing rules (e.g., requiring energy companies to test water quality before they begin fracturing). We also suggest other design features for the liability system, such as one-way fee shifting and provisions to ensure that defendants will not be judgment proof. To ensure that the regulatory regime draws on existing regulatory expertise and is both dynamic and tailored to local conditions, we recommend keeping the regulatory centre of gravity in the states, instead of fashioning a new federal regime.

Conclusions: Fracturing is transforming the energy landscape of the United States. By unlocking massive reserves of natural gas and oil in shale beds, fracturing is creating drilling jobs, fuelling a revival of domestic manufacturing, strengthening consumer purchasing power, improving our balance of payments, enhancing our energy independence, and reducing U.S. greenhouse gas emissions.

Yet at the same time, fracturing poses a number of risks. Some arise in conventional oil and gas drilling as well as in other economic activities, such as competition with renewable energy, traffic and congestion, air pollution, the use of significant amounts of water, and the risk of inducing earthquakes. Fracturing also poses unique risks of water contamination, which are the focus of this Article. Although there is only limited evidence of water contamination from fracturing so far, the risks are not yet fully understood and mechanisms for regulating them are not yet fully developed.

In response, we offer a general framework for regulating in the face of uncertainty and apply it to water contamination from fracturing. A core element of our proposal is best practices regulation, which should provide significant reassurance to a public worried about water contamination, as well as predictability to energy companies making large commitments of capital. Since best practices regulations cannot be adopted until we know what the best practices are, we favour such regulation only for issues that are already well understood. This includes the thickness and depth of well casings, the need for liners for storage pits and blowout preventers, and the like. Over time, as we develop more experience, the number of issues governed by such regulations is likely to grow.

Meanwhile, we can encourage the development of a robust best practices regime by backstopping it with liability rules. Under our proposed liability regime, unless an energy company is in full compliance with applicable best practices regulations, it generally would have to pay for any water contamination harms caused by fracturing operations. Such a liability system will motivate energy companies to take precautions and develop risk-minimizing innovations, and will also compensate victims. Moreover, it spares regulators the need to mandate best practices before we know enough about the risks and how to address them. A key challenge in implementing such a liability regime is to make reliable judgments about causation, and we recommend a system of information-forcing rules to inform these judgments, including baseline testing, the disclosure of fracturing chemicals, and possibly also the use of tracer chemicals. We also consider the proper measure of damages, the allocation of attorney fees, the risk that defendants will be judgment proof, as well as other issues.

Finally, we believe our proposed regime should be implemented at the state level. Although this could take the form of new legislation prescribing all desirable elements of the liability regime, a more realistic option, at least in the near term, is to adapt the existing common law of torts to the unique problems posed by fracturing. In our view, this blended strategy – an evolving body of best practices regulation paired with a well-crafted liability regime – can perform the vital function of protecting our water resources, while also harnessing the substantial economic, national security and environmental advantages of the shale oil and gas revolution.

Citation: Nicholas Schroeck & Stephanie Karisny, 'Hydraulic Fracturing and Water Management in the Great Lakes' (2013) 63 *Case Western Reserve Law Review* 1167- 1185

Topic Area: Hydraulic Fracturing and Water Contamination

Jurisdiction: USA

Introduction: The Great Lakes are a truly astounding natural resource. The Lakes are the largest freshwater system on earth, bordering eight American states and two Canadian provinces, and holding approximately 21 percent of the world's freshwater supply.1 About 10 percent of the United States population and 30 percent of the Canadian population live in the Great Lakes Basin, and millions of people depend upon the Lakes for drinking water supply.2 The Great Lakes also support a world-class fishery, with over 250 species of fish, as well as robust tourism, transportation, and agriculture industries within the Great Lakes region.3 Many endangered and threatened animal species make their homes in the unique ecological environment the Great Lakes provide.

Aims & Research Methods: But despite the extensive ecological and economic importance of the Great Lakes, and the formidable protection provided by the Agreement and the Compact, the integrity of this vast water resource is threatened by the practice of high-volume, slick-water hydraulic fracturing (or fracking) in the Great Lakes basin. This technique, used to "stimulate" oil and natural gas wells, allowing for increased production, requires the use of millions of gallons of water and has the potential to cause significant water depletion and aquifer contamination. This Article will look at new ways of utilizing the

Agreement and the Compact to protect the Great Lakes Basin from the environmental hazards posed by fracking.

Scope: Part I provides a brief overview of hydraulic fracturing regulation in United States and Canada, with a focus on the state of Michigan and the province of Ontario. Part II focuses on the ban on new and increased diversions of Great Lakes water in the Agreement and the Compact, and how this ban might be used to protect the Great Lakes from the potentially hazardous practice of fracking. Part II also proposes the promulgation and implementation of new rules and regulations under the Compact by the Great Lakes–St. Lawrence River Basin Water Resources Council, which would promote sustainable energy development in the Great Lakes Region by giving special attention to the protection and conservation of Great Lakes water resources. Finally, this Article concludes that while both the Great Lakes states and the Canadian provinces have made a start at regulating hydraulic fracturing, more work needs to be done in order to create a region-wide, comprehensive regulatory system that will ensure the environmental integrity of Great Lakes water for years to come.

Conclusions: Patchwork management of the hydraulic fracturing process in the Great Lakes region has left huge regulatory gaps at the federal, state, and provincial levels. These gaps leave the Lakes vulnerable to the wide array of possible water resource harms posed by fracking, including aquifer contamination. Selective implementation of provisions in the Agreement and the Compact could fill these gaps and help curb fracking's impact on Great Lakes water, but in order to create a truly comprehensive regulatory system for fracking, more is needed. The Council should apply its powers, granted in the Compact, to promulgate new rules and regulations that will bring the Compact up to date with the Great Lakes Regions' recent shale gas "boom," and ensure that our valuable water resources are being managed according to the spirit of the Compact.

Citation: Kelvin B. Gregory, Radisav D. Vidic, and David A. Dzombak, 'Water Management Challenges Associated with the Production of Shale Gas by Hydraulic Fracturing' (2011) 7 *Elements* 181-186

Topic Area: Water Use, Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: Natural gas plays a central role in meeting the demand for energy around the world. This versatile, readily transportable fossil fuel has long been used for residential and industrial heating, steam production, and thermoelectric power production. While coal remains the dominant fuel source for electric power production, economic, technological, regulatory, and environmental drivers have shifted the focus of new electrical power generation towards natural gas. Currently, natural gas is the fuel source for 21% of electricity production and for 24% of the total energy demand in the United States (EIA 2011). Over the next 25 years, these proportions are expected to remain constant or increase. Global demand for natural gas is on the rise as well. For example, natural gas currently provides 4% of China's energy, and that country's goal is to increase the amount of natural gas used to 8% of the energy supply by 2020 (Peoples Daily Online 2010). The main advantages of natural gas are its widespread availability, its ease of transport, and its efficient and clean combustion. Also, natural gas combustion yields lower emissions of greenhouse gases and other pollutants relative to coal combustion for equivalent amounts of power generation (Jaramillo et al. 2007). To meet the growing demand for natural gas, energy companies have greatly expanded their exploration and development of unconventional natural gas resources, such as coal bed methane, tight sands, and shale gas. The fastest growing source of natural gas is shale gas, which is projected to be the largest contributor to growth in natural gas production in the United States for the next 25 years (EIA 2011). The same is true in many other nations, as recent assessments of global shale gas resources indicate substantial technically recoverable resources in many countries, including China, Argentina, Mexico, South Africa, and others.

Aims & Research Methods: Development of unconventional, onshore natural gas resources in deep shales is rapidly expanding to meet global energy needs. Water management has emerged as a critical issue in the development of these inland gas reservoirs, where hydraulic fracturing is used to liberate the gas. Following hydraulic fracturing, large volumes of water containing very high concentrations of total dissolved solids (TDS) return to the surface. The TDS concentration in this wastewater, also known as "flow back," can reach 5 times that of sea water. Wastewaters that contain high TDS levels are challenging and costly to treat. Economical production of shale gas resources will require creative management of flow back to ensure protection of groundwater and surface water resources. Currently, deep-well injection is the primary means of management. However, in many areas where shale gas production will be abundant, deep-well injection sites are not available. With global concerns over the quality and quantity of fresh water, novel water management strategies and treatment technologies that will enable environmentally sustainable and economically feasible natural gas extraction will be critical for the development of this vast energy source.

Conclusions: Natural gas production from deep shale formations by hydraulic fracturing has been growing exponentially in the United States. With growing global energy demands and expanding discovery of global shale resources, similar trajectories for global shale gas production are expected. Hydraulic fracturing uses thousands of cubic meters of water for fracturing fluid at each well and therefore have the ability to strain local freshwater resources. The water that returns to the surface is a brine solution with very high concentrations of salts, metals, oils, and greases, and it is commonly impounded at the surface prior to treatment, reuse, or disposal. If not responsibly managed, the release of flow back water into the environment can have a range of impacts. While many options are available for the treatment of flow back water, many are limited by high capital and operating costs. The most widely used option for management of flow back water is deep-well injection disposal. However, in regions where deep-well injection sites are not available, a widely practiced alternative is precipitation softening for a partial reduction of TDS, followed by reuse of the flow back in subsequent hydraulic fracturing procedures.

While shale gas appears to be an abundant resource in many countries, it will remain untapped without favourable economics for its production. The economics of shale gas development is a complex multivariate optimization, with water resource management as a critical input. It is important to note that optimized strategies for one basin or locality may not apply in others. Environmental, geographical, geological, economic, social, and political considerations will ultimately determine the water management solutions that will enable production of shale gas resources while protecting that locality's other natural resources.

Citation: Anna Marie Nottmeier, 'Groundwater Quality Assessment from Domestic Water Wells in the Fayetteville Shale Gas Play Area in Central' (Master of Science in Geology thesis, University of Arkansas, 2009)

Topic Area: Groundwater Quality

Jurisdiction: USA

Introduction: Natural gas production has increased from 28% of the United States total natural gas production in 1998 to 46% in 2007, due to the advent of technological advances in horizontal drilling and hydraulic fracturing (Arthur et al., 2008). The natural gas production has increased in unconventional natural gas plays such as shale basins which are located within geologic structural basins created from tectonics that warped once flat lying sediments. The increase in shale gas production across the United States (Figure 1.1) has the public's attention focused on hydraulic fracturing and the potential effects on groundwater quality. Hydraulic fracturing is a method used to stimulate the flow of gas, particularly from low-permeability shale formations, towards a wellbore for extraction. Hydraulic fracturing helps to increase production of natural gas helping to meet the growing demand for energy, and has expanded oil and gas exploration and production activities into areas without a long history of exposure to the industry where residents are unfamiliar and mistrustful of potential problems. In Arkansas, the Fayetteville Shale of the Arkoma Basin (Figure 1.2) is the current primary targeted Formation for natural gas exploration and production. Residents in central Arkansas have expressed concerns about the potential impacts the extensive development and extraction of natural gas from the Fayetteville Shale may have on the aquifers that supply their domestic water wells.

Aims & Research Methods: This study establishes a spatially distributed domestic water well groundwater quality data set, throughout the Fayetteville Shale Gas Play (FSGP) in central Arkansas. The data set facilitates characterization of the geology and groundwater quality across the study area, benefits residents who may have concerns about the potential impacts on their well water quality, and provides a groundwater quality basis to which complaints can be compared and resolved. The assessment included: research of the study area, site reconnaissance, water sampling and collection, interviews with owners of the property, analytical analysis, Quality Assurance and Quality Control, and groundwater data interpretation.

Conclusions: The purpose of the study was to identify domestic water wells to establish a spatially distributed data set of groundwater quality, throughout the Fayetteville Shale Gas Play (FSGP) in central Arkansas. The assessment included: research of the study area, site reconnaissance, water sampling and collection, interviews with owners of the property, analytical analysis, Quality Assurance and Quality Control, and groundwater data interpretation. The groundwater quality data characterized the geology across the study area, and was specifically tied to the varying lithologies within formations. The groundwater data also showed a strong relation to groundwater evolution through the processes of redox and ion exchange, due to direct rock/water interaction.

The collection and interpretation of the data will hopefully provide a baseline to assist residents with concerns about potential impacts on the quality of their groundwater. Based on the data of 105 groundwater samples, all wells were within the USGS's pre-existing groundwater quality parameters for central Arkansas. A few groundwater samples showed outliers possibly due to anthropogenic conditions, laboratory error, and/or field collection issues. Two constituents (iron and manganese) exceeded the EPA's SDW SMCLs in several of the groundwater samples, but pose no health risks to humans. Based on the multivariate statistical analysis, Piper diagrams, and scatter plots, five groundwater clusters and four groupings were recognized. Cluster one and two had the dominate constituents (sodium and calcium-bicarbonate) and Group 1 with the dominate groundwater type (sodium-bicarbonate). Iron, manganese, and sulphate are key constituents in the areas groundwater oxidation-reduction processes. Iron and sulphate have caused residents to be subjected to aesthetically displeasing taste, odour, and stains on fixtures because of the vertical fractures, where groundwater is stored has undergone redox processes in the water wells borehole.

Unlike Clouiter and others (2008) classic groundwater flow system, the study areas Stiff diagrams tells us is that the area shows no discernible pattern because the groundwater quality is controlled by the lithology within each of the well bores and basins. The area does show classic water type end members and accelerated groundwater chemistry evolution and redox conditions which are evident based on the scatter plots, clustering and group analysis, with Cluster one and two having the dominate constituents (sodium and calcium-bicarbonate) and Group 1 with the dominate groundwater type (sodium-bicarbonate). Iron, manganese, and sulphate are also key constituents in the areas groundwater through oxidation-reduction processes that have caused residents to be subjected to aesthetically displeasing taste, odour, and stains on fixtures. The direct rock/water interaction and redox processes that creates the groundwater quality in the study area are controlled by three factors 1) recharge percolating through thin organic rich soils 2) domestic water wells withdrawing from vertical fractures that interact with multiple lithologies dominated by sandstones and shales, and 3) normal south-trending faults and very low permeability in the Western Interior Plains Confining system that results in small isolated basins that are dominated by short lateral flow to seeps and springs. The groundwater quality data for the area exhibits classic water type end members, and shows an accelerated continuum of groundwater chemistry evolution on account of the study areas lithology's highly reactive geochemical properties.

Citation: Hannah J. Wiseman, 'Hydraulic Fracturing and Information Forcing' (2013) 74 *Ohio State Law Journal* 87- 97

Topic Area: Hydraulic Fracturing and Information Disclosure

Jurisdiction: USA

Introduction: The recent, dramatic rise of drilling and hydraulic fracturing for domestic oil and natural gas has highlighted the fact that the United States remains, in certain regions, an industrial economy. In states like North Dakota, there were more active oil wells in 2012 than ever before in the state's history. Two practices are driving this boom in many areas of the United States: horizontal drilling through shales and tight sandstones and the use of slickwater hydraulic fracturing—the pumping of large quantities of water and smaller quantities of chemicals down wells at high pressures.

Natural resource extraction has long driven portions of the U.S. economy, but the recent growth in unconventional oil and gas has led to vocal demands for more and better information. This unusually strong call for data may result from several factors. First, unconventional petroleum development is widespread, with large numbers of wells being drilled in many regions, from North Dakota and Pennsylvania to Arkansas, Louisiana, Colorado, and Texas among other states. And the promise (or threat, depending on one's perspective) of abundant unconventional fuel reaches farther. California might have even larger shale oil reserves than North Dakota, and oil and gas companies are still ascertaining the quantities of gas in the Utica Shale underlying Ohio, New York, and other nearby states. Still other states are feeling the indirect effects of this boom, with Minnesota and Wisconsin experiencing extensive sand mining, which provides the proppant that holds open fractures in formations once they are created.

Unconventional oil and gas development also involves large numbers of small facilities—thousands of several-acre sites, some of which are, literally, in people's backyards. The sheer number of wells contributes to habitat fragmentation and threatens the contamination of soil, water resources, and air in the many areas in which drilling and fracturing are now occurring. It also may call more attention to this industry as energy companies develop wells in rural, suburban, and urban communities.

Aims & Research Methods: This short essay explores three ways in which unconventional petroleum development has begun to force the systematic production and recording of data, which could lead to broader information forcing efforts. Part I provides examples of efforts to collect baseline contamination data in certain regions and around well sites, and Part II discusses certain requirements for disclosure during development, including disclosure of the chemicals and quantities and sources of water used in hydraulic fracturing. Readers should note that this is not a comprehensive regulatory survey. Rather, it provides limited examples of some states' requirements. Finally, Part III briefly introduces post-development sampling and studies of the impacts of drilling and fracturing. The essay concludes that much more must be done if we are to systematically and effectively measure the impacts of the unconventional petroleum boom, but that the boom may inspire broader information forcing reforms. Particularly where large baseline surveys are conducted, this could aid other efforts to identify the causes of contamination, beyond oil and gas drilling. And the proliferation of thousands of new oil and gas sites might lead us to finally implement widespread automated monitoring of small sources of pollution. The impact remains to be seen, but the public demand for data presents a rare window of opportunity.

Conclusions: In a world with no cost limitations, we would know the exact state of the environment in a given region prior to drilling and fracturing—the amount of industrial and residential development (and associated pollution) that already has occurred; existing human populations in the area and their current health status; plant and animal species in the area; habitat fragmentation, average air quality for each regulated air pollutant; and current water quality as measured by the concentration of every potential substance that could enter water as a result of drilling and fracturing. We would then identify and record data on the types and area of habitat affected by new development, the types and numbers of species impacted, the types and volumes of chemicals and wastes spilled and total area affected by the spill, and the types and quantities of air pollutants emitted at each site. We would also assess the extent to which human health in the area had been impacted. Finally, post-development surveys might comprehensively assess the extent of total air pollution and soil and/or water contamination as well as any long-term impacts that would be difficult to remedy, such as a plume of highly persistent pollution within a relatively inaccessible aquifer.

The information forcing regulations and voluntary disclosure efforts emerging in the area of unconventional oil and gas development do not come close to this level of detail—in part likely due to the costs of monitoring and disclosure and more pressing regulatory priorities, and, in some cases, resistance from industry actors. But existing laws and studies do show that public agencies, and industry itself, are beginning to pay more attention to the need for information at all stages—before, during, and after development. And some of the information being collected, such as baseline water surveys, might be useful in the future to assess a broad range of environmental impacts—not just those from oil and gas development. Further, the move toward monitoring well operations as they occur could lead us somewhat closer to the world of data collection envisioned by Daniel Esty, in which small technological devices would continuously monitor the impacts of a range of activities. Currently, we tend to monitor only large pollution sources—through continuous emissions monitoring devices installed at large stationary facilities that emit air pollution, for example. The public demand for more information about activities happening at each of the thousands of well sites around the country might lead us toward micro monitoring, however, which could be applied in other industries. Why not install water-quality monitors below farms, for example, to measure manure, fertilizers, pesticides, and other pollutants running off of thousands of acres of fields? Why not place magnetized, digital emissions monitors on the tailpipes of cars? While there will of course be a range of objections to this type of pervasive information collection, it could move us toward a world of more and better information about the impacts of our many activities, from oil and gas development to growing thousands of acres of crops. Information forcing in oil and gas, although nascent, might be an initial step toward a world with better and more extensive data to guide industry behaviour, and public responses.

Citation: Rebecca Nelson, 'Unconventional gas and produced water' (Draft) *Stanford University SJD Candidate*

Topic Area: Groundwater Law

Jurisdiction: Global

Introduction: Producing unconventional gas, particularly coal seam gas (CSG), is a thirsty business. It involves releasing the gas by dewatering or depressurising the aquifer containing the gas. This can cause a variety of water impacts—depleting aquifers and streams connected to those aquifers, changing groundwater quality, changing the water quality and flow regimes of any rivers into which "produced water" is disposed, and affecting the structure of any aquifers subject to hydraulic fracturing to increase gas production. Public concerns and government inquiries show that these potential water impacts are a key challenge to gaining acceptance for unconventional gas developments—and realizing the potential contribution of Australia's CSG and our largely untouched shale gas and tight gas reserves to our energy supplies. And this is so for good reason: not dealing with these impacts risks inadvertently allowing severe and potentially irreversible impacts on the environment and other water users. The lack of robust law and policy for controlling these impacts also precludes the creation of a secure and certain investment environment for aspiring proponents of unconventional gas projects.

Aims & Research Methods: This review recommends that law and policy dealing with the extraction of produced water should:

- include produced water within regular water licensing frameworks that cover other groundwater-using activities, like irrigation, to ensure comprehensive water management and equity in relation to water use;

- assess the impacts of withdrawing produced water before a particular development occurs, in a way that:
    - is comprehensive as to the range of water users and values that could be affected;
    - uses regional models capable of assessing cumulative impacts, funded by CSG proponents;
    - uses public and private data;
    - involves collaborative, strategic data collection between companies and governments at a regional scale;
    - applies a middle-road, "slow down and learn" approach to risk assessment, that neither bans production, nor charges ahead in the face of potentially very serious and uncertain impacts;
- Require CSG proponents to mitigate water impacts felt by people who use groundwater or surface water connected to affected aquifers, as well as environmental flows in affected rivers, springs, and other impacted groundwater-dependent ecosystems—in a way that is robust in light of time-lagged and cumulative impacts.

This review draws from US experience relating to CSG and shale gas. Although key differences separate the Australian and US regulatory contexts,[i] US experience can usefully indicate key points of contention that law and policy must aim to resolve, as well as highlight potentially valuable policy mechanisms for doing so. These mechanisms include water allocation laws that include CSG activities, laws that better protect holders of rights to surface waters that are affected by CSG development, and broad requirements to mitigate water impacts.

Conclusions: Withdrawing produced water poses a number of important challenges for Australian law and policy for CSG. Whether to integrate produced water into regular water allocation frameworks is a fundamental issue. Considerations of national policy, the requirements of comprehensive resources management, and public perceptions of equity all recommend this course. Recent NSW law as well as some western US states have taken this path. Assessing the impacts of produced water withdrawals is complicated by the interacting factors of uncertainty, time lags, and cumulative impacts. An "integrated risk management" framework offers promise for dealing with these challenges by running a middle course between ordinary risk assessment procedures and blunt calls for moratoria on CSG development. Finally, mitigation arrangements in Australia aim to deal with impacts of withdrawing produced water on consumptive groundwater users, but this narrow scope does not sufficiently cover those potentially affected, nor a full range of ecosystems that may be impacted. These arrangements should be broadened to ensure that potential impacts are reduced or offset as far as possible.

REGULATION, GUIDELINES AND POLICY

Citation: API Guidance Document HF1 First Edition, *Hydraulic Fracturing Operations- Well Construction and Integrity Guidelines* (2009)

Topic Area: Hydraulic Fracturing Activities, Well Design, Construction and Abandonment

Jurisdiction: USA

Aims & Research Methods: The purpose of this guidance document is to provide guidance and highlight industry recommended practices for well construction and integrity for wells that will be hydraulically fractured. The guidance provided here will help to ensure that shallow groundwater aquifers and the environment will be protected, while also enabling economically viable development of oil and natural gas resources. This document is intended to apply equally to wells in either vertical, directional, or horizontal configurations.

Scope: Many aspects of drilling, completing, and operating oil and natural gas wells are not addressed in this document but are the subject of other API documents and industry literature (see Bibliography). Companies should always consider these documents, as applicable, in planning their operations. Maintaining well integrity is a key design principle and design feature of all oil and gas production wells. Maintaining well integrity is essential for the two following reasons.

1) To isolate the internal conduit of the well from the surface and subsurface environment. This is critical in protecting the environment, including the groundwater, and in enabling well drilling and production.

2) To isolate and contain the well's produced fluid to a production conduit within the well.

Although there is some variability in the details of well construction because of varying geologic, environmental, and operational settings, the basic practices in constructing a reliable well are similar. These practices are the result of operators gaining knowledge based on years of experience and technology development and improvement. These experiences and practices are communicated and shared via academic training, professional and trade associations, extensive literature and documents and, very importantly, industry standards and recommended practices.

Conclusions: Throughout the life of a producing well, the well conditions should be monitored on an ongoing basis to ensure integrity of the well and well equipment. Mechanical integrity pressure monitoring is used to determine the mechanical integrity of tubulars and other well equipment when the well is producing and during fracturing operations. Initially during well drilling, positive pressure tests that are part of normal well construction determine the casing and casing shoe integrity—as noted earlier in this document. During well fracturing, casing integrity is inferred by showing there is no leakage into the "A" annulus (if a frac string is used), or between the "A" annulus and "B" annulus by monitoring these pressures. After fracturing and upon final completion the tubing/packer integrity is demonstrated by showing there is no leakage of injected fluids through the tubing or packer into the "An" annulus causing pressure build-up.

It is important to monitor these annular pressures during production to determine if there are potential leaks. If an annulus is being charged with gas, an analysis of the gas content may give an indication of the source and the nature of a potential leak.

Maximum and minimum allowable annular surface pressures should be assigned to all annuli and these should consider the gradient of the fluid in each. These upper and lower limits establish the safe working range of pressures for normal operation in the well's current service and should be considered "do not exceed" limits.

Wellhead seal tests are conducted to test the mechanical integrity of the sealing elements (including valve gates and seats) and determine if they are capable of sealing against well pressure. If non-normal pressures are noted in an annulus, a repressure test of the wellhead seal system can help determine if the source of communication is in the surface in the wellhead system. When equipment is removed from a well or depressurized for maintenance, a breakdown or visual inspection should be conducted to document the condition of the equipment after being in service. For example, if tubing is pulled from a well, it can be inspected for corrosion/erosion damage. While the tubing is out of the well, a casing inspection log can be considered to verify the casing condition. Regular visits by lease operators/well pumpers should identify any abnormal well conditions and should be used to monitor well pressures.

This regular inspection of the casing head equipment and annulus pressures will readily indicate any leaks between any of the casing strings. In addition to wellhead pressures, gas, oil, and water production rates should be regularly monitored. This data is can be analysed by engineers and help identify any anomalous behaviour or problems.

Citation: API Recommended Practice 51R First Edition, *Environmental Protection for Onshore Oil and Gas Production Operations and Leases* (July 2009)

Topic Area: Environmental Protection, Production Operations and Leases, Well Design and Construction

Jurisdiction: USA

Introduction: Before drilling or construction, and, in some instances, before modification of onshore oil and gas production facilities, it may be necessary to obtain approvals from one or more government agencies. In addition to drilling and building permits, permits may be required because of air emissions, discharges to surface waters or sewer systems, injection activities, stormwater discharges (including during construction activities), impacts to threatened or endangered species or their critical habitat, impacts to wetlands and other environmental impacts, or impacts to other cultural resources. Operators should ensure that all necessary permits have been obtained before commencing operations. Operators should ensure that operations are conducted in accordance with local, state or federal regulatory requirements.

Aims & Research Methods: This standard provides environmentally sound practices for domestic onshore oil and gas production operations. It is intended to be applicable to contractors as well as operators. Facilities within the scope of this document include all production facilities, including produced water handling facilities.

Scope: Offshore and arctic areas are beyond the scope of this document. Operational coverage begins with the design and construction of access roads and well locations, and includes reclamation, abandonment, and restoration operations. Gas compression for transmission purposes or production operations, such as gas lift, pressure maintenance, or enhanced oil recovery (EOR) is included; however, gas processing for liquids recovery is not addressed. Annex A provides guidance for a company to consider as a "good neighbour."

Citation: API, *Overview of Industry Guidance/ Best Practices on Hydraulic Fracturing* (2011)

Topic Area: Hydraulic Fracturing Activities and Guidelines

Jurisdiction: USA

Introduction: Industry, working through organizations like the American Petroleum Institute (API), has a long history of developing consensus based "best practices." These best practices are developed by industry experts in a variety of areas of technology and operations and go through a rigorous review process before being adopted. They are then evaluated regularly to incorporate evolving technology and operational practices.

Aims & Research Methods: Building on existing API standards and practices pertaining to oil and gas extraction, we have developed a set of 5 documents which specifically address the risk management issues accompanying unconventional well construction and management.

Conclusions: These robust practices help to protect the public by providing a blueprint for strong, carefully tended wells. They were created to meetor exceed federal requirements while remaining flexible enough to accommodate the variations in state regulatory frameworks that often occur due to fundamental differences in regional geology and other factors.

Citation: United States Department of the Interior Bureau of Land Management and United States Department of Agriculture Forest Service, *Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development The Gold Book* (4th ed, 2007)

Topic Area: Surface Operating Standards and Guidelines

Jurisdiction: USA

Aims & Research Methods: *The Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development* (commonly referred to as The Gold Book) was developed to assist operators by providing information on the requirements for obtaining permit approval and conducting environmentally responsible oil and gas operations on Federal lands and on private surface over Federal minerals. Operations include exploration, production, reclamation, associated rights-of-way (ROWs), and Special Use Authorizations (SUAs).

Scope: The Gold Book provides operators with a combination of guidance and standards for ensuring compliance with agency policies and operating requirements, such as those found in the Code of Federal Regulations at 43 CFR 3000 and 36 CFR 228 Subpart E; Onshore Oil and Gas Orders (Onshore Orders); and Notices to Lessees (NTLs). Agency field offices and websites can provide more detailed discussions of specific procedures and requirements and copies of regulations, Onshore Orders, Notices to Lessees, and other agency policies currently in effect. Every operation authorized under a Federal oil and gas lease should conform to USDI Bureau of Land Management (BLM), USDA Forest Service (FS), or other agency standards and reflect relevant, site-specific conditions. Knowledge of BLM resource management plans (RMPs) and FS land and resource management plans, as well as agency operational standards, procedures, and environmental protection requirements will help operators meet those standards.

Citation: API STANDARD 65—PART 2 SECOND EDITION, *Isolating Potential Flow Zones During Well Construction* (December 2010)

Topic Area: Well Construction and Design, Environmental issues

Jurisdiction: USA

Introduction: This standard contains practices for isolating potential flow zones, an integral element in maintaining well integrity.

Aims & Research Methods: The objectives of this guideline are two-fold. The first is to help prevent and/or control flows just prior to, during, and after primary cementing operations to install or "set" casing and liner pipe strings in wells. Some of these flows have caused loss of well control. They threaten the safety of personnel, the environment, and the drilling rigs themselves. The second objective is to help prevent sustained casing pressure (SCP), also a serious industry problem. API RP 90, provides guidelines on managing annular casing pressure (ACP) including SCP, thermal casing pressure, and operator-imposed pressure. These guidelines include monitoring, diagnostic testing, establishing the maximum allowable wellhead operating pressure (MAWOP), documenting annular casing pressure, and risk assessment methodologies.

Scope: The focus of this standard is the prevention of flow through or past barriers that are installed during well construction. Barriers that seal wellbore and formation pressures or flows may include mechanical barriers such as seals, cement, or hydrostatic head, or operational barriers such as flow detection practices. Operational barriers are practices that result in activation of a physical barrier. Though physical barriers may dominate, the total system reliability of a particular design is dependent on the existence of both types of barriers.

Citation: NSW Government, *Trade & Investment Resources & Energy*, *Code of Practice for Coal Seam Gas Fracture Stimulation Activities* (September 2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: Australia (NSW)

Aims & Research Methods: This Code has been developed by the NSW Government in consultation with the CSG industry. This Code is designed to ensure that fracture stimulation activities are conducted in a safe manner and that communities, the environment and water resources are protected.

Scope: This Code applies to the conduct of CSG fracture stimulation activities. It does not apply to fracture stimulation activities conducted for other purposes (such as conventional petroleum, shale gas, geothermal or geosequestration), except at the discretion of the department. This Code should be read in conjunction with the NSW Code of Practice for Coal Seam Gas Well Integrity, as both Codes regulate CSG fracture stimulation in NSW.

The regulatory requirements of this Code are set out under the heading Requirements for Fracture Stimulation

Activities and are broadly organised to correspond with the design, planning, operational and post-operational phases of a fracture stimulation activity.
Further sub-headings identify the nature of the specific requirements applying to each phase of fracture stimulation activity:
• Principles – set out the objectives of the requirements and expected outcomes
• Mandatory requirements – define regulatory requirements (minimum standards)
• Leading practice – outline aspirational standards which are expected to be targeted by NSW CSG titleholders.

Citation: NSW Government, *Trade & Investment Resources & Energy*, *Code of Practice for Coal Seam Gas Well Integrity* (September 2012)

Topic Area: Well Integrity, Design and Construction

Jurisdiction: Australia (NSW)

Aims & Research Methods: The NSW Code of Practice for Coal Seam Gas Well Integrity has been developed by the NSW Government in consultation with the CSG industry. This code provides a practical guide for coal seam gas (CSG) titleholders on how to comply with a condition of title for CSG exploration, extraction or production under the Petroleum (Onshore) Act 1991 (PO Act) and the Petroleum (Onshore) Regulation 2007 to ensure that well operations are carried out safely, without risk to health and without detriment to the environment

Scope: Section 23 of the Petroleum (Onshore) Act 1991 provides for conditions of title which may be imposed by the Minister or prescribed by the regulations. The current version of the legislation is at: www.legislation.nsw.gov.auThis code of practice applies to the design, construction, production, maintenance and ultimate abandonment of CSG wells in NSW. This code sets out activities, actions, technical requirements, responsibilities or responses to events. This document should also be read alongside the NSW Code of Practice for Hydraulic Fracture Stimulation Activities, to form part of a regulatory framework for the CSG industry in NSW.
These guidelines are an essential minimum set of requirements to ensure that:
• The health and safety of workers, landholders and other persons is not put at risk arising from well operations, so far as is reasonably practicable
• Risks to the environment (surface water and groundwater, air, vegetation, fauna) are identified, eliminated where possible or minimised through appropriate management practices
• Water used in well operations is properly sourced (refer to section 4.5 of this document. Also refer to the NSW Code of Practice for Hydraulic Fracture Stimulation Activities)
• Waste products are safely and appropriately managed (refer to section 4.5 of this document. Also refer to the NSW Code of Practice for Hydraulic Fracture Stimulation Activities)
• Landholders, local councils and relevant authorities (including the department) are notified of specified well operations in a timely manner
• Regulatory requirements are understood and implemented. This document is designed to be considered in conjunction with the operator's internal risk assessment processes and operating procedures. Title holders will have met the requirements of the environmental impact assessment process required under Parts 41 and 5 of the Environmental Planning and Assessment Act 1979 including, where required, the Review of Environmental Factors for petroleum prospecting. This code of practice may also apply to other types of petroleum wells at the discretion of the department.

This includes existing exploration and production approvals under former Part 3A of the EP&A Act IV Code of Practice for Coal Seam Gas

The following types of drilling do not fall within the meaning of a coal seam gas well to which this Code applies:
• seismic shot holes
• tiltmeter and monitoring bores
• water monitoring bores
• Exploration holes demonstrated by risk assessment (eg. likelihood of high pressures, presence of shallow depth hydrocarbons, whole instability) and scientific or technically sound analysis to be 'frontier exploration' holes.

Citation: NSW Government, *Draft Code of Practice for Coal Seam Gas Exploration* (March 2012)

Topic Area: Land Use, CSG Exploration

Jurisdiction: Australia (NSW)

Aims & Research Methods: On 6 March 2012, the Minister for Planning & Infrastructure, together with the Minister for Resources and Energy, announced the release of a draft Code of Practice for Coal Seam Gas Exploration **(**‘the Draft Code’**).**

The Draft Code is part of the NSW Government’s Strategic Lands package. Under that package, Strategic Regional Land Use Plans will be released and ‘define land use priorities for different areas of land within the region. The plans will identify the best places for agriculture, mining, CSG extraction …and all other types of land use.’ The plans, together with the Draft Code, aim to address community concerns about environmental standards for coal seam gas exploration and safeguard high-quality agricultural land and water resources

Conclusions: The Draft Code sets out a best practice framework for coal seam gas exploration companies to follow in dealing with landholders and the community.

The Draft Code contains the following guidelines:

1. A process for communicating with Landholders

- Coal Seam Gas (**‘**CSG’) exploration companies (**‘**Explorers’) should make contact with the landholders in the area where exploration activities are proposed.
- In relation to landholders who are willing to negotiate the use of their land for CSG exploration, further discussion should be followed up by the preparation of an Access Arrangement.
- An Access Arrangement is an agreement between the landholder and the Explorer which establishes the ground rules for an Explorer’s access to a property.
- Compensation arrangements are also dealt with under the Access Arrangement. Compensation relates to both the reasonable costs incurred in negotiating and making the Access Arrangement, and compensation to offset the inconvenience, noise and deprivation of part of the land.
- Further requirements of an Access Arrangement are set out under the *Petroleum (Onshore) Act 1991* and the Draft Code.
- A standard Access Arrangement template is being prepared by NSW Farmers’ Association and the Australian Petroleum Production and Exploration Association.

2. Communication with the Community

- The community should be engaged at an early stage of the exploration process. The exact timing of community engagement will depend on individual circumstances.
- The Draft Code recommends that community engagement should occur before any Access Arrangements are signed.
- The Draft Code lists the qualities of ‘Good Consultation’. The list includes *‘making sure all stakeholders are aware of any real or potential impacts’* and *‘setting up channels of communication that allow…feedback.*‘
- The Explorer will be required to set up a record of community engagement.
- The Explorer will also be required to publish either annual or quarterly exploration activity reports on their website, and in addition provide a copy to their relevant local Council.

- The Explorer is to give the relevant local Council, or Councils, a minimum of six (6) months' notice of an intention to start an exploration program within the local Council area.

3. *Protection of Water*

- The NSW Government is concerned to ensure '*that the State's water resources are adequately protected while the State's abundant reserves of natural gas are developed for the benefit of all*.'
- In relation to the disposal of CSG water, the NSW Government is developing a Managed Aquifer Recharge Policy which will regulate the re injection of water into aquifers.
- In addition to this, Stage One of the Aquifer Interference Regulation was released in June 2011. This regulation places requirements on Explorers to obtain water access licenses.
- The NSW Government is also developing standards for well construction which explorers will be obliged to follow under the Draft Code.

Citation: NSW Government, Strategic Regional Land Use Policy, *Fact Sheet-Land and Water Commissioner* (March 2013)

Topic Area: Strategic Agricultural Land Use Policy, Hydraulic Fracturing, Other Social Issues, Land Use

Jurisdiction: Australia (NSW)

Aims & Research Methods: This fact sheet provides information that the NSW Government has appointed a Land and Water Commissioner to provide independent advice to the community regarding exploration activities on Strategic Agricultural Land throughout the State. The role of the Land and Water Commissioner is to build community understanding of the coal seam gas industry in NSW. The Commissioner will facilitate greater consultation between government, community and industry. The Commissioner will also be responsible for overseeing the finalisation of the standardised land access agreements which are being developed in conjunction with key agricultural sector and minerals/petroleum industry representatives.

Conclusions: The fact sheet outlines that the Commissioner will:
a. Provide guidance to landholders and the community in relation to:
• applications for mineral and petroleum (including coal seam gas) exploration licences throughout the State
• exploration activities throughout the State
• Strategic Regional Land Use Plans
• regulatory approval and assessment processes
• compliance and enforcement matters (eg compliance with exploration licence conditions)
• landowner rights, access agreements and compensation
• the rights and responsibilities of exploration companies

b. Oversee land access agreements by:
• supervising the finalisation and implementation of standard land access agreements for mineral and petroleum exploration;

• collating and publishing general remuneration information to assist parties in relation to negotiations on land access agreements; and
• appointing a mediator if requested by either party.

c. Provide advice to Government on applications for exploration or production activities by:
• providing advice as part of the assessment process on all proposed exploration drilling and 'extractive' exploration activities on SAL (representing landholder concerns and agriculture impacts);
• responding to concerns raised in relation to determinations on exploration activity by reviewing the process to ensure compliance with policy, regulations and the relevant Acts; and
• providing advice on all CSG exploration wells outside mapped areas as an interim arrangement pending completion of mapping processes in unmapped regions.

Citation: NSW Government, *Strategic Regional Land Use Plan- New England North West* (September 2012)

Topic Area: Strategic Agricultural Land Use Policy, Hydraulic Fracturing, Other Social Issues, Land Use

Jurisdiction: Australia (NSW)

Aims & Research Methods: The New England North West Strategic Regional Land Use Plan represents one component of the Government's broader Strategic Regional Land Use Policy which comprises multiple initiatives being staged over time to address land use conflict in regional areas, particularly focused on managing coal and coal seam gas issues. The plan provides a clear strategic framework for the New England North West region, delivering the necessary context for Government investment priorities, servicing strategies and local environmental plan making.

The plan is a whole of Government plan which has been developed in consultation with a range of stakeholders, including local government and the Strategic Regional Land Use Policy Stakeholder Reference Group. The Stakeholder Reference Group includes representatives of the Association of Mining Related Councils, Total Environment Centre, NSW Minerals Council, Australian Petroleum Production and Exploration Association, NSW Farmers Association, Nature Conservation Council of NSW, NSW Irrigators Council, Hunter Valley Wine Industry Association, and Thoroughbred Breeders of the Hunter Valley.
The draft Strategic Regional Land Use Plans for the New England North West and the Upper Hunter were exhibited for public comment from 8 March to 14 May 2012. During this time approximately 1,600 written submissions were received. A public forum and four drop-in sessions were held across the New England North West. In addition, online forums were set up on the Department of Planning and Infrastructure's website which received more than 5, 700 page views.

Scope: This plan outlines a range of key challenges facing the New England North West region and lists clear actions to address these challenges.

Conclusions: This plan outlines a range of key challenges facing the New England North West region and lists clear actions to address these challenges.

While the region is a highly productive agricultural region, it also has rapidly developing coal and coal seam gas industries. The plan includes maps of the region's mineral resources and areas of strategic agricultural land. Strategic agricultural land includes both land with unique natural resource characteristics, known as biophysical strategic agricultural land, and clusters of significant agricultural industries that are potentially impacted by coal seam gas or mining development, known as critical industry clusters. While there are a number of important agricultural industries in the region, they do not meet all the critical industry cluster criteria. Accordingly, there are no critical industry clusters in the New England North West.

The key policy response for resolving land use conflict between mining and coal seam gas proposals and agricultural land is the Gateway process. Under the Gateway process, mining and coal seam gas proposals that are located on strategic agricultural land will have their impacts on agricultural land and water resources rigorously assessed by a panel of independent experts before a development application can be lodged. This will include an assessment of potential aquifer impacts based on the advice of the Minister for Primary Industries and the Commonwealth Independent Expert Scientific Committee.

If the panel considers that the proposal does not meet the Gateway criteria relating to agricultural and/or water impacts, it can issue a conditional Gateway Certificate. Any such conditions will be tailored to address the panel's issues in relation to the potential impacts of the proposal on agricultural land and water. Conditions could include, for example, the requirement for additional environmental studies or physical amendments to the project to avoid or minimise impacts. These conditions must then be comprehensively addressed through the assessment and determination of the relevant development application. This process will deliver greater balance and rigour to the assessment process and ensure that the impacts of mining and coal seam gas proposals on agriculture and water resources are assessed at a much earlier stage.

Key infrastructure issues are identified, particularly those relating to the growth of the mining industry. These issues include road and rail capacity and increased demand for health and social services. A key action is the delivery of a fully costed infrastructure plan for the region.

The economic benefits and impacts associated with the growth of the mining industry are addressed. Issues include the uneven distribution of economic growth and impacts on other industries in terms of access to labour supply, land and infrastructure. A key action is the preparation of Regional Workforce Plans that will set out skills and workforce development strategies, including apprenticeship programs, to address labour shortages.

Land supply and housing issues are highlighted, particularly associated with growth of the mining industry. New and more varied housing will be needed to cater for the expected population growth. Housing affordability across the region varies. There is likely to be ongoing demand for short-term accommodation and temporary housing. The plan commits the Government to working with the housing and development industry on models for delivering more housing for the region and a more diverse range of housing types.

The plan outlines a comprehensive suite of actions aimed at minimising the impacts of mining and coal seam gas, including air quality and noise, on community health and amenity.

These actions include the establishment of an air quality monitoring network in the region, development of a cumulative impact assessment methodology for mining and coal seam gas development, and the preparation of a development assessment guideline on the health risks associated with dust.

The plan describes the region's natural environment, with a focus on the Southern Gunnedah Basin where most mining and coal seam gas activity is proposed. A database of existing biodiversity offsets which have been achieved in the region will be completed. Natural Hazards and Climate Change The plan identifies likely future weather patterns and challenges for the region, including increased flooding and bushfire events. The actions commit Government to working with local councils and industry to avoid flood and bushfire prone development and to encourage low emission energy development. Cultural Heritage The region is rich in both Aboriginal and historic cultural heritage, however urban and mining growth have the potential to further impact on known and yet to be identified cultural heritage places, objects and landscapes. Actions include the completion of Aboriginal cultural heritage landform mapping and the compilation of a database of lands currently identified for cultural heritage conservation in the region.

Citation: NSW Government, *NSW Coal and Gas Strategy- Scoping Paper* (February 2011)

Topic Area: Sustainable Development, Land Use, Other Social Issues, Hydraulic Fracturing

Jurisdiction: Australia (NSW)

Aims & Research Methods: In July 2010, the Government formed a Ministerial Sub-Committee to lead the development of a Coal & Gas Strategy for NSW.

This Sub-Committee comprises the Ministers for Planning (Chair), Primary Industries, Health, Climate Change and the Environment, and the Treasurer.
The main aims of the Strategy are to:
•Guide the sustainable development of the coal mining and coal seam gas industry and associated infrastructure;
• Minimise the adverse health, environmental, agricultural and land use impacts of the industry;
• Ensure the industry is regulated efficiently and effectively; and
•Strengthen the communication between Government, industry and the community on mining-related matters.

This Scoping Paper has been prepared to:
•Provide a brief overview of the coal and coal seam gas industry, its place in the
State and regional economies and its potential growth prospects over the next 25 years, especially in response to the expected increase in global energy demand;
•Identify the key environmental, economic, social, and health issues likely to be associated with growth in the coal mining and coal seam gas industry, and initiatives already being taken by the Government to address these issues;
•Outline key additional initiatives that could be taken to manage this growth so the benefits are maximised and the costs and impacts minimised; and

•Promote community and stakeholder discussion to provide input to the development of the Strategy.

Conclusions: Overall, the Strategy concludes that it will address four areas:
•Facilitate sustainable development of the coal mining and coal seam gas industries and associated activities;
•Identify and minimise any adverse health, environmental and land use impacts associated with development of the industry;
•Ensure the industry is regulated efficiently and effectively; and
•Strengthen the communication between Government, industry and the community on mining-related matters.

Citation: NSW Government, *Strategic Regional Land Use Policy, Fact Sheet, Aquifer Interference Policy* (September 2012)

Topic Area: Sustainable Development, Aquifer Policy, Land Use

Jurisdiction: Australia (NSW)

Aims & Research Methods: The Aquifer Interference Policy is a new policy which defines the protection of NSW underground water resources and strikes a balance between the water use requirements of towns, farmers industry and the environment. A key plank of the NSW Government's Strategic Regional Land Use Policy, the Aquifer Interference Policy details how potential impacts to aquifers should be assessed, and how this information is provided to the relevant planning process, including the Gateway Panel and/or the Planning Assessment Commission.

Conclusions:
THE AQUIFER INTERFERENCE POLICY

- Will apply across the State to clarify water licence and impact assessment requirements for aquifer interference activities;
- Ensures equitable water sharing among different types of water users;
- Ensures that water taken by aquifer interference activities is properly licensed and accounted for in the water budget and water sharing arrangements; and
- Enhances existing regulation, resulting in a comprehensive framework to protect the rights of all water users and the environment.

FOR THE FIRST TIME THERE ARE OBJECTIVE MEASURES TO ASSESS AQUIFER IMPACTS

- The policy objectively defines the process through which the NSW Office of Water will assess projects to determine any potential impacts on aquifers.
- These 'minimal impact considerations' include the risk of seepage between aquifers, impacts on the water table, water pressure levels and water quality changes in different types of groundwater systems.
- Protection of alluvial aquifers and their highly connected surface water systems will be considered.

Citation: NSW Government, Department of Primary Industries Office of Water, *NSW Aquifer Interference Policy* (September 2012)

Topic Area: Sustainable Development, Aquifer Policy, Land Use

Jurisdiction: Australia (NSW)

Aims & Research Methods: The purpose of this Aquifer Interference Policy ("this Policy") is to explain the role and requirements of the Minister administering the *Water Management Act 2000* ("the Minister") in the water licensing and assessment processes for aquifer interference activities under *the Water Management Act 2000* and other relevant legislative frameworks.

This Policy:
1. Clarifies the requirements for obtaining water licences for aquifer interference activities under NSW water legislation; and
2. Establishes and objectively defines considerations in assessing and providing advice on whether more than minimal impacts might occur to a key water-dependent asset. Importantly, this Policy will assist proponents of aquifer interference activities in preparing the necessary information and studies to be used by the Minister in the assessment of project proposals that have some level of aquifer interference. Furthermore, this Policy will form the basis of the assessment and subsequent advice provided by the Minister (or the NSW Office of Water) at the various stages of an assessment under the *Environmental Planning and Assessment Act 1979*.

Conclusions: Aquifer interference activities may or may not take water from the water source in which they occur. They may take water from connected groundwater and surface water sources. Water is taken when it is specifically required to be used as part of an activity, for example the washing or processing of ore. Water is also taken incidentally where the take is required to allow the effective and safe operation of the activity, for example dewatering to allow mining or coal seam gas extraction. In all cases, the activity is taking water from a water source. Many of these water sources are at or near full commitment and have extraction limits set by water sharing plans. If there is unaccounted take, less water is available for the environment and other users that have a legal right to access water in the aquifer or connected water sources.

To comply with extraction limits set by water sharing plans it is important that the volumetric take of water by aquifer interference activities is appropriately licensed and accounted for.
Section 2 of this Policy covers water licensing requirements under the *Water Act 1912* or *Water Management Act 2000*. Mining and coal seam gas development proposals on strategic agricultural land will need to be assessed by a gateway panel before they can proceed to development application lodgement. Part of this assessment requires consideration of the impacts of the proposal on aquifers against the Aquifer Interference Policy. Further information on the gateway process can be found at http://www.planning.nsw.gov.au/ nothing in this Policy exempts an activity from any requirement to obtain an Environmental Protection Licence under the *Protection of the Environment Operations Act 1997* in relation to waste disposal and preventing and minimising pollution of water or land.

Citation: NSW Government, *CSG Regulation in NSW Fact Sheet* (March 2012) Version 2

Topic Area: Hydraulic Fracturing, Other Social Issues

Jurisdiction: Australia (NSW)

Introduction: Coal seam gas (CSG) exploration and production is highly regulated and involves multiple governmental agencies and numerous pieces of legislation. The main legislation relating to CSG is the Petroleum (Onshore) Act 1991 (the Petroleum Act) and the Environmental Planning and Assessment Act (NSW) 1979 (the EP&A Act). All government agencies insist on environmentally acceptable outcomes during exploration appraisal and production. Licences for coal, mineral and petroleum exploration may be granted simultaneously over the same piece of land by the government, referred to as overlapping tenure. Note that mining licences are regulated by the NSW Mining Act (1992).

Aims & Research Methods: This Fact Sheet provides information regarding Petroleum Licensing, Petroleum Exploration Licences, Petroleum Assessment and Production Leases, Environmental Planning and Assessment Act (NSW) 1979 and Social Licences to Operate in NSW.

Citation: NSW Government, *Coal Seam Gas Protections and Controls* (2013)

Topic Area: Hydraulic Fracturing

Jurisdiction: Australia (NSW)

Aims & Research Methods: This fact sheet provides information on the NSW Government's policy framework which is aimed at balancing the growth of the CSG industry with the need to protect our environment, valuable agricultural land, water resources and residential communities.

Any company or individual seeking to explore for petroleum (including
CSG) must first apply to the NSW Minister for Resources and Energy for a title under the Petroleum (Onshore) Act 1991. If a licence is granted, the title holder must still seek multi-agency approval before undertaking any exploration activities. The NSW Government has announced tough new regulations for the CSG industry.
As part of the measures:

• The independent Environment Protection Authority (EPA) is the lead regulator of environmental and health impacts of CSG activities in NSW with responsibility for compliance and enforcement;
• CSG operations, including exploration, assessment or production titles, will be required to hold an Environment Protection Licence;
• The agricultural impacts of a project must specifically be addressed by the applicant in an Agricultural Impact Statement, at both the exploration and development application stages;
• A two kilometre exclusion zone will apply to existing and future residential areas to prevent new CSG exploration and production activities (both surface and underground); and
• Exclusion zones will also apply to identify Critical Industry Clusters such as the viticulture and equine industries in the Upper Hunter region.

Conclusions: This fact sheet analyses the regulations controlling the exploration and production of natural gas reserves including the Strategic Regional Land Use Policy, The Land An d Water Commissioner, A Code of Practice for Coal Seam Gas Well Integrity and a Code of Practice for Coal Seam Gas Explorers

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Citation: NSW Government, *Strategic Regional Land Use Policy* (September 2012)

Topic Area: Land Use, Other Social Issues, Water Use and Distribution

Jurisdiction: Australia (NSW)

Introduction: The Strategic Regional Land Use Policy Package sets out a range of initiatives to better balance growth in the mining and coal seam gas (CSG) industries with the need to protect important agricultural land and water resources.

Aims & Research Methods: This policy is the result of an extensive consultation process, during which the views of farmers, miners and the wider community were heard and have informed its development and final form. The policy has 27 new measures that work together to identify, map and protect the State's most valuable agricultural land and critical water resources. This document provides an overview of the initiatives contained in the Strategic Regional Land Use Policy and provides a guide for appropriate future land use in regional NSW.

Citation: NSW Government, Strategic Regional Land Use Policy, *Protecting Our Land and Water* (2012)

Topic Area: Land Use, Strategic Planning, Water Use and Distribution

Jurisdiction: Australia (NSW)

Aims & Research Methods: This document provides a comparative table outlining the exploration initiatives, planning indicatives, CSG initiatives and Aquifer protection initiatives before March 2011 in contrast to the initiatives after the introduction of the Strategic Regional Land Use Policy.

Citation: NSW Government, *Strategic Regional Land Use Policy, Fact Sheet, The Gateway Process* (September 2012)

Topic Area: Land Use, Hydraulic Fracturing, Strategic Agricultural Land

Jurisdiction: Australia (NSW)

Introduction: The Gateway is an independent, scientific and upfront assessment of how a mining or coal seam gas (CSG) production proposal will impact the agricultural values of the land on which it is proposed.

Aims & Research Methods: This document outlines information regarding The Strategic Regional Land Use Plans for the State's Upper Hunter and New England North West regions identify and map over two million hectares of land as "Strategic Agricultural Land". The document outlines the development application process and stages and its relationship to planning law.

Citation: NSW Government, *Strategic Regional Land Use Plan, Upper Hunter* (September 2012)

Topic Area: Land Use, Strategic Agricultural Land

Jurisdiction: Australia (NSW)

Introduction: More than two million hectares of NSW's most valuable agricultural land as well as the critical water sources that supply it are now subject to protections never before seen in NSW. Much of that land is located in the Upper Hunter.

Aims & Research Methods: This plan for the Upper Hunter region forms a key part of the overall policy package. It follows one of the most extensive community consultation programs ever undertaken in NSW and strongly reflects the public and industry feedback. Importantly, the plan also complements the extensive range of state wide initiatives put in place by this Government to better regulate exploration and coal seam gas activities such as the creation of a Land & Water Commissioner and strict industry codes of practice as well as an Aquifer Interference Policy that protects vital water sources.

Citation: Queensland Government, Department of Environment and Heritage Protection, *Coal Seam Gas Water Management Policy* (2012)

Topic Area: Water Use and Distribution, Hydraulic Fracturing

Jurisdiction: Australia (Qld)

Introduction: The coal seams from which the coal seam gas (CSG) is obtained contain both water and natural gas—consisting primarily of methane—which is bonded to the coal. For CSG to be released, the water must be pumped from the coal seams to reduce pressure—thereby releasing gas that is bonded to the coal. A well is constructed to enable installation of a pump which is required to lower the water pressure. The released gas then travels to the surface via the well. The water that is pumped from the coal seams to the surface is referred to as CSG water in this policy.

CSG water is also known as 'produced' or 'associated' water. The quality of CSG water quality varies greatly, however it is generally rich in salts and other minerals. The amount of CSG water produced over the life of a project is known as the 'water production profile'. This profile is linked to: the volume of water in the coal seams; the permeability of the coal seam; and the rate and volume of gas production. The rate at which CSG water is produced is generally the highest in the early stages of a well's productive life and declines over time.

The volume of CSG water produced at each well and across a CSG project will change over time. Because of this, the management of CSG water is likely to require a number of approaches or solutions working together.

These management solutions may vary through the life of the operation, and will often be different between geographical areas because of the differing geological characteristics of the coal seams, the proximity of the extraction site to available beneficial uses, the qualities and characteristics of the surrounding environment, and the quality of the CSG water. It is important that CSG operators are strategic and proactive in their management of CSG water so that impacts on the environment are avoided and managed, and to ensure the water is used in a way that reflects its value as a resource.

Wherever possible, CSG water should be used and managed in a way that is of benefit to the community, and reduces impacts on the environment. As the exploration stage of an operation produces minimal CSG water, the primary focus of the policy is on production activities—all activities after exploration, appraisal and piloting activities. The government aims to provide certainty for industry but in return expects high-quality social and environmental outcomes. This requires a sensible balance that can be best achieved via an ongoing and collaborative interaction between government, CSG operators and the community.

Aims & Research Methods: The role of this policy is to:

- clearly state the government's position on the management and use of CSG water
- guide CSG operators in managing CSG water under their environmental authority
- ensure community understanding about the government's preferred approach to managing CSG water.

Rights to extract gas and produced water are provided under the *Petroleum and Gas (Production and Safety) Act 2004 (P&G Act)* and the *Petroleum Act 1923*. The impacts of the extraction of CSG water on groundwater supplies are managed under the *Water Act 2000* (Water Act), and the environmental management of CSG operations, including the management of CSG water, is dealt with under the *Environmental Protection Act 1994* (EP Act).

Other legislation that may control the use of CSG water, depending upon how it is to be managed and used, includes:

- The *Water Supply (Safety and Reliability) Act 2008* (Water Supply Act)—where operators undertake a water supply service such as supplying treated CSG water for the purposes of a municipal drinking water supply
- The *Waste Reduction and Recycling Act 2011—*for authorising particular and general beneficial uses of CSG water and what would otherwise be CSG-related wastes.

This policy deals primarily with the management and use of CSG water under the EP Act, and does not vary the requirements of the Water Act such as a CSG operator's 'make good' obligations. The policy does, however, encourage CSG operators to consider the feasibility of using CSG water to meet these obligations as part of developing their CSG water management strategies and plans.

Conclusions: This policy sets out the government's position on the management of CSG water. To streamline the implementation of CSG water management policy, the government will:

- establish water quality standards to ensure that CSG water that is of a suitable quality (or has been treated to a suitable quality) is not a regulated waste, and give effect to this through amendment of the *Environmental Protection Regulation 2008*
- undertake a review of the Water Supply Act to ensure that regulatory requirements are not duplicated— particularly where public health interests are appropriately protected under the Waste Act and the EP Act
- provide clearer guidance around 'fit-for-purpose' standards for using CSG water in irrigation schemes
- engage industry and community stakeholders to consider ways to more effectively use existing statutory consultation processes in determining CSG water management options.

The government has also introduced temporary emission licenses in response to the Flood Commission of Inquiry. Temporary emission licenses were designed to licence emission releases in response to an applicable event (which includes in response to an emergency). This will also include the emergency release of CSG water.

Citation: DEEDI, *Code of Practice for Constructing and Abandoning Coal seam Gas Wells in Queensland* (November 2011)

Topic Area: Water Use and Distribution, Well Abandonment

Jurisdiction: Australia (Qld)

Introduction: Coal Seam Gas (CSG), a natural gas consisting mainly of methane, is an important energy source for Queensland and currently supplies around 80% of reticulated gas for Queensland's domestic, commercial, manufacturing and industrial needs. It is piped throughout many of Queensland's major cities and is essential to the State's economy. Natural gas is also reticulated throughout almost every major city in the world and this fuel is relied upon to drive economic growth. CSG is extracted from coal seams in several Basins in Queensland. Unlike extraction of conventional natural gas where gas is generally produced at much higher pressures, the development of a coal seam gas field requires many more wells to be drilled at regular spacings to extract equivalent quantities of gas. There have been some community concerns in regard to the impact of CSG (and other wells) on the valuable and significant water resources in the coal seams and surrounding formations, particularly in the Great Artesian Basin. Well integrity during construction, operation and abandonment is fundamental to ensuring sustainable gas production and is also critical to ensure safety outcomes and the protection of groundwater resources. This Code addresses safety and environmental issues in the construction and abandonment of CSG wells.

Aims & Research Methods: This Code of Practice has been developed to ensure that all CSG wells are constructed and abandoned to a minimum acceptable standard resulting in long term well integrity, containment of gas and the protection of groundwater resources.

CSG wells and their associated facilities can be made low risk through compliance to high design standards, robust safety obligations, documented industry standards and experience, and strong governance programs. Whilst CSG Operators have their own standards and procedures with regard to well construction and abandonment, this Code of Practice has been developed as a minimum acceptable standard for these operations.

The Code is designed to complement the CSG Operator's internal risk assessment processes and operating procedures. It outlines the recommended process for managing the construction of CSG wells and their eventual abandonment throughout Queensland. This ensures that these activities are completed in a consistent manner and that the processes are effectively monitored to ensure that –

- The environment, in particular underground sources of water is protected;
- Risk to the public and CSG workers are managed to a level as low as reasonably practicable;
- Regulatory and applicable Australian and International Standards and requirements, as well as the Operator's internal requirements, are understood and implemented;
- The life of a CSG well is managed effectively through appropriate design and construction techniques and ongoing monitoring. *The Queensland Petroleum Act 1923, Petroleum and Gas (Production and Safety) Act 2004 (P&G Act)* and the *Petroleum and Gas (Production and Safety) Regulation 2004 (P&G Regulation)* stipulate broad requirements for the construction and abandonment of petroleum wells which include CSG wells. They also reference some International standards in regard to well equipment and construction.

This Code provides more detailed requirements and guidance to CSG well construction, well management including abandonment and related drilling activities. It is intended that this Code of Practice will have enforceable effect in Queensland by being called up under the P&G Regulation as a "safety requirement". However the provisions of the P&G Act and the P&G Regulation take precedence over the Code where there is any conflict. Petroleum activities which include CSG activities are also regulated as part of the conditions within an Environmental Authority for petroleum activities issued under *the Environmental Protection Act 1994*. Under the Environmental Authority, petroleum tenure holders are required to monitor, identify and manage risks to the environment. This includes a requirement to conduct a groundwater quality monitoring program to identify and manage impacts to groundwater quality. Petroleum tenure holders are required to communicate these impacts to DERM. *The Queensland Water Act 2000* provides a regulatory framework for petroleum tenure holders to monitor, assess and manage the impacts of their underground water rights on water bores, aquifers and springs. The Code of Practice for Constructing and Abandoning CSG Wells in Qld has been developed so that it is consistent with principles of groundwater resource protection (see Appendix 3 - References).

Scope: This Code of Practice covers only Coal Seam Gas (CSG) wells and does not cover the safety or environmental issues associated with conventional oil and gas exploration and production. The Code may be extended or other Codes developed to address those well types and issues. The Code covers all CSG well types including exploration, appraisal and production wells. For the purposes of the Code a CSG well is a "prescribed well" as defined in the P&G Act, where the well is drilled on a petroleum authority and where the purpose of the well is to explore for or produce natural gas from a coal seam reservoir. As the safety of people, integrity of assets and protection of the environment are inextricably connected, it is appropriate that any code addressing one, must of necessity address, or be cognisant of, the others.

The Code looks specifically at two stages of well life, namely construction and decommissioning (commonly called abandonment in the petroleum industry). Within those stages, it considers equipment and material selection, risk assessment (both safety and environment), industry practices, management, monitoring and reporting.

The Code does not, however, address the manufacture or the certification of drilling rigs or associated equipment or the operation of a well. These are adequately covered in existing technical standards. It also does not include well stimulation activities such as fraccing. Likewise the Code does not refer to any necessary technical training of the various operatives.

Citation: PIRSA, *Criteria for Classifying the Level of Environmental Impact of Regulated Activities: Requirement under Part 12 Petroleum Act 2000* (2000)

Topic Area: Environmental Impact Criteria for the purpose of Part 12 of the Petroleum Act 2000

Jurisdiction: Australia (SA)

Aims & Research Methods: For the purpose of Part 1 of the Petroleum Act 2000, this document provides the criteria upon which the level of environmental impact of a regulated activity will be assessed and subsequently classified. This document also provides guidance for the application of these criteria. In the Petroleum Act 2000, environmental is broadly defined to include its natural, social, cultural and economic aspects. Therefore, reference to environment in this document also incorporates all these aspects.

Under Part 12 of the Petroleum Act 2000, the Minister is required to classify the level of environmental impact of regulated activities. Regulated activities- as defined under Part 3 of the Petroleum Act 2000- are to be classified as either low, medium or high impact. The level of environmental impact of regulated activity will determine the level of public consultation in its approval. Low impact activity approvals will entail consultation only between government agencies. Medium impact activities will entail a 30 business day public consultation process and high impact activities will be referred for EIS assessment under Part 8 of the *Development Act 1993*. The criteria outlined in this document can also be used to:

- Guide the preparation of an EIR as required under Part 12 of the Petroleum Act 2000, by providing a clearer understanding of the type of issues that need to be addressed in the EIR.
- Assist in the environmental assessment of the proposed activity.

Conclusions: It is found that decision making relating to environmental impact issues- such as the process for the classification of the level of environmental impact of a proposed activity under Part 12 of the Petroleum Act 2000- involves identifying and quantifying the level of significance of the environmental consequences of a proposed activity. In light of criteria used in other documents, the classification of the level of environmental impact requires an assessment of the level of certainty in the predicted environmental consequences associated with an activity, and the degree to which such consequences can be managed. Therefore the criteria proposed here are:

a) Predictability Criterion: In terms of the level of certainty in the prediction of adverse consequences of a proposed activity including the potential events related to the activity which could lead to such consequences, and if relevant, the likelihood of occurrence of the consequences.
b) Manageability Criterion: The degree to which the consequences can be avoided or mitigated. This involved where relevant consideration of the likelihood of occurrence of the particular consequences.

Citation: SA Government, *Criteria and Methodology for Determining Project Environmental Significance* (2000)

Topic Area: Environmental Impact Criteria for the purpose of Part 12 of the Petroleum Act 2000

Jurisdiction: Australia (SA)

Aims & Research Methods: This report outlined the philosophy of the Petroleum Group of the Department of Primary Industries and Resources South Australia of what constitutes an environmentally significant activity or project. It also provides a summary of the approach adopted by the Petroleum Group in using this philosophy for determining the level of environmental impact of a proposed activity as required under Part 12 of the Petroleum Act.

Conclusions: It has been found that decision making relating to the environmental significance of an activity or project basically involves identifying and quantifying the significance of the environmental consequences associated with the activity. In light of criteria used in the ANZECC and NSW DP Guidelines, the level of significance of an activity's environmental consequences relates to the level of certainty in the prediction of these environmental consequences and the degree to which such consequences can be managed. That is, if we are uncertain of what the actual consequences are, then the activity should be considered as a significant environmental concern. On the other hand, despite having high certainty in the actual consequences, if we cannot manage the detrimental consequences so as to limit their size, scope duration and or cumulative effects on the environment, then the activity becomes a significant environmental concern.

In addition to the level of predictability and manageability of an activity's consequences, the other dimension to the issue of environmental significance is the degree of public/stakeholder concern or perception of severity of an activity's environmental consequences.

Citation: Government of South Australia, *Roadmap of Unconventional Gas Projects in South Australia* (December 2012)

Topic Area: Unconventional Gas Projects

Jurisdiction: Australia (SA)

Introduction: The development of unconventional gas is proving to be positively transformational for North American economies and Australia is a first mover in developing shallow coal seam gas as feedstock for liquefied natural gas (LNG) export. In addition, when developed to leading practice standards for well integrity, gas is a much less carbon intensive fuel (than coal) for electricity supplies.

The progress already made with the development of unconventional gas is underpinned by significant technological advances and the emergence of export liquefied natural gas (LNG) markets. Most recently, supply-side competition in North America is seeing a shift to unconventional gas resources that also contain petroleum liquids to cushion the commerciality of projects.

Given these investment drivers, more than 20 companies/Joint Ventures are now focusing on exploring unconventional gas plays with giant discovery potential in South Australia. This is in addition to exploration for conventional oil and gas plays in proven producing basins and the State's frontier basins. With such diversification, the chance at least one of these unconventional gas plays will lead to a major discovery is high. Realistic expectations are held for economic success in one or more of South Australia's unconventional gas plays, and each of at least nine plays has potential to yield at least one giant gas field1, that can underpin domestic gas, export LNG and/or synthetic transport fuel (synfuel) supplies from South Australia.

With these drivers for commercialising unconventional gas in mind, the South Australian Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE) convened a South Australian Roundtable for Unconventional Gas in October 2010. A total of 212 organisations (and one individual) are now2 participating in the Roundtable, covering: peak representative bodies focused on economic, social and natural environment outcomes; companies, universities, and key agencies from all States, the Northern Territory and Commonwealth governments. A list of Roundtable members is provided in Appendix 1 to this Roadmap.

Last but not least, this Roadmap will be concluded in the context of the South Australian Government's Strategic Priorities and Strategic Plan Targets.

Aims & Research Methods: This Roadmap will inform stakeholders and sets the course for environmentally sustainable development of South Australia's large endowment of unconventional gas. This Roadmap transparently lays out the factors that will be taken into account in considering whether or not to approve unconventional gas projects so as to ensure compatibility with co-existing natural, social and economic environments.

Some unconventional Australian and international gas projects have, or have been perceived to have significant environmental, health or social impacts. Whilst it is not feasible to identify each and every potential local to regional impact of unconventional gas project activities in this document, this Roadmap informs stakeholders of the prevailing:

(a) regulatory framework;

(b) robust and transparent processes for environmental impact assessments that are precedents to activity approvals; and

(c) how people and enterprises potentially affected by prospective unconventional gas operations are given information and time to draw considered views, so their rights to object in part or full to activity- and location-specific land access are supported.

Indeed, regulation, in South Australia requires risks to be reduced to as low as reasonably practical (ALARP) and to also be managed to meet community expectations for net outcomes.

The Roundtable was tasked with producing a *Roadmap for Unconventional Gas Projects in South Australia* to clarify opportunities (rewards) and threats (risks) to: inform markets; inform people and enterprises that may someday compatibly co-exist with unconventional gas projects; and to reduce critical uncertainties that may impede efficient, profitable and welcomed investment.

The first draft of the Roadmap was the subject of public comment in the term 14th May – 27th July 2012. A meeting of the Roundtable was convened to consider and add to draft recommendations on 27th July 2012. All stakeholders who sought an extension of time to make submissions for the first draft Roadmap in August 2012, and the second draft Roadmap in September 2012 were given extensions to provide comments. This input from the public plus advice from the Roundtable has informed this third and final draft of the Roadmap.

Objectives of this final Roadmap are to credibly inform: industry strategies; government policies; and public perceptions. This will facilitate the efficient, profitable and welcomed deployment of capital, technologies and infrastructure for the commercialisation of unconventional gas in the South Australia, to supply: domestic and international markets for gas (including LNG); petroleum liquids; manufactured synthesis gas (syngas); and synthetic liquid transport fuels (synfuel).

Rhodri Thomas, from international energy analyst Wood Mackenzie, commented in 2010 *"It is too early to say how the future of unconventional gas will play out, but it is clear that stakeholders across the gas value chain—gas suppliers, resource holders, buyers and policy makers—need to understand the possible impact of future developments. Those that do this early and monitor key signposts will be best placed to benefit from the unconventional gas revolution."*

Conclusions:

1. Welcomed investment in the development of unconventional gas will effectively reduce risks to as low as reasonably practical while simultaneously meeting community expectations for net outcomes.

   This will be achieved with, amongst other actions, astute investment in economic unconventional plays, and by adhering to the golden rules for the golden age of gas, as published by the International Energy Agency3 – which are:

- Measure, disclose, engage;
- Watch where you drill;
- Isolate wells – protect against leaks;
- Treat water responsibly;
- Eliminate venting and minimise flaring;
- Think big;
- Consistent high environmental performance;

A key element in implementing these 'golden rules' (and leading practice more generally) is early, effective, informative stakeholder consultation by both project operators and regulators. This engagement is best initiated well ahead of land access. South Australia's regulatory framework drives operators to explain their planned activities and any potential risks, seek feedback on areas of interest or concern for the community, and establish relationships and terms for land access with stakeholders well before applying for activity approval from DMITRE. For details – see Chapter 5.

1. This roadmap could never be exhaustive or provide all salient information relevant for every unconventional gas play in the State. It does at least alert people, enterprises and government agencies as to the nature of unconventional gas plays and projects in South Australia as understood in December 2012.
2. Australia should adopt international standards for unconventional gas resource and reserve definitions. For details – see Chapter 1.
3. At least nine unconventional gas plays are being explored by more than twenty joint ventures in South Australian sedimentary basins. There is a high probability for two or more unconventional gas plays being profitably developed in the next five years.
4. The most advanced unconventional gas projects in South Australia are located in the Cooper Basin. Gas has been flowed during production tests of shale gas, tight gas and deep coal seam gas in the Cooper Basin and shale gas reservoirs in Moomba 191 have already been commercialised by the Santos operated Joint Venture that includes Origin Energy and Beach Energy. Other operators in the Cooper Basin (especially Beach Energy and Senex Energy) are also actively exploring and appraising multiple unconventional gas plays. Elsewhere in South Australia, attractive unconventional gas plays are recognised in the Arckaringa, Pedirka, Eromanga, Otway, Simpson, Officer and Gambier basins. In particular, the Altona – CNOOC Arckaringa Coal-to-Liquid and Power Project has advanced to the Project Bankable Feasibility Study phase, with sampling and testing expected to commence shortly. For details – see Chapter 4.

5. The US Government's Energy Information Agency estimates the shale gas play in the Cooper Basin could yield 85 tcf of sales gas4. Geoscience Australia (20125) estimates there is potential to develop Australia-wide unconventional gas reservoirs to recover 716,540 PJ of sales gas.
6. Santos estimates a potential range for its net recoverable raw gas from unconventional resources in its licences in the Cooper Basin to be between a low of 15 tcf to a high of 125 tcf (raw gas)6. The high-side estimate corresponds to a gross total of more than 200 tcf raw recoverable unconventional gas.
7. Eastern Australian Proven and Probable (2P) gas reserves currently total over 51,000 PJ, over 85 percent of which are CSG reserves. This estimate does not account for future discoveries which would extend the current reserves. For South Australia, gas demand is forecast to be 106 PJ for 2012, 15 percent of the eastern Australian demand. Demand growth in SA is forecast to reach 117 PJ by 2025. This is not accounting for possible gas demand for potential future industrial projects. For details – see Chapter 3.

8. Onshore unconventional gas development is expected to be higher cost than present onshore conventional gas resources. Supply-side competition in both domestic and LNG markets, and gas liquids richness in domestic unconventional gas production will factor into the spot and long-term (contracted) market price paid by gas buyers. For economic modelling – see Chapter 8.

9. Effective regulation (to enable trusted land access) and attractive investment settings (resulting in multiple joint ventures independently marketing gas) are the most effective inputs from governments to beget safe, secure, and competitively priced gas for domestic and international gas markets for decades to come. For details of regulation – see Chapter 5. For details of investment settings – see Chapter 7.
10. Regulators must have relevant and up-to-date capabilities (competence and capacity) to be trusted to act in the interests of the public in protecting natural, social and economic environments in relation to the full-cycle of mineral and energy resource projects, including unconventional gas operations.
11. One-stop-shops (lead agencies) are the most efficient regulatory approach when well managed without capture. The *Petroleum and Geothermal Energy Act 2000* (PGE Act) is designed to enable a one-stop-shop to deploy compliance enforcement policies and actions to simultaneously meet the objectives of all relevant legislation, not just the PGE Act. This enables a step-change in both efficiency of regulation, without diluting the rigor or the effectiveness of regulation. Upstream gas producers, contractors to those producers, and gas users have a common interest in efficient, high quality and competitive supply chains. The difference in the cost of exploration and development for gas to markets between scenarios with efficient, high quality supply chains that leverage on economies of scale and scenarios with uncompetitive supply chains is easily AUD 1 per GJ. Such a difference can result from a variety of factors such as well costs and/or well productivity profiles. A competitive gas price that is, for example, $6 per GJ rather than $7 per GJ would provide more than double the value of royalties to South Australians through lower energy bills, and the associated flow-on effect of competitive energy prices.

14. Unconventional gas development demonstrably creates opportunities for competitive local, national and international content in supply chains. This Roadmap and the implementation of its recommendations will foster informed risk-taking by people and enterprises to prepare to compete for supply-chain opportunities associated with unconventional gas development in South Australia. For details – see Chapter 6.
The path to this publication reveals 125 recommendations to smooth the road to environmentally sustainable and profitable development of unconventional gas in the State of South Australia. These recommendations can be generalised under the following categories:

Investor and public trust (41)
Subsurface knowledge (21)
Environmental protection (18)
Supply-chains (17)
Infrastructure (17)
Innovation in gas markets (16)
Efficiency (16)
Red tape reduction (8)
Fiscal framework (4)

The numbers in brackets ( ) are the count of overlapping recommendations in each of these nine categories. That said, each and every one of the recommendations is worth progressing by industry, or by governments, or by industry-government partnerships. In particular, there is considerable scope for cooperation to:

- demonstrate the efficacy of risk management, and in doing so, sustain trusted land access for unconventional gas projects;
- support efficient supply chains for materials, equipment and services while bolstering local content in projects;
- enable informed public understanding of unconventional gas projects. Key stakeholders are: investors in unconventional gas projects; people and enterprises potentially affected by unconventional gas projects; and government policy-makers.
- share facilities through commercial arrangements to reap economies of scale;
- enhance transparency in markets to foster efficiencies; and
- share experience and innovate to minimise both the cost and time taken while progressing through learning curves.

Citation: APPEA, *Code of Practice for Hydraulic Fracturing* (2013)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: Australia (WA)

Aims & Research Methods: Australian Petroleum Production and Exploration Association members have developed a Code of Practice, to provide best-practice guidelines for hydraulic fracturing – part of the tight and shale gas production process.

The Code also reflects industry priorities for working with communities. The intention of the Code is to involve the public in all the essential elements of the assessment and monitoring of the industry's development.

The code addresses the following areas in 7 different guidelines:

- consultation with the community on development and operations
- protection and conservation of groundwater
- public disclosure of any chemicals used in hydraulic fracturing
- management of process water
- gas emission control and
- continuous improvement.

This Code was developed as part of industry input to an independent review of the regulation of these activities in WA which was released on 31 October 2011: http://www. = dmp.wa.gov.au/7105_14068.aspx Western Australia's shale and tight gas industry will support these regulatory reforms to help ensure safe natural gas development, responsible water management and enhanced transparency. In addition, the industry commits to the guiding principles set out in this operating framework.

Citation: Western Australian Government, *Guidelines for Industry in Relation to Onshore Petroleum Activities* (2012)

Topic Area: Coal Seam Gas Industry Guidelines

Jurisdiction: Australia (WA)

Aims & Research Methods: This document outlines the Western Australian Government's expectations in relation to development of onshore petroleum resources. This document has been developed by the Department of Mines and Petroleum, with input from the Department of Water, Environmental Protection Authority, Department of Health and Department of Environment and Conservation. DMP's priority is to regulate to ensure that safety, health and environmental standards are consistent with relevant State and Commonwealth legislation, regulations and policies. In general:
1. Activities are assessed under the Petroleum and Geothermal Energy Resources Act 1967 and are required to submit a Drilling Program, Environmental Management Plan and Safety Management Plan.
2. DMP will make as much information publicly available as possible, while giving consideration to commercial-in-confidence aspects. Details of permits and their distance from population centres are already available on the DMP website.
3. Proponents should engage openly with landowners and local communities from an early stage to communicate intended activities to stakeholders and receive feedback from stakeholders.
4. While DMP is the lead agency for shale and tight gas activities, a whole of-government approach is utilised to identify and address risks. DMP regularly liaises with the Environmental Protection Authority, Department of Environment and Conservation, Department of Water and Department of Health.
5. Proponents are expected to comply with relevant Western Australian Government legislation, regulations and policies. Proponents are also responsible for ensuring that any parties contracted to undertake activities are aware of, and abide by, these documents.

Citation: WA Government, *Department of the Premier and Cabinet, Lead Agency Framework: A Guidance Note for Implementation* (2009)

Topic Area: Shale Gas Development and Regulation

Jurisdiction: Australia (WA)

Introduction: A lead agency provides a single entry point for proponents. All proposals within the Lead Agency Framework receive a level of service by the lead agency commensurate to its size, complexity or environmental, economic or social impact. It applies to State initiated proposals, such as the Kimberley Browse LNG Precinct, Perth-Bunbury Highway and the Ord-East Kimberley Expansion Plan. It also applies to proponent initiated proposals, such as Gorgon JV, Karara Iron Ore Project and Belmont Park Development.

Aims & Research Methods: The aim of this guidance note is to help departments put in place structures, policies and procedures to give effect to the Lead Agency Framework.

It will assist officers within lead and approval agencies to fulfil their role within the Lead Agency Framework.

This guidance note:

- Sets out the responsibilities and accountabilities of agencies for the delivery of the Lead Agency Framework;
- Gives the agencies the ability to manage their interests in the Lead Agency Framework;
- Supports agencies to deliver the required outcomes by giving direction and guidance; and
- Disseminates information to agencies so that they can effectively fulfil their roles.

The guidance note identifies the roles and responsibilities of the five lead agencies in Western Australia. Approval agencies and their respective roles and responsibilities are also described.

The guidance note describes the general criteria by which lead agencies will determine a proposal's level of significance and the resources they give to those proposals. It gives examples of some of the coordinating mechanisms available to lead agencies.

The guidance note also outlines the administrative issues to be addressed when the proponent is the Government of Western Australia. Lead agencies oversee the approvals pathway for proposals through administrative arrangements with approval agencies to ensure the timely delivery of approvals or advice.

The statutory roles and functions currently assigned to agencies remain unchanged under the Lead Agency Framework.

Administrative arrangements

The Lead Agency Framework requires that assistance with, or coordination of, approvals for a proposal is administered by one department; the lead agency. The lead agency is responsible for:

- providing proponents with information on statutory requirements through agency guidelines and referrals;
- case-managing and coordinating approvals applications across government for proposals, where appropriate;
- assisting proponents to identify the potential impacts of the proposal on matters such as infrastructure, the environment and regional communities as well as the social considerations that arise from the proposal.

Consultation

Lead agencies will consult on each proposal with relevant agencies. Statutory roles and functions currently assigned to agencies remain unchanged.

In broad terms, the Lead Agency Framework operates by:

- Nominating a single agency responsible for case management, either through existing (or upgraded) project tracking systems, or through an identified case manager within the lead agency; and
- Scoping the proposal upfront and determining the approvals required, identifying the potential for approvals under Commonwealth legislation and setting indicative timeframes.

The Lead Agency Framework explicitly acknowledges that some proposals may be complex and require both primary and secondary approvals. As such, it is important that proponents receive accurate information about relevant legislative and 7

administrative requirements to assist them in scoping the range of approvals necessary to implement their proposal.

This guidance note outlines:

- lead agencies and the type of proposals for which each agency will be responsible for guiding through the approvals process;
- criteria for assigning different levels to proposals;
- roles and responsibilities of lead agencies;
- roles and responsibilities of approval agencies;
- process adopted when the State is the proponent;
- coordinating mechanisms; and
- monitoring and evaluation mechanisms.

The effectiveness of the Lead Agency Framework is dependent upon:

- responsibility, authority and accountability for the proposal – this means roles and responsibilities must be clear, formally given and managed;
- a formal reporting structure and feedback mechanisms;
- identification of interfaces with other proposals;
- appropriate resourcing and skills within agencies;
- fostering a culture of case management and problem solving, good communication, cooperation and respect between all parties;
- quality information by proponents; and
- identification of internal and external stakeholders and their roles for the relevant phases of the proposal.

Allocation of a particular level does not imply that the Government guarantees the commercial success or acceptability of the proposal. It also does not absolve the proponent from meeting the full statutory and other requisite criteria of relevant approval processes.

Citation: APPEA, *Western Australian Onshore Gas Code of Practice for Hydraulic Fracturing* (2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: Australia (WA)

Introduction: Western Australia's gas industry is confident it can explore, develop and produce onshore gas resources safely and responsibly. The industry commits to these guiding principles as a framework for its activities, as well as supporting and abiding by all regulations governing well safety and integrity, hydraulic fracturing, water use and water protection.

Aims & Research Methods: The Code of Practice for Hydraulic Fracturing summary sheet provides 7 principles to collaborate with regulators and local communities to ensure that the economic and environmental benefits of onshore gas do not come at the expense of safety or protection of water resources or the environment.

1– We will communicate openly and as early as practicable with landholders, local communities and other stakeholders, including explaining how risks are being managed to minimise any potential unwanted or adverse impacts.

2 – We will ensure that well design and implementation practices include protection of aquifers or groundwater which may be accessed for commercial or residential water supply.

3 – We will efficiently and responsibly use groundwater resources where it is required.

4 – We will minimise the use of chemicals in well stimulation operations, provide clear and accurate information on any chemicals that may be used, and promote the safe and responsible use of chemicals.

5 – We will ensure that post-stimulation clean-up flow back or produced fluids (the fluid that returns to the surface after stimulation operations) cannot come into contact with production aquifers or pollute soil or soil substrate.

6 – We will ensure the fugitive emissions from stimulated wells during flow back and testing activities are minimised.

7 – We will ensure continuous performance improvement, and share information with regulators and other stakeholders to continuously improve fracture stimulation operations.

Citation: Queensland Government, *Standard Conduct and Compensation Agreement* (2013)

Topic Area: Land Access and Compensation

Jurisdiction: Australia (Qld)

Introduction: This document has been developed by the Queensland Government in consultation with landholder groups and groups representing resources explorers and producers. It is intended to represent a fair and balanced approach as between those parties to land access and compensation issues.

Parties undertaking negotiations may use this as their conduct and compensation agreement. Alternatively, clauses contained in this document can be modified to meet the specific needs of the parties. In either case any required schedules and annexures should be attached.

Aims & Research Methods: The relevant legislative authorities requiring the use of the Standard Conduct and Compensation Agreement include:

Pursuant to s 536 of the *Petroleum and Gas (Production and Safety) Act 2004* (Qld) the negotiation period must meet the minimum of 20 business days from the giving of the negotiation notice ('the usual period') and either party may, within the usual period, ask the other to agree to a longer minimum negotiation period because of the stated reasonable or unforeseen circumstances for as long as the parties wish.

s 536 Negotiations

(1) On the giving of the negotiation notice, the petroleum authority holder and the eligible claimant (the "parties") must use all reasonable endeavours to negotiate a conduct and compensation agreement or a deferral agreement (a "relevant agreement").

(2) The period of the negotiations—

- (a) must be at least for the period provided for under section 536A (the "minimum negotiation period"); but
- (b) may continue for as long as the parties wish.

(3) If, during the minimum negotiation period, the parties enter into a relevant agreement the petroleum authority holder cannot enter the relevant land to carry out advanced activities for the authority until the period ends.

(4) Subsection (3) applies despite the terms of the agreement.

536A Provision for the minimum negotiation period

(1) Generally, the minimum negotiation period is 20 business days from the giving of the negotiation notice (the "usual period").

(2) Either party may, within the usual period, ask the other to agree to a longer minimum negotiation period because of stated reasonable or unforeseen circumstances.

(3) If the other party so agrees, the longer minimum negotiation period is the minimum negotiation period.

537 Cooling-off during minimum negotiation period

(1) This section applies if the parties enter into a conduct and compensation agreement or a deferral agreement during the minimum negotiation period.

(2) Either of the parties may, within the minimum negotiation period, terminate the agreement by giving notice to the other party.

(3) On the giving of a notice under subsection (2), the terminated agreement is taken never to have had any effect.

(4) To remove any doubt, it is declared that subsection (3) does not change the time when the negotiation notice was given.

Citation: Bureau of Land Management, *Federal Register: Oil and Gas: Hydraulic Fracturing on Federal and Indian Lands; Proposed Rule* (24 May 2013)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: On May 11, 2012, the Bureau of Land Management (BLM) published in the Federal Register a proposed rule entitled Oil and Gas; Well Stimulation, Including Hydraulic Fracturing, on Federal and Indian Lands. The BLM has used the comments on that draft to make improvements and is now seeking additional comment on a revised proposed rule. Key issues in this updated draft include: the use of an expanded set of cement evaluation tools to help ensure that usable water zones have been isolated and protected from contamination; and more detailed guidance on how trade secrets claims will be handled, modelled on the procedures promulgated by the State of Colorado. The revised proposed rule would also provide opportunities for the BLM to coordinate standards and processes with individual States and tribes to reduce administrative costs and to improve efficiency.

Aims & Research Methods: Like the initial proposed rule, this revised proposed rule would apply to Indian lands so that these lands and communities receive the same level of protection provided on public lands. In most cases, the requirements in this rule can be satisfied by submitting additional information during the existing process that the BLM currently applies to operators when reviewing and approving an operator's Application for Permit to Drill (APD) on public or Indian lands. The rule would require that disclosure of the chemicals used in the fracturing process be provided to the BLM after the fracturing operation is completed.

This information may be submitted to the BLM through an existing Web site known as FracFocus.org, already used by some states for reporting mandatory chemical disclosure of hydraulic fracturing chemicals. Submission of this information through this Web site allows an operator to provide the public and many State and tribal regulators with prompt access. This approach also has the benefit of reducing reporting burdens for oil and gas operators by avoiding duplicative reporting requirements and administrative duties for the BLM in many instances. The BLM developed this revised proposed rule and the initial proposed rule with the intention of improving public awareness and strengthening oversight of hydraulic fracturing operations without introducing unnecessary new procedures or delays in the process of developing oil and gas resources on public and Indian lands. Some states, like Colorado, Wyoming, Arkansas, and Texas, have issued their own regulations addressing disclosures and oversight for oil and gas drilling operations. Operators with leases on Federal lands must comply with both BLM's regulations and with State permitting and notice requirements to the extent they do not conflict with BLM regulations. State regulations pertaining to hydraulic fracturing operations are not uniform.

The States that have regulated hydraulic fracturing typically require some notification to a state agency and some require reporting on FracFocus. Other States have not taken action in this area. This revised proposed rule seeks to create a consistent oversight and disclosure model that will apply across all public and Indian lands that are available for oil and gas development, and aims to streamline and minimize the efforts required to comply with any new requirements, while also protecting Federal and tribal interests and resources. Currently nearly 36 million acres of Federal land are under lease for potential oil and gas development. These leases can be found on public land and for public minerals in 24 states The BLM has revised the proposed rule to reduce some of the information requirements to avoid duplication with the requirements of States (on Federal land) and tribes (on tribal land). The BLM has considered various options to encourage streamlining, flexibility, and more efficient operation on both BLM and tribal leases.

Citation: The Rt Hon Edward Davey MP, *Written Ministerial Statement: Exploration for Shale Gas* (December 2012)

Topic Area: Shale Gas Exploration

Jurisdiction: UK

Introduction: Shale gas development has been of increasing importance in the US for some years, but exploration has only just begun in the UK. The potential of producing shale gas from a suitable formation can only be established by fracturing the rock, and it happens that the fracturing of the first shale gas well in the UK, at Preese Hall near Blackpool last year, resulted in noticeable seismic tremors. These were not at a level which could cause any damage, but seismic activity at this level was not an expected consequence of the fracking activity, and DECC therefore suspended all fracking operations for shale gas pending a thorough investigation of the causes of these tremors and the scope for mitigation of seismic risks in any future operations of this type. I am announcing today the outcome of that investigation and the way forward on exploration for shale gas in the UK.

Aims & Research Methods: Having carefully reviewed the evidence with the aid of independent experts, and with the aid of an authoritative review of the scientific and engineering evidence on shale gas extraction conducted by the Royal Academy of Engineering and the Royal Society, I have concluded that appropriate controls are available to mitigate the risks of undesirable seismic activity. Those new controls will be required by my Department for all future shale gas wells. On that basis, I am in principle prepared to consent to new fracking proposals for shale gas, where all other necessary permissions and consents are in place.

This opens the way to a resumption of work on exploration for shale gas, though I stress the importance of the other regulatory consents, and planning permission, which are also necessary for these activities, and which must be in place before my Department will consider consent to individual operations. In practice, it will be well into next year before any new exploration work has all the necessary consents to proceed. Whether any production operations may be proposed will depend on the success of the exploration work, but, in any event, this is likely to be some years away yet.

The background is that, in most oil and gas fields worldwide, the oil or gas is extracted from a relatively porous rock, usually a sandstone or calcareous rock, in which it has been accumulated or trapped. The original source of the petroleum however lies elsewhere, in deeper formations of non-porous rocks classed as shales. These shale source rocks are widely distributed around the world, and exist in many areas of the UK. One of the key technologies involved is hydraulic fracturing, or fracking. This is carried out by pumping water at high pressure into the shale formation, which forms blade-like fractures, a few millimetres wide and extending several hundred feet away from the well bore. Once the fractures have started to form, sand or a similar material is pumped in, to hold the fractures open once the pressure is released. The fractures can continue to grow only so long as pressure is maintained. When the fractures have sufficiently developed, the pressure is released and the frac fluid, followed by the released gas, can flow into the well. The process is not novel and is also widely used in conventional oil and gas production, It is however, more intensively used in the production of shale gas.

It has been recognised for some time that injection of large quantities of water into the subsurface can cause seismic tremors. This has happened, for example, in those areas of the US in which disposal of waste water into deep injection wells is permitted. However, the quantities of water used in fracking are substantially smaller, and up until the time of the Preese Hall tremors, no association had been recognised between injection of these smaller volumes and any seismic activity. The analysis carried out by Cuadrilla's advisers, and confirmed by our independent panel of experts, has however concluded that the most likely cause of the tremors is the movement of the frac fluid into and along a fault which was already under stress. The additional pressure of the fluid allowed the fault to move, releasing the energy stored in the fault and resulting in the perceived tremors at the surface.

Our experts advise that there are many other faults in the Lancashire area which similarly have unrelieved stresses, and could in a similar scenario likewise result in tremors. Because of the relatively weak nature of these rocks, the amount of energy likely to be stored in these faults is not large, and the largest earthquake likely in this area from such a cause is assessed at magnitude 3. While this is not large enough to cause significant material damage, it would be perceptible and disturbing. I consider that new controls to minimise disturbance to those living and working nearby, and to prevent the risk of any damage, are now a prerequisite for further exploration.

Conclusions: I am therefore announcing new controls to mitigate these risks, which will be applied to all future fracking operations for shale gas. As this is a developing area of knowledge, I stress that we will be moving forward with appropriate caution. The controls are not at this stage to be regarded as definitive, but as appropriate precautionary measures for our present state of knowledge. Initial operations under

these controls will be subject to careful scrutiny to ensure the effectiveness of the controls. And they will be reviewed, as experience develops, to ensure that they are proportionate to the risks. The controls will be enforced by my Department, though the data obtained will of course be shared with other regulators.

Citation: Department of Energy and Climate Change, *Oil and gas: petroleum licensing guidance* (2013)

Topic Area: Petroleum Licensing

Jurisdiction: UK

Aims & Research Methods: This website provides guidance on how to apply for licences: using the PEARS online system for licence assignments, operator approvals and licence relinquishments or transfers. The website has the following sections:

- Overview

- Petroleum e-business assignments and relinquishment system (PEARS)
- Legislative background
- Types of licence
- Applying for a licence
- Licence assignments (transfers)
- Change of control of licensee
- Licence extensions
- Criteria To Become A Licensee
- Equity interests and operating agreements
- Charges on licences
- Streamlined transfer and pre-emption arrangements

Citation: UKOOG, *UK Onshore Shale Gas Well Guidelines Exploration and appraisal phase* (2013)

Topic Area: Onshore Shale Gas Well Regulations

Jurisdiction: UK

Introduction: The Guidelines are relevant to all shale gas wells, onshore in Great Britain, designed and constructed for the extraction of naturally occurring hydrocarbons which include stimulation by techniques involving high volume hydraulic fracturing. The Guidelines contain what is considered to be good industry practice and reference the relevant legislation, industry standards and practices.

The first issue of the Guidelines relates to the exploration and appraisal phase of shale gas well developments. The shale gas industry in Great Britain is at an early stage and the early wells drilled will be regarded as the pilot phase of development and as such the guidelines are to enable operators to follow good practice while gathering information and gaining experience from operations.

All duty holders should comply with their duties under all relevant regulations and be aware of the associated regulatory guidance. These guidelines will assist with regulatory compliance but they are not a substitute for a full understanding of the regulations. Also planning conditions and permits may be applied to well operations and well sites and operators will need to comply with any such conditions/permit requirements.

Oil and Gas UK have established guidelines related to wells and well operations in Great Britain, including shale gas wells. They contain what is believed to be good industry practice and reference relevant legislation, standards and practices.

These guidelines are intended to supplement the Oil and Gas UK guidelines not to replace any of them. They have been developed to cover the areas that are unique to shale gas wells and high volume fracturing operations and which are not presently covered in detail by Oil and Gas UK guidelines.

Therefore operators involved in shale gas well operations should refer to the following Oil and Gas UK guidelines:

1. Well Integrity Guidelines.

2. Guidelines for the Suspension and Abandonment of Wells.

3. Guidelines on Qualification of Materials for the Suspension and Abandonment of Wells.

4. Guidelines for Well Operators on Well Examination.

5. Guidelines for Well Operators on Competency of Well Examiners.

6. Guidelines on Competency for Wells Personnel.

Aims & Research Methods: These guidelines are produced by the UK Onshore Operators Group (UKOOG), a body representing the UK onshore oil and gas industry. They were written by a workgroup which included operating and service companies with input from DECC, HSE and the EA/SEPA.

The guidelines are relevant to UK onshore shale gas wells designed and constructed for the extraction of naturally occurring hydrocarbons which includes stimulation by techniques involving high volume hydraulic fracturing. Issue 1 of the guidelines is restricted to the exploration and appraisal phases of shale gas developments. The initial operations will be treated as a pilot to ensure that high standards of safety and environmental management are achieved and to enable the guidelines to be fully evaluated. Further revisions will be required and will be based on experience gained during the pilot phase. A further revision will also be necessary for the eventual operations (production) phase anticipated for shale gas developments.

The guidelines contain what is considered to be good industry practice and they reference the relevant legislation, standards and practices.

The guidelines are not intended as a complete guide to all the regulations that apply to well sites or to equipment or to human factors. Guidance on these matters is available elsewhere through the relevant regulations, Approved Codes of Practice, regulations' guidance etc. Operators should be aware of all the regulations, Approved Codes of Practice and guidance that apply to well sites and to all associated operations.

The guidelines refer extensively to Oil and Gas UK Guidelines, particularly to the Well Integrity Guidelines (issued in July 2012). These apply to every onshore well and concentrate on 'typical' wells and 'standard' operations. Therefore shale gas well operators should use these guidelines in conjunction with the referenced Oil and Gas UK Guidelines.

By adopting the practices presented in these guidelines and the various, referenced, Oil and Gas UK, guidelines, Operators should be able to assure themselves and demonstrate to other stakeholders, on matters of well integrity and fracturing operations, including matters concerning fracturing fluids and flow-back fluids and that they have complied with all relevant regulations that apply to shale gas well designs and operations, including fracturing operations.

The guidelines are not intended to prevent any organisation from adopting an alternative approach to managing well integrity, fracturing operations or environmental management. However, the implications of adopting an alternative approach need to be considered in relation to the overall intent of well integrity and fracturing operational management to ensure, so far as reasonably practicable, there can be no unplanned escape of fluids from the well or equipment involved in fracturing operations, and that the risk to the environment and risks associated with health and safety are as low as reasonably practicable.

Citation: House of Commons Hansard Debates for 03 Nov 2011 (pt 0001), Westminster Hall *Thursday 3 November 2011* [Mr Roger Gale *in the Chair*] Shale Gas *[Relevant document s : Fifth Report from the Energy and Climate Change Committee , Session 2010-11 , HC 795, and the Government response, HC 1449 .] Motion made, and Question proposed,* That the sitting be now adjourned.—*(Charles Hendry.)* (2011)

Topic Area: Shale Gas Development

Jurisdiction: UK

Introduction: Mr Roger Gale (in the Chair): I will explain the process for the debate this afternoon, which is slightly unusual because we have two reports. We have agreed—I hope that Members present will approve—to split the debate in two, although not necessarily into two equal halves. I understand that the first report may attract more comment than the second, and on that basis I am prepared to let the first debate run for slightly longer than might otherwise have been the case. The second debate will therefore be slightly shorter; I hope that is okay. In such cases, the convention that a Member may speak only once falls by the wayside. As we will treat our proceedings as two debates, I am perfectly content for Members who have participated in the first debate to contribute also to the second, should they choose to do so. I trust that whoever takes the Chair at 4 o'clock will feel the same. If that is not clear, hon. Members should ask and I will clarify the matter further.

Aims & Research Methods: Since the Committee published its report on shale gas last May, the subject has become even more topical. Potential UK reserves now appear to be much larger than first thought, and the conclusions of the team that investigated the seismic events—what I would think of as earth tremors—were also published this week. This debate gives us the chance to address concerns about the potential impact of shale gas development, and to consider those concerns in the context of the fact that enough shale gas reserves may exist in the UK to make the country self-sufficient in gas supplies once again, possibly for a long time.

Conclusions: The Minister of State, Department of Energy and Climate Change (Charles Hendry): We have had an interesting debate. This is one of the rare occasions where one can say that we should have had more time to have a debate on energy; we would happily fill a much longer time scale. That says a great deal about the complexity of the issues, the knowledge of many Members on both sides of the House and our joint determination to try to reach the right conclusions.

Citation: WA Government, *Guidelines for Industry in Relation to Onshore Petroleum Activities* (2012)

Topic Area: Development of onshore petroleum resources

Jurisdiction: Australia (WA)

Aims & Research Methods: This document outlines the Western Australian Government's expectations in relation to development of onshore petroleum resources. This document has been developed by the Department of Mines and Petroleum, with input from the Department of Water, Environmental Protection Authority, Department of Health and Department of Environment and Conservation.

DMP's priority is to regulate to ensure that safety, health and environmental standards are consistent with relevant State and Commonwealth legislation, regulations and policies.

Conclusions: In general:

1. Activities are assessed under the *Petroleum and Geothermal Energy Resources Act 1967* and are required to submit a Drilling Program, Environmental Management Plan and Safety Management Plan.

2. DMP will make as much information publicly available as possible, while giving consideration to commercial-in-confidence aspects. Details of permits and their distance from population centres are already available on the DMP website.

3. Proponents should engage openly with landowners and local communities from an early stage to communicate intended activities to stakeholders and receive feedback from stakeholders.

4. While DMP is the lead agency for shale and tight gas activities, a whole-of-government approach is utilised to identify and address risks. DMP regularly liaises with the Environmental Protection Authority, Department of Environment and Conservation, Department of Water and Department of Health.

5. Proponents are expected to comply with relevant Western Australian Government legislation, regulations and policies. Proponents are also responsible for ensuring that any parties contracted to undertake activities are aware of, and abide by, these documents.

Citation: APPEA, *Western Australian Onshore Gas Code of Practice for Hydraulic Fracturing* (2011)

Topic Area: Hydraulic Fracturing

Jurisdiction: Australia (WA)

Introduction: APPEA has facilitated the preparation of this Code of Practice to demonstrate what the gas industry is doing to successfully and responsibly develop significant onshore gas reservoirs in Western Australia.

The Code has been developed by a working group of industry operators based on established operating principles and leading practices in other jurisdictions that are relevant to local conditions.

Onshore gas reservoirs in Western Australia typically occur in tight sandstone and shale formations at depths of between two to four kilometres and in geological formations that are isolated from surface aquifers by significant barriers. Developing these resources can potentially deliver major environmental and economic benefits.

The shale and tight gas industry aims to assess and if feasible develop these reservoirs in a safe and environmentally responsible way consistent with regulatory requirements.

Aims & Research Methods: This Code was developed as part of industry input to an independent review of the regulation of these activities in WA which was released on 31 October 2011: http://www.dmp.wa.gov.au/7105_14068.aspx Western Australia's shale and tight gas industry will support these regulatory reforms to help ensure safe natural gas development, responsible water management and enhanced transparency. In addition, the industry commits to the guiding principles set out in this operating framework.

Conclusions: In Western Australia, the Department of Mines and Petroleum (DMP) is the lead agency responsible for regulating unconventional gas activities. Shale, tight and coal seam gas are regulated using a similar process to conventional oil and gas activities under the *Petroleum and Geothermal Energy Resources Act 1967*, *Petroleum Pipelines Act 1969*, and the Schedule of Onshore Petroleum Exploration and Production Requirements 1991.

Proponents intending to carry out drilling and hydraulic fracturing operations must submit a number of applications to DMP, including:

• a drilling application;

• an environmental management plan; and

• a safety management plan.

This Code of Practice has a particular focus on well stimulation given that requirements for drilling and well integrity in the broader oil and gas industry are well developed and dealt with in detail in the Schedule of Onshore Petroleum Exploration and Production Requirements 1991.

Citation: EPA, *Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources* (2011)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: As natural gas production has increased, so have concerns about the potential environmental and human health impacts of hydraulic fracturing in the United States. Hydraulic fracturing, which involves the pressurized injection of water, chemical additives, and proppants into a geologic formation, induces fractures in the formation that stimulate the flow of natural gas or oil, thus increasing the volume of gas or oil that can be recovered from coal beds, shales, and tight sands—the so-called "unconventional" reservoirs. Many concerns about hydraulic fracturing centre on potential risks to drinking water resources, although other issues have been raised. In response to public concern, Congress directed the United States Environmental Protection Agency (EPA) to conduct research to examine the relationship between hydraulic fracturing and drinking water resources. This document presents the plan for the EPA study.

Aims & Research Methods: The overall purpose of this study is to understand the relationship between hydraulic fracturing and drinking water resources. More specifically, the study is designed to examine the conditions that may be associated with the potential contamination of drinking water resources, and to identify the factors that may lead to human exposure and risks. The scope of the proposed research includes the full lifecycle of water in hydraulic fracturing, from water acquisition through the mixing of chemicals and actual fracturing to the post-fracturing stage, including the management of flow back and produced water and its ultimate treatment and/or disposal. Figure 1 illustrates the hydraulic fracturing water lifecycle and the key research questions EPA will address through this study. The research identified in this study plan has been designed to answer the questions listed in Figure 1 and will require a broad range of expertise, including petroleum engineering, fate and transport modelling, ground water hydrology, and toxicology. EPA will use case studies and generalized scenario evaluations as organizing constructs for the research identified in this plan. *Retrospective case studies* will focus on investigating reported instances of drinking water resource contamination or other impacts in areas where hydraulic fracturing has already occurred. EPA will conduct retrospective case studies at three to five sites across the United States. The sites will be illustrative of the types of problems that have been reported to EPA during stakeholder meetings, and will provide EPA with information regarding key factors that may be associated with drinking water contamination. These studies will use existing data and possibly field sampling, modelling, and/or parallel laboratory investigations to determine the potential relationship between reported impacts and hydraulic fracturing activities.

Prospective case studies will involve sites where hydraulic fracturing will occur after the research is initiated. These case studies allow sampling and characterization of the site before, during, and after water extraction, drilling, hydraulic fracturing fluid injection, flow back, and gas production. EPA will work with industry and other stakeholders to conduct two to three prospective case studies in different regions of the United States. The data collected during prospective case studies will allow EPA to gain an understanding of hydraulic fracturing practices, evaluate changes in water quality over time, and assess the fate and transport of potential chemical contaminants. *Generalized scenario evaluations* will allow EPA to explore hypothetical scenarios relating to hydraulic fracturing activities, and to identify scenarios under which hydraulic fracturing may adversely impact drinking water resources based on current understanding and available data. To better understand potential human health effects, EPA plans to summarize the available data on the toxicity of chemicals used in or released by hydraulic fracturing, and to identify and prioritize data gaps for further investigation. The substances to be investigated include chemicals used in hydraulic fracturing fluids, their degrades and/or reaction products, and naturally occurring substances that may be released or mobilized as a result of hydraulic fracturing. The research projects identified for this study are organized according to the hydraulic fracturing water lifecycle shown in Figure 1 and are summarized in Appendix A (p. 70). EPA is working with other federal agencies to collaborate on some aspects of the research described in this study plan. Additionally, EPA will announce requests for applications for extramural research projects related to this study as the study plan is finalized. These projects will be conducted through EPA's Science To Achieve Results (STAR) program. All research activities associated with this study will be conducted in accordance with EPA's Quality Assurance Program for environmental data. EPA will provide periodic updates on the progress of various projects as the research is being conducted. The results of individual research projects will be made available after undergoing a quality assurance review. Early results may indicate the need for EPA to conduct further investigations to identify the key factors that may impact drinking water resources. It is expected that a report of interim research results will be completed in 2012. This interim report will contain a synthesis of EPA's research to date and will include results from retrospective case studies and initial results from scenario evaluations. However, certain portions of the work described here, including prospective case studies and work performed under STAR grants, are long-term projects that are not likely to be finished at that time. Additional reports of study findings will be published as these long-term projects progress, with a follow-up report on the study in 2014. EPA recognizes that there are important potential research areas related to hydraulic fracturing other than those involving drinking water resources, including effects on air quality, aquatic and terrestrial ecosystem impacts, seismic risks, public safety concerns, occupational risks, and economic impacts. These topics are outside the scope of the current study, but should be examined in the future.

This draft study plan will be submitted to EPA's Science Advisory Board (SAB) for review before being finalized. Consistent with the operating procedures of the SAB, stakeholders and the public will have an opportunity to provide comments for the SAB to take into account during the review.

Citation: Government of South Australia, *Roadmap for Unconventional Gas Projects in South Australia* (December 2012)

Topic Area: Development of Unconventional Gas

Jurisdiction: Australia (SA)

Introduction: The development of unconventional gas is proving to be positively transformational for North American economies and Australia is a first mover in developing shallow coal seam gas as feedstock for liquefied natural gas (LNG) export. In addition, when developed to leading practice standards for well integrity, gas is a much less carbon intensive fuel (than coal) for electricity supplies.

The progress already made with the development of unconventional gas is underpinned by significant technological advances and the emergence of export liquefied natural gas (LNG) markets. Most recently, supply-side competition in North America is seeing a shift to unconventional gas resources that also contain petroleum liquids to cushion the commerciality of projects.

Given these investment drivers, more than 20 companies/Joint Ventures are now focusing on exploring unconventional gas plays with giant discovery potential in South Australia. This is in addition to exploration for conventional oil and gas plays in proven producing basins and the State's frontier basins. With such diversification, the chance at least one of these unconventional gas plays will lead to a major discovery is high. Realistic expectations are held for economic success in one or more of South Australia's unconventional gas plays, and each of at least nine plays has potential to yield at least one giant gas field1, that can underpin domestic gas, export LNG and/or synthetic transport fuel (synfuel) supplies from South Australia.

With these drivers for commercialising unconventional gas in mind, the South Australian Department for Manufacturing, Innovation, Trade, Resources and Energy (DMITRE) convened a South Australian Roundtable for Unconventional Gas in October 2010. A total of 212 organisations (and one individual) are now2 participating in the Roundtable, covering:

peak representative bodies focused on economic, social and natural environment outcomes; companies, universities, and key agencies from all States, the Northern Territory and Commonwealth governments. A list of Roundtable members is provided in Appendix 1 to this Roadmap.

Last but not least, this Roadmap will be concluded in the context of the South Australian Government's Strategic Priorities and Strategic Plan Targets.

Aims & Research Methods: This Roadmap will inform stakeholders and sets the course for environmentally sustainable development of South Australia's large endowment of unconventional gas. This Roadmap transparently lays out the factors that will be taken into account in considering whether or not to approve unconventional gas projects so as to ensure compatibility with co-existing natural, social and economic environments.

Some unconventional Australian and international gas projects have, or have been perceived to have significant environmental, health or social impacts. Whilst it is not feasible to identify each and every potential local to regional impact of unconventional gas project activities in this document, this Roadmap informs stakeholders of the prevailing:

(a) regulatory framework;

(b) robust and transparent processes for environmental impact assessments that are precedents to activity approvals; and

(c) how people and enterprises potentially affected by prospective unconventional gas operations are given information and time to draw considered views, so their rights to object in part or full to activity- and location-specific land access are supported.

Indeed, regulation, in South Australia requires risks to be reduced to as low as reasonably practical (ALARP) and to also be managed to meet community expectations for net outcomes.

The Roundtable was tasked with producing a *Roadmap for Unconventional Gas Projects in South Australia* to clarify opportunities (rewards) and threats (risks) to: inform markets; inform people and enterprises that may someday compatibly co-exist with unconventional gas projects; and to reduce critical uncertainties that may impede efficient, profitable and welcomed investment.

The first draft of the Roadmap was the subject of public comment in the term 14th May – 27th July 2012. A meeting of the Roundtable was convened to consider and add to draft recommendations on 27th July 2012. All stakeholders who sought an extension of time to make submissions for the first draft Roadmap in August 2012, and the second draft Roadmap in September 2012 were given extensions to provide comments. This input from the public plus advice from the Roundtable has informed this third and final draft of the Roadmap.

Objectives of this final Roadmap are to credibly inform: industry strategies; government policies; and public perceptions. This will facilitate the efficient, profitable and welcomed deployment of capital, technologies and infrastructure for the commercialisation of unconventional gas in the South Australia, to supply: domestic and international markets for gas (including LNG); petroleum liquids; manufactured synthesis gas (syngas); and synthetic liquid transport fuels (synfuel).

Rhodri Thomas, from international energy analyst Wood Mackenzie, commented in 2010 "It is too early to say how the future of unconventional gas will play out, but it is clear that stakeholders across the gas value chain—gas suppliers, resource holders, buyers and policy makers—need to understand the possible impact of future developments. Those that do this early and monitor key signposts will be best placed to benefit from the unconventional gas revolution."

Conclusion: Welcomed investment in the development of unconventional gas will effectively reduce risks to as low as reasonably practical while simultaneously meeting community expectations for net outcomes.

This will be achieved with, amongst other actions, astute investment in economic unconventional plays, and by adhering to the golden rules for the golden age of gas, as published by the International Energy Agency3 – which are:

. Measure, disclose, engage;

. Watch where you drill;

. Isolate wells – protect against leaks;

. Treat water responsibly;

. Eliminate venting and minimise flaring;

. Think big;

. Consistent high environmental performance;

A key element in implementing these 'golden rules' (and leading practice more generally) is early, effective, informative stakeholder consultation by both project operators and regulators. This engagement is best initiated well ahead of land access. South Australia's regulatory framework drives operators to explain their planned activities and any potential risks, seek feedback on areas of interest or concern for the community, and establish relationships and terms for land access with stakeholders well before applying for activity approval from DMITRE. For details – see Chapter 5.

This roadmap could never be exhaustive or provide all salient information relevant for every unconventional gas play in the State. It does at least alert people, enterprises and government agencies as to the nature of unconventional gas plays and projects in South Australia as understood in December 2012.

Australia should adopt international standards for unconventional gas resource and reserve definitions. For details – see Chapter 1.

At least nine unconventional gas plays are being explored by more than twenty joint ventures in South Australian sedimentary basins. There is a high probability for two or more unconventional gas plays being profitably developed in the next five years.

The most advanced unconventional gas projects in South Australia are located in the Cooper Basin. Gas has been flowed during production tests of shale gas, tight gas and deep coal seam gas in the Cooper Basin and shale gas reservoirs in Moomba 191 have already been commercialised by the Santos operated Joint Venture that includes Origin Energy and Beach Energy. Other operators in the Cooper Basin (especially Beach Energy and Senex Energy) are also actively exploring and appraising multiple unconventional gas plays. Elsewhere in South Australia, attractive unconventional gas plays are recognised in the Arckaringa, Pedirka, Eromanga, Otway, Simpson, Officer and Gambier basins. In particular, the Altona – CNOOC Arckaringa Coal-to-Liquid and Power Project has advanced to the Project Bankable Feasibility Study phase, with sampling and testing expected to commence shortly. For details – see Chapter 4.

The US Government's Energy Information Agency estimates the shale gas play in the Cooper Basin could yield 85 tcf of sales gas4. Geoscience Australia (20125) estimates there is potential to develop Australia-wide unconventional gas reservoirs to recover 716,540 PJ of sales gas.

Santos estimates a potential range for its net recoverable raw gas from unconventional resources in its licences in the Cooper Basin to be between a low of 15 tcf to a high of 125 tcf (raw gas)6. The high-side estimate corresponds to a gross total of more than 200 tcf raw recoverable unconventional gas.

Eastern Australian Proven and Probable (2P) gas reserves currently total over 51,000 PJ, over 85 percent of which are CSG reserves. This estimate does not account for future discoveries which would extend the current reserves. For South Australia, gas demand is forecast to be 106 PJ for 2012, 15 percent of the eastern Australian demand. Demand growth in SA is forecast to reach 117 PJ by 2025. This is not accounting for possible gas demand for potential future industrial projects. For details – see Chapter 3.

4 85 tcf is roughly equivalent to 93,500 PJ

Santos' equity in the Cooper Basin production licences is 66.6% in South Australia and 60.1% in Queensland. Hence, Santos of estimate of the potential range for recoverable raw gas from its licences in the Cooper Basin is, in gross terms, at least 22 tcf to a high of more than 200 tcf (raw gas). Santos' November 2012 estimates of its unconventional resources in the Cooper Basin can be accessed from: http://www.santos.com/ library/121112_EABU_Cooper_Basin_Unconventional_ Gas_Opportunities_and_Commercialisation.pdf

Onshore unconventional gas development is expected to be higher cost than present onshore conventional gas resources. Supply-side competition in both domestic and LNG markets, and gas liquids richness in domestic unconventional gas production will factor into the spot and long-term (contracted) market price paid by gas buyers. For economic modelling – see Chapter 8.

Effective regulation (to enable trusted land access) and attractive investment settings (resulting in multiple joint ventures independently marketing gas) are the most effective inputs from governments to beget safe, secure, and competitively priced gas for domestic and international gas markets for decades to come. For details of regulation – see Chapter 5. For details of investment settings – see Chapter 7.

Regulators must have relevant and up-to-date capabilities (competence and capacity) to be trusted to act in the interests of the public in protecting natural, social and economic environments in relation to the full-cycle of mineral and energy resource projects, including unconventional gas operations.

One-stop-shops (lead agencies) are the most efficient regulatory approach when well managed without capture. The *Petroleum and Geothermal Energy Act 2000* (PGE Act) is designed to enable a one-stop-shop to deploy compliance enforcement policies and actions to simultaneously meet the objectives of all relevant legislation, not just the PGE Act. This enables a step-change in both efficiency of regulation, without diluting the rigor or the effectiveness of regulation.

Upstream gas producers, contractors to those producers, and gas users have a common interest in efficient, high quality and competitive supply chains. The difference in the cost of exploration and development for gas to markets between scenarios with efficient, high quality supply chains that leverage on economies of scale and scenarios with uncompetitive supply chains is easily AUD 1 per GJ. Such a difference can result from a variety of factors such as well costs and/or well productivity profiles. A competitive gas price that is, for example, $6 per GJ rather than $7 per GJ would provide more than double the value of royalties to South Australians through lower energy bills, and the associated flow-on effect of competitive energy prices.

Unconventional gas development demonstrably creates opportunities for competitive local, national and international content in supply chains. This Roadmap and the implementation of its recommendations will foster informed risk-taking by people and enterprises to prepare to compete for supply-chain opportunities associated with unconventional gas development in South Australia. For details – see Chapter 6.

The path to this publication reveals 125 recommendations to smooth the road to environmentally sustainable and profitable development of unconventional gas in the State of South Australia. These recommendations can be generalised under the following categories:

- Investor and public trust (41)
- Subsurface knowledge (21)
- Environmental protection (18)
- Supply-chains (17)
- Infrastructure (17)
- Innovation in gas markets (16)
- Efficiency (16)
- Red tape reduction (8)
- Fiscal framework (4)

The numbers in brackets ( ) are the count of overlapping recommendations in each of these nine categories. That said, each and every one of the recommendations is worth progressing by industry, or by governments, or by industry-government partnerships. In particular, there is considerable scope for cooperation to:

- demonstrate the efficacy of risk management, and in doing so, sustain trusted land access for unconventional gas projects;

- support efficient supply chains for materials, equipment and services while bolstering local content in projects;

- enable informed public understanding of unconventional gas projects. Key stakeholders are: investors in unconventional gas projects; people and enterprises potentially affected by unconventional gas projects; and government policy-makers.

- share facilities through commercial arrangements to reap economies of scale;

- enhance transparency in markets to foster efficiencies; and

- share experience and innovate to minimise both the cost and time taken while progressing through learning curves.

Citation: APPEA, *CSG Well Construction and Bore Specifications* (2012)

Topic Area: Well Construction and Design

Jurisdiction: Australia

Introduction: CSG wells are the lifeblood of the CSG industry. They are critical to identify, test and produce CSG. They are designed and constructed using proven procedures and equipment, and represent a major investment by CSG companies. A great deal of Effort goes into their construction to ensure that wells are isolated from overlying geological strata, including overlying aquifers. Broadly speaking, there are three phases of CSG operations: exploration, pilot testing, and production. Exploration aims to identify gas bearing coals and wells are generally widespread, with approximately one well per 30 km2depending on the area.

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- If exploration indicates the potential for gas production, pilot wells may be drilled. A pilot test is essentially a small scale production trial, with associated water and gas handling facilities. If pilot testing indicates that commercial quantities of gas can be produced, full scale production may commence. Production wells are generally spaced at some 600m–1200m or more, and may operate for several years. All activities conducted in association with petroleum tenements are subject to government environmental approvals
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- **Aims & Research Methods:** This report was prepared by the Australian Petroleum Production and Exploration Association (APPEA) to explain the procedures commonly used to drill and complete coal seam gas (CSG) wells. The procedures described are representative for the industry, but some aspects may vary across companies (for example, the area cleared for a lease or pit sizes used)
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- **Conclusions:** This report provides a factual explanation relating to exploration drilling, drilling and pilot testing of coal seam gas.

REPORTS

Citation: Parlimentary Commissioner for the Environment, *Evaluating the environmental impacts of fracking in New Zealand: An Interim Report* (November 2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: New Zealand

Aims & Research Methods: The Parliamentary Commissioner for the Environment is an independent Officer of Parliament, with functions and powers granted by the Environment Act 1986. Her role allows a unique opportunity to provide Members of Parliament with independent advice in their consideration of matters that may have impacts on the quality of the environment. The Commissioner received many requests to undertake an investigation into fracking. The purpose is two-fold – first, to assess the environmental risks with fracking, and second to assess whether the policies, laws, regulations and institutions in this country are adequate for managing these risks. It has not been possible in the time available to adequately investigate just how well these risks are actually managed in New Zealand. Consequently, this is an *interim report* and contains interim findings rather than the usual formal recommendations.

For instance, it is clear that the integrity of the casing of a well is of great importance, but how well the current system ensures that well casings meet 'best practice' requires more investigation. Therefore, this investigation will now move into a second phase with a final report planned for release in the first half of next year. This report has been produced pursuant to s16 of the Environment Act 1986.

Conclusions:

1. Complexity and accountability

Government oversight and regulation of the oil and gas industry is complex and multifaceted. Finding out who is responsible for what during different stages of the process has been a major exercise during this investigation. Three issues are briefly discussed below as illustrations of the kinds of questions that arise. The risk of environmental damage depends on where a well is drilled – on the geology and hydrogeology. Once granted permits which sometimes cover very large areas, companies appear to decide where to drill with no guidance from either central or local government about where drilling might best take place. Companies drilling wells are also using different design and construction standards. It is not clear who is responsible for ensuring well integrity – the High Hazards Unit or the regional councils. There is some overlap between risks to the health and safety of workers and risks to the environment. For example, blowouts and methane leaks from wells are dangerous for workers and can damage the environment. Well integrity is critical for both. In New Zealand health and safety regulation is completely separate from environmental regulation. Combining the two regulatory roles to at least some extent is a common theme in other reviews. For example, the Royal Society of London recommended that: *"Well designs should be reviewed by the well examiner from both a health and safety perspective and an* *environmental perspective."*197 The Ministry for the Environment has not provided any guidance to councils specifically on fracking. Perhaps the EPA would be better placed to provide such guidance because of the expertise it will need to develop to consider proposals for drilling offshore.

2. 'Light-handed' regulation

Globally the last 30 years has seen a shift away from 'heavy-handed' regulation of industries. The oil and gas sector in New Zealand is no exception. The current approach involves a high degree of reliance on a company being motivated to 'do the right thing' by consumers, by workers, and by the environment. While this has worked well in some circumstances, there are problems with this approach in high risk industries. Oil and gas is one industry where New Zealanders need to have confidence that it is being done safely and in an environmentally responsible way. In New Zealand, to a considerable extent, companies appear to be not only regulating themselves, but monitoring their own performance. The United Kingdom has a well examination scheme; New Zealand has no such scheme. Companies are required to provide (often highly technical) information to councils, to New Zealand Petroleum & Minerals and to the High Hazard Unit. However, this is no guarantee that the information, is always being understood and used to enforce best practice – or even good practice. New Zealand regulations are currently under review. It may be that light-handed regulation of the oil and gas industry is working well, but this cannot be assumed. In August 2012, speaking about fracking, the Executive Director of the IEA was reported as saying that the industry's 'just-trustme approach is fuelling public skepticism.'198 Such skepticism is one of the real challenges for the industry.

3. A 'social licence' to operate

In releasing the 'Golden Rules' report earlier this year, IEA Chief Economist Faith Birol warned *"If this new industry is to prosper, it needs to earn and maintain its social licence to operate."*

In New Zealand, it appears that fracking has not yet earned its 'social licence'. Concerns about fracking are many and wide-ranging. They include the potential for contamination of important aquifers, triggering earthquakes, whether regulators have the capacity to deal adequately with concerns, as well as the impact on climate change. The concerns are not just environmental; some are questioning to whom and where the economic benefit will accrue. Increasing public understanding of the technology should help address some concerns. There may well be some changes in public engagement that could help – for example, combining regional council and district council hearings on applications for resource consents. But ultimately what is needed is trust – trust that government oversight is occurring, and that regulation is not just adequate but enforced, and seen to be so. As the Western Australian EPA has observed: *"…community confidence about the effective management of environmental impacts and risks associated with this industry is best achieved through open and transparent regulatory processes."*

Citation: National Centre for Groundwater Research (NCGRT), *Australia's Groundwater: The Nation's Buried Treasure* (April 2012) 68- 73

Topic Area: Water use and Management

Jurisdiction: Australia

Introduction: Over the next 40-50 years the need for fresh water will escalate as Australia's population doubles. More droughts are expected to occur and with climate change we can expect less rain and more evaporation in the nation's south-east. At the same time we are dealing with major policy issues such as the proposed Murray-Darling Basin Plan, which recommends a near tripling of groundwater usage from 1580GL to 4340GL a year. Policymakers and scientists are also working through the potential long-term impacts of coal seam gas (CSG) mining, with the National Water Commission estimating that large volumes of water will be taken from groundwater systems over the next 20 years as a result of CSG operations.

Aims & Research Methods: This report was commissioned by AWA to interview experts in groundwater extraction and outline vacuums in current groundwater policy making.

Scope: Analysing the opinions of experts in groundwater research to indemnity challenges to manage the policy approach of the National Water Commission.

Conclusions: Despite current groundwater challenges, the future of groundwater research will encompass greater scientific capacity and policy imperative to begin successfully answering the big questions and making informed decisions about groundwater use and management.

Citation: National Water Commission, *Position Statement the CSG and Water Challenge* (2010) 1-3

Topic Area: Water use and Management

Jurisdiction: Australia

Introduction: The Coal Seam Gas (CSG) industry offers substantial economic and other benefits to Australia. At the same time, if not adequately managed and regulated, it risks having significant, long-term and adverse impacts on adjacent surface and groundwater systems. In light of the scale of potential benefits and associated risks, the National Water Commission is highlighting the need for appropriate management of CSG developments, consistent with the objectives of the National Water Initiative (NWI). To meet NWI objectives, the Commission recommends that industry, water and land-use planners, and governments adopt a precautionary approach to CSG developments, ensuring that risks to the water resource are carefully and effectively managed.

Aims & Research Methods: The Commission is concerned that CSG development represents a substantial risk to sustainable water management given the combination of material uncertainty about water impacts, the significance of potential impacts, and the long time period over which they may emerge and continue to have effect. Therefore, an adaptive and precautionary management approach will be essential to allow for progressive improvement in the understanding of impacts, including cumulative effects, and to support timely implementation of 'make good' arrangements.

Scope: Position statement outlining NWC progress in obtaining sustainable water management in CSG practices.

Conclusions: The Commission is completing a discussion paper on CSG water issues and potential impacts to provide useful background information for regulators, water managers and other water users. A$1.8 million *Potential local and cumulative effects of mining on groundwater resources* project funded by the Commission is also developing tools and guidelines to account for potential local and cumulative effects of mining on groundwater resources. These guidelines and tools are intended to assist in the management of CSG.

Citation: John Williams Scientific Services Pty Ltd, *An Analysis of Coal Seam Gas Production and Natural Resource Management in Australia* (2012) 56-171

Topic Area: Water use and Management

Jurisdiction: Australia

Introduction: This report was derived from an extensive range of literature, most of which is accessible via the internet. The authors have sought to ensure that sources for their use of text, figures, diagrams and images are provided in text, footnotes or references. If inadvertently the authors have failed to adequately acknowledge a source of material used they would appreciate prompt notification so the matter can be corrected in the electronic copy of the document and a full acknowledgement provided.

Aims & Research Methods: The authors of the present report have attempted to collect the facts from that huge amount of material and bring them all together in one place in a digestible form. Inevitably some points will have been missed, but this report condenses a great deal of information and analysis into its pages.

Scope: This report outlines a review and analysis of some of the rapidly growing published literature, grey literature, and documentation on coal seam gas (CSG) production, from perspectives of government, industry and community. The first chapters describe and examine the science and engineering which underpin CSG production in Australia and overseas, with a view to considering potential impacts of the industry on natural resource management issues in the Australian landscape. Next, an outline is provided of the social, economic and community development issues associated with expansion of the CSG industry, with particular attention to research and analysis in Queensland and to a lesser extent in NSW. The current and emerging legislative and regulatory frameworks in Queensland and NSW are examined, along with actions of the Australian Government to manage the natural resource issues for CSG development.

Limitations (If Applicable): There are other issues, including those listed here, which we have not covered in this report and which may emerge as important:

•the source of water to replenish the coal seam ‘aquifers’ once production of gas has ceased;
•decommissioning and management of the legacy of large numbers of wells in a gas field so that the integrity of the geological strata is maintained indefinitely; it is an issue for the long-term sustainability of water resources;
•management of surface infrastructure with respect to bushfires and surface flooding;

•seismic impacts, which are clearly an issue with shale gas;
•other social issues, such as those around impacts of coal seam gas operations on the values of rural land.

Conclusions: In principle, CSG production is no different to any other land use development within a landscape and should be treated as such. Managing the production of CSG, an 'unconventional' gas requiring unconventional methods of extraction, is essentially another part of managing the whole landscape. It is one more demand on the landscape, competing with production of energy, water, food, fibre, minerals, and with human settlement, and with the need to maintain biodiversity to underpin the ecological functioning of the landscape itself. Fundamentally, CSG production is no different to any other development of our landscapes. Like them, it poses risks to the condition of the water, soil, vegetation and biodiversity, and has the potential to reduce the capacity of our natural resources to supply human, as well as ecological, needs. It is important to see CSG operations in this context. The potential impacts of CSG could be significantly less than the impacts and degradation already experienced as a result of agricultural and urban development over the past two centuries in Australia.

Citation: Robert Varady, Frank van Weert, Sharon Megdal, Andrea Gerlak, Christine Abdalla Iskandar, Lily House-Peters, *Groundwater Governance: A Global Framework for Country Action* (2011) FAO 1-38.

Topic Area: Water use and Management

Jurisdiction: Global

Introduction: The present paper, whose focus is the policy aspect of groundwater governance, proceeds from the following set of basic understandings:

• Groundwater is far-and-away the largest source of freshwater in a world where many regions worry about critical shortages
• In the recent past, the study and management of water in general, and groundwater in particular, have benefited from a more well-rounded, more forward-looking, and more comprehensive set of principles and tools • Non-technical, "soft" approaches to managing water have accepted the centrality of understanding modes of governance. The present water crisis—insofar as the growing lack of access to potable water and water for agricultural and industrial use can be described in such alarming terms—is "mainly a crisis of governance," the Global Water Partnership proclaimed at the turn of the current century (Mukerjee and Shah, 2005).
• Ultimately, principles of governance (which are reviewed and elaborated in this paper)—to the extent that they are appropriate—can result in the development and implementation of effective policies, and
• Such policies can yield a set of practices for "responsible groundwater use," including equity, sustainability and efficiency considerations.

Aims & Research Methods: Our purpose here has been to discover principles, knowledge gaps, challenges, and perhaps most importantly, lessons learned. By analysing these lessons—both positive and negative—through the medium of case studies and other practical and theoretical findings, we have attempted to uncover a set of practices that with luck may guide the way to "responsible groundwater use." These practices, if they are to succeed, will need to be flexible, responsive, incremental, cost-effective, culturally sensitive, equitable, and politically astute. Put another way, they will have to factor in the dynamics— that is, the prevailing physical and societal driving forces—and the desires and vagaries of human and institutional behaviour in the particular social-process system in which the management of water is embedded. In other words, insofar as feasible, governance should strive to be context-based and adaptive to the greatest degree possible.

Scope: Governance is an immense conceptual construct, encompassing a suite of precepts, principles, ideas, theories, contexts, objectives, and practices. The FAO/ GEF project "Groundwater Governance: A Global Framework for Country Action" is a comprehensive attempt to understand and articulate this notion in its entirety—as applied to the particular subject of groundwater.

Conclusions: to achieve long-term sustainability of groundwater management (and water management, in general), each country will have to govern its water resources within its own financial, technological, and institutional capability, and strategically use available international resources. This calls for considerable ingenuity at the appropriate governance levels to figure out the most appropriate ways of proceeding in specific contexts.

Citation: Patsy Richards and Mike Fell, *Shale Gas and Fracking* (2013) Library of the House of Commons 1-14

Topic Area: Fracking Activities

Jurisdiction: UK

Introduction: This report examines the recent rapid development of unconventional gas resources in the UK and collates resources regarding the development of fracking regulation in the UK.

Conclusions: The current Energy Bill seeks to introduce "clean, secure and affordable" energy supplies. For the UK, energy security means diversity of generation and supply. Gas is cleaner than unabated oil or coal, and cheaper up-front than renewables or nuclear. Both the Energy Bill provisions and other Government policy announcements indicate a strong continuing role for gas and shale gas. Recent announcements include those in the Gas Generation Strategy, in the 2013 Budget, and new planning guidance and promised benefits to communities.

Citation: A. Sinclair, K. Tayler, R. van Dam & A. Hogan, ' Site-specific quality guidelines' (2013) 10 Environ *Sci Pollut Res* 1922-4

Topic Area: Water use and Management

Jurisdiction: Australia

Introduction: The Ranger Uranium Mine, in northern Australia, is monitored by the Supervising Scientist Division (SSD) of the Australian Government to ensure that it does not impact on the highly valued aquatic ecosystems of Kakadu National Park. In 2010, the SSD adopted the continuous monitoring of electrical conductivity (EC) and turbidity, in combination with event-triggered automated grab samples, as its primary water quality monitoring method. The continuous monitoring of EC has shown that mine discharges typically occur over short-term ‘pulse’ durations of minutes to hours. Given that magnesium (Mg) is the most likely mine-derived solute to approach or exceed the applicable water quality limit value, the focus has been on developing a pulse exposure assessment framework for Mg, as represented by its proxy EC, which is tracked by the continuous monitoring system.

Aims & Research Methods: This paper presents the development of an ecotoxicologically based Mg pulse exposure limit and trigger value regulatory framework for Magela and Gulungul Creeks and an assessment of its application to historical continuous monitoring data. The framework is intended to supersede the current EC guideline and supplement the trigger levels based on longer duration (up to 4 days) chronic exposure periods reported by van Dam et al.

Scope: This study presents a possible ecotoxicologically derived Mg pulse exposure limit and trigger regulation framework for Magela and Gulungul Creeks and an assessment of historic continuous monitoring EC data from these creeks. This framework demonstrates potential to supersede the current EC guideline and associated trigger levels, which are statistically derived from historic grab sample data.

Conclusions: Commonwealth regulations concerning uranium mining at the Ranger Mine require background water quality values to be determined and necessitate a framework to identify water quality changes downstream of the mine. The existing water quality guideline for EC, based on the distribution of historic grab samples at the upstream reference site, whilst in line with the Australian and New Zealand Water Quality Guidelines (ANZECC&ARMCANZ 2000) no longer presents best practice in accordance with the best practicable technology offered by the continuous monitoring programme. The new approach recommended in this paper satisfies the Commonwealth requirements of the Supervising Scientist and represents anadvancement under the national guidelines (ANZECC/ARMCANZ 2000), whereby water quality objectives are based on site-specific ecotoxicological testing.

Citation: National Water Commission, *Water Policy and Climate Change in Australia* (2012) 1-278

Topic Area: Water use and Management

Jurisdiction: Australia

Introduction: This report provides the National Water Commission’s assessment of the national water policy implications of climate change mitigation policies and adaptation responses.

Aims & Research Methods: Climate change and water management are two of the most important public policy issues facing Australia. Adding to existing water management challenges is the fact that climate change, and policies aimed at mitigating and adapting to climate change, can strongly affect water management outcomes.

The National Water Commission’s 2011 biennial assessment of progress under the National Water Initiative pointed to the interactions between water and climate change, suggesting that policies and investment decisions involving climate change, energy and water are intrinsically entwined (NWC 2011a). The Commission recommended that it would be prudent to analyse the interactions between climate change and water in one of 12 headline recommendations made in the assessment.

Scope: This report responds to that need. Its specific objectives are to:

- better understand the interactions between water policy and climate change policy
- assess the likely location, timing and materiality of climate change impacts on water resources, water infrastructure and services
- assess whether Australia's water policy settings are sufficiently robust to deal with the potential implications of climate change mitigation policies and adaptation responses
- assess whether current water policy settings have implications for the implementation of climate change policy
- inform further water policy development and implementation.

To meet those objectives, a comprehensive assessment of the interactions between climate change policy and water policy was undertaken across seven key sectors that supply water, use water or otherwise affect water policy (urban water, rural water, the environment, agriculture, electricity generation, forestry and mining). An overview of the approach and outcomes is illustrated in Figure 1 below. This framework has been applied to identify and assess the potential impacts on water resources and service provision of:

- climate change mitigation policies or actions designed to reduce greenhouse gas emissions
- climate change adaptation policies or actions designed to better manage the impacts and/or risks associated with climate change that has already occurred and will continue regardless of short- to medium-term mitigation efforts.

Limitations (If Applicable): The report does not assess the effectiveness or appropriateness of current climate change policies; nor does it provide scientific analysis or modelling on the projected climatic impacts of climate change. Instead, the project considers a range of plausible mitigation policy scenarios and adaptation responses and draws upon the best available scientific information on the climatic impacts of climate change.

Conclusions: This study has found that, in the main, current water policy settings will not impede cost-effective implementation of climate change policy. However, there are a small number of exceptions, including some that might affect the shift towards lower emissions energy sources. They include the following:

- Lack of clear and secure entitlements and access to water markets might inhibit investment in new, less emissions-intensive electricity generation facilities.
- The inability of water and related environmental regulations to keep pace with alternative and emerging energy sources may inhibit the development of less emissions-intensive energy sources.
- Uncertainty surrounding the water entitlements of some coal-fired generators may affect the willingness of some energy companies to enter into agreements for the early closure of some high-emissions generators.

- Recycled water targets and subsidies for some demand management measures may not be adequately considering increased greenhouse gas emissions.
- While well intentioned, some voluntary mitigation actions by WSPs are unlikely to be the most cost-effective means of achieving national mitigation objectives.

Citation: American Water Works Association, *Water and Hydraulic Fracturing* (2013) 1-17

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: In recent years, there has been substantial public scrutiny of the process of hydraulic fracturing, commonly known as "fracking." Citizens' groups, environmental advocates, municipal leaders, and others have expressed concern that the process and activities associated with fracking could result in the contamination of water resources. Media has elevated these concerns in many national and local stories, but the facts and risks surrounding hydraulic fracturing are not widely understood.

Aims & Research Methods: This report compiles research by the AWWA in order to explain the position of the Oil and Gas Industry and regulatory authorities of hydraulic fracturing in the US.

Scope: AWWA has produced this white paper in response to growing public awareness and concern about hydraulic fracturing and related activities. The paper provides water utilities with background, facts, and resources to help them understand and communicate fracking processes, risks, and regulations. Additionally, the paper considers both hydraulic fracturing itself and other components in the life cycle of oil and natural gas development that may present concerns to drinking water utilities. Although this document primarily discusses drinking water utility risks and concerns—and ways to mitigate them—it is important to remember that any policy decisions regarding energy development must take both risks and benefits into account. Although summarized briefly, the benefits of energy development—which can be substantial—are not discussed in detail in this paper.

Conclusions: This paper demonstrates that fracking is just one limited aspect of overall oil and gas development activities. At this time, AWWA is aware of no proven cases of groundwater contamination directly attributable to hydraulic fracturing. However, shale gas development has brought new or increased concerns about the potential for adverse effects in many areas. These concerns include the risk of accidents and spills, improper construction, improper waste disposal, and improper well abandonment. Ultimately many concerns are about the safety of drinking water and water resources.

Citation: NSW Government, *Code of Practice for Coal Seam Gas Fracture Stimulation Activities* (2012) 1-26

Topic Area: Fracking Activities

Jurisdiction: Australia

Aims & Research Methods: The Code of Practice for Coal Seam Gas Fracture Stimulation establishes a best practice framework which covers:

- The hydraulic fracturing process;
- The use of chemicals in fracturing fluid;
- The sourcing of the water using in fracturing; and
- the protection of aquifers from the fracturing fluid.

Scope: To protect groundwater, surface water and the environment, the NSW Government has banned the use of harmful chemicals, known as BTEX, used interstate and overseas in hydraulic fracturing operations.

The new controls stipulate all CSG drilling additives must be tested by a National Association of Testing Authorities-certified laboratory and demonstrated to meet Australian drinking water health guidelines.

Samples of drilling additives and fracture stimulation additives may be taken at any time by the EPA to verify compliance.

To avoid any impact on water resources and to keep the fractures within the targeted area, each fracture stimulation must include:

- Identification of the rock types, the condition of aquifers and their distance from the target coal seams;
- Determination of the faults and stresses in the surrounding geology and the maximum pressure that can safely be applied; and
- Identification of the intervening strata and their porosity and permeability.

The Code also stipulates a risk assessment must be made before each fracture stimulation of the effects on public safety, land contamination, air pollution, noise and vibration, loss of well integrity, induced ground movements or seismicity and conflicts with existing land uses.

Citation: Marylou Potts, *Does the NSW regulatory regime for onshore petroleum projects effectively protect beneficial water resources from significant environmental impact?* (2012)

Topic Area: Water use and management, Fracking Activities, Other Social Issues Associated

Jurisdiction: Australia

Introduction: The government, both Federal and State, appears keen to gain the scientific evidence one way or another. However, all its scientific studies, whether done in NSW, Queensland or by the Commonwealth, are funded by industry. As a consequence, the independence and integrity of the evidence, and the ownership and manipulation of the evidence gleaned, is in question.

Aims & Research Methods: This paper initially examines the environmental impact of onshore petroleum operations on beneficial water resources. It then considers the regulatory regime in NSW as it applies to protection of water in CSG operations, from the exploration phase through to production.

Scope: The paper primarily focuses on the *Petroleum Act*, Parts 5 and 4 of the EP&A Act, the *Water Management Act 2000* (NSW), the SRLUP and the Aquifer Interference Policy in their application to the protection of beneficial water resources.

Limitations (If Applicable): An examination of ESD is unfortunately beyond the scope of the word limit for this paper.

Conclusions: The regulatory process attempts to capture significant environmental impact at various stages of CSG operations, both in exploration and in production, and significant progress has been made in recent years.

Citation: EPA, *Draft Underground Injection Control Program Guidance on Class VI Well Pluggin, Post Injection Site Care and Site Closure* (2012)

Topic Area: Well design, construction and abandonment, Fracking Activities, Water Use and Management

Jurisdiction: USA

Introduction: The Federal Requirements under the Underground Injection Control Program for Carbon Dioxide Geologic Sequestration Wells (75 FR 77230, December 10, 2010), referred to as the Class VI Rule, establishes a new class of injection well (Class VI).

Aims & Research Methods: The Safe Drinking Water Act (SDWA) provisions and EPA regulations cited in this document contain legally-binding requirements. In several chapters, this guidance document makes recommendations and offers alternatives that go beyond the minimum requirements indicated by the Class VI Rule. This is intended to provide information and recommendations that may be helpful for UIC Class VI Program implementation efforts. Such recommendations are prefaced by the words ‘may’ or ‘should’ and are to be considered advisory. They are not required elements of the Class VI Rule. Therefore, this document does not substitute for those provisions or regulations, nor is it a regulation itself, so it does not impose legally-binding requirements on EPA, states, or the regulated community. The recommendations herein may not be applicable to each and every situation.

Limitations (If Applicable): Note that this document only addresses issues covered by EPA’s authorities under the SDWA. Other EPA authorities, such as Clean Air Act (CAA) requirements to report carbon dioxide injection activities under the Greenhouse Gas Mandatory Reporting Rule (GHG MRR), are not within the scope of this document.

Conclusions: The guidance also discusses the information that the owner or operator must submit to demonstrate non-endangerment [40 CFR 146.93(b)(3)] showing that no additional monitoring is needed to ensure that the project does not pose a risk to USDWs before the UIC Program Director will authorize site closure. Once the non-endangerment demonstration is approved by the UIC Program Director and site closure has been authorized, 120 days’ notice of intent must be submitted [40 CFR 146.93(d)]; following site closure, a site closure report must be sent to the UIC Program Director within 90 days [40 CFR 146.93(f)]. The types of documentation to be included in the notifications (e.g., well plugging, notification to authorities, records regarding the injective) are described at 40 CFR 146.93(f). This document includes guidance on providing the necessary information that the UIC Program Director will need to make a decision regarding site closure, as well as guidance on completing requirements for the site closure report.

Citation: Brandon Murrill and Adam Vann, *Hydraulic Fracturing Chemical Disclosure Requirements* (2012) Congressional Research Service

Topic Area: Chemical Use and Disclosure, Fracking Activities, Water Use and Management, Well Design, Construction and Abandonment

Jurisdiction: USA

Introduction: The Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board (SEAB) has recommended public disclosure, on a well-by-well basis, of all of the chemical ingredients added to fracking fluids, with some protection for trade secrets. Currently, no such law or regulation exists at the federal level. In his 2012 State of the Union Address, President Barack Obama said he would obligate "all companies that drill for gas on public lands to disclose the chemicals they use," citing health and safety concerns. Not long afterward, the draft of a proposed fracking chemical disclosure rule from the Bureau of Land Management (BLM) was disclosed. This draft rule would require companies employing hydraulic fracturing on lands managed by BLM to disclose the content of the fracking fluid. In addition, there have been legislative efforts in the 112th Congress. H.R. 1084 and S. 587, the Fracturing Responsibility and Awareness of Chemicals Act (FRAC Act), would create more broadly applicable disclosure requirements for parties engaged in hydraulic fracturing.

Aims & Research Methods: This report provides an overview of current and proposed laws at the state and federal levels that require the disclosure of the chemicals added to the fluid used in hydraulic fracturing. Appendix A provides a glossary of many of the terms used in this report. Appendix B contains a table summarizing the fracking chemical disclosure requirements described in this report.

Conclusions: Chemical disclosure laws or proposals at the state level vary widely. Of the 11 current laws and three proposals examined in this report, only a few require direct public disclosure of chemical information by mandating that parties post the information on the FracFocus chemical disclosure website. The level of detail required to be disclosed often depends on how states protect trade secrets, as these protections may allow submitting parties to withhold information from disclosure at their discretion or to submit fewer details about proprietary chemicals, except, perhaps, in emergencies. Even if a disclosure law does not protect information from public disclosure, other state laws, such as an exemption in an open records law, may do so. A few states require the submission of MSDSs for certain chemicals. MSDSs may offer a relatively low level of disclosure, as the most specific details that parties must include on the data sheets under OSHA regulations are the chemical or common names of certain hazardous ingredients instead of chemicals' internationally unique CAS numbers and concentrations. With regard to the timing of disclosure, a few state laws require at least some disclosure of information about fracking fluid chemical composition before fracking is performed, but these states typically require less detailed information to be provided before fracking than afterward.

Citation: The Royal Academy of Engineering, *Shale Gas Extraction in the UK: A Review of Hydraulic Fracturing* (2012) UK Parliament

Topic Area: Fracking Activities, Other Social Issues Associated, Chemical Use and Disclosure

Jurisdiction: UK

Introduction: Shale gas extraction in the UK is presently at a very small scale, involving only exploratory activities. Uncertainties can be addressed through robust monitoring systems and research activities identified in this report. There is greater uncertainty about the scale of production activities should a future shale gas industry develop nationwide. Attention must be paid to the way in which risks scale up. Co-ordination of the numerous bodies with regulatory responsibilities for shale gas extraction must be maintained. Regulatory capacity may need to be increased.

Aims & Research Methods: A Working Group was set up to oversee this project. The Working Group met on six occasions when it was briefed by other experts. Consultations with other experts and stakeholders were held between meetings. Submissions were received from a number of individuals and learned societies. This report has been reviewed by an expert Review Panel and approved by the Engineering Policy Committee of the Royal Academy of Engineering and the Council of the Royal Society. The Royal Academy of Engineering and The Royal Society are grateful to the Government Office for Science for its financial support for this review**.**

Scope: The UK Government's Chief Scientific Adviser, Sir John Beddington FRS, asked the Royal Society and the Royal Academy of Engineering to carry out an independent review of the scientific and engineering evidence relating to the technical aspects of the risks associated with hydraulic fracturing to inform government policymaking about shale gas extraction in the UK.

The terms of reference of this review were:

• What are the major risks associated with hydraulic fracturing as a means to extract shale gas in the UK, including geological risks, such as seismicity, and environmental risks, such as groundwater contamination?

• Can these risks be effectively managed? If so, how?

Limitations (If Applicable): This report has analysed environmental and health and safety risks. Climate risks have not been analysed. The risks addressed in this report are restricted to those associated with the onshore extraction of shale gas. The subsequent use of shale gas has not been addressed.

Conclusions: The Research Councils, especially the Natural Environment Research Council, the

Engineering and Physical Sciences Research Council and the Economic and Social Research Council, should consider including shale gas extraction in their research programmes, and possibly a cross-Research Council programme. Priorities should include research into the public acceptability of the extraction and use of shale gas in the context of UK policies on climate change, energy and the wider economy.

Citation: Norton Rose and Fulbright & Jaworski, *Trade Secrets and the Regulation of Hydraulic Fracturing* (2013)

Topic Area: Chemical Use and Disclosure, Social Issues and Fracking Activities

Jurisdiction: USA, Canada and Australia

Introduction: Many governments around the globe face a conundrum. Their citizens consume energy conspicuously, but many of their citizens oppose energy development passionately. The development of natural gas and oil through a process called hydraulic fracturing is only the most recent example of the dilemma. Hydraulic fracturing is a practice now associated with the development of oil and gas in shales. In nations where shale resources appear abundant, governments try to strike the best balance between the benefits hydraulic fracturing brings – jobs, increased public revenue, lower-cost energy, and energy security – and concerns that hydraulic fracturing may pose risks to public supplies of drinking water and to human health.

Aims & Research Methods: This paper explores how some governments have tried to get the most benefits from both sets of public interests. After some introductory explanation about hydraulic fracturing, it looks at several of the states within the United States. It then considers approaches taken in Canada and Australia.

Scope: This paper will briefly discuss how several democratically-elected governments have struck the balance. It will focus on one highly controversial issue: the degree to which companies conducting fracturing operations must publicly disclose the chemical compounds they inject into the wellbore to fracture the hydrocarbon-bearing rock.

Conclusions: In the United States, Canada, and Australia, disclosure of chemicals may now fairly be said to be the rule and trade secrets the exception. But they are an exception vital to any nation hoping fully to exploit the benefits that shale development can bring.

Citation: Adam Carpenter, *Water and Hydraulic Fracturing* (2013) AWWA

Topic Area: Fracking Activities, Social Issues, Well Construction

Jurisdiction: USA

Introduction: On Jan. 28, 2013, AWWA issued the white paper Water and Hydraulic Fracturing that provides an overview of hydraulic fracturing and the many related facets of oil and natural gas development that have the potential to affect drinking water utilities. It is intended to help utilities gain an understanding of the issues involved in fracking, learn how to separate tangible concerns from more speculative ones, and find ways to meaningfully address concerns that arise from staff and customers.

Aims & Research Methods: The development of the white paper was requested by AWWA's Water Utility Council in response to increasing oil and natural gas development and the difficulty many utilities have experienced in seeking balanced and authoritative information on this issue. Indeed, the subject has been fraught with misinformation and misunderstanding in the media and among those concerned with protecting water resources. Discussions with representatives of drinking water utilities, citizen groups, and others around the United States revealed tremendous diversity in the levels of understanding about hydraulic fracturing and its potential consequences for drinking water.

Scope: This article provides an overview of the AWWA whitepaper—Water and Hydraulic Fracturing—that was requested by AWWA 's Water Utility Council in response to increasing oil and natural gas development and the difficulty many utilities have experienced in seeking balanced and authoritative information on this issue.

Conclusions: Everyone drinks water, and everyone uses energy. Both water and energy are vital to our well-being and to our economy. Treating and distributing water requires energy, and energy production requires water. The greatest benefit to society and the environment will certainly come from professionals concerned with both water and energy resources working together toward the common goals of environmental and public health protection. The white paper's conclusions are not absolute— although the risks of hydraulic fracturing and related development activities appear to be manageable through prudent measures, it is always possible that additional research may identify additional concerns or require the implementation of new safeguards. What is absolute is that safe and secure water must be a paramount concern. With thoughtful protections, water and energy development can co-exist well into the future.

Citation: CEDA, *Australia's Unconventional Energy Options* (September 2012) Chapter 3 Property Rights Agriculture and the Coal Seam Gas Industry

Topic Area: Fracking Activities, Land Access,

Jurisdiction: Australia

Aims & Research Methods: The key issues discussed in this policy perspective that must be properly examined and addressed in Australia concern:
• Property rights;
• Water management;
• The robustness of the current legislative and regulatory regime;
• How we can ensure lessons learnt in other countries with more advanced development of these resources are not lost here; and
• How Australia can best capitalise on the economic opportunities presented by unconventional energy.
CEDA is consequently calling for improvements in community consultation and land access negotiation processes, and for industry to adopt internationally recognised best practice standards.

In addition, specifically around water management, CEDA is calling for:
• Unconventional energy water use to be integrated into regular water allocation frameworks;

• Industry to be required to develop a risk management framework that applies stringent precautionary measures until more is known about the long term implications for water resources of unconventional energy extraction; and
• Water management requirements for unconventional energy extraction to be made long enough to ensure industry is responsible for all consequences of the activity.

Conclusions: The experience of unconventional gas highlights why CEDA is advocating that Australia needs to develop robust regulatory frameworks for all energy sources prior to their widespread utilisation. Technological innovation can radically re-order the economics of energy supply, particularly in an era of extensive research and development in energy generation. Likewise, government policies to mitigate greenhouse gas emissions must be flexible, adaptable and reviewed to make sure they are relevant and achieving the desired outcome as technology evolves. The contributions to this policy perspective suggest that, irrespective of how well established the energy supply is internationally, Australia should develop appropriate regulatory frameworks to enable its extraction and integration prior to its utilisation domestically. This would ensure government is providing business with the certainty it requires to invest in long term infrastructure. It also provides the community with the certainty that business is responsibly using the nation's natural endowment of resources.

Citation: Dayna Linley, *Fracking Under Pressure: The Environmental and Social Impacts and Risks of Shale Gas Development* (2011) Sustainalystics

Topic Area: Environmental and Social Impacts

Jurisdiction: Global

Introduction: This report is the first in Sustainalytics' series exploring unconventional fossil fuel development. Shale gas, deep water drilling and oil sands are examples of the unconventional oil and gas plays that producers are currently exploiting in response to growing global energy demands. Sustainalytics will examine these emerging trends in fossil fuel production and address the potential risks and opportunities faced by companies and their investors.

Aims & Research Methods: In this report Sustainalytics looks at the consequences and risks of shale gas development that are of primary interest to investors, profiles best practices, outlines an investor initiative, and provides a clear agenda for shareholder engagement with shale gas companies.

Scope: This report provides a comprehensive analysis of the shift toward unconventional oil and gas, potential impacts of Shale Gas extraction, investor risks and best practices in the Shale Gas industry.

Conclusions: As global demand for natural gas increases, producers are increasingly looking to unconventional oil and gas sources such as shale gas. The shift is, however, raising the risk profile of the industry. Global reserves of shale gas are vast, but its development causes environmental and social impacts, the most significant of which are impacts on water, the release of greenhouse gas emissions and methane migration. Such impacts have created reputational, regulatory and litigation risks for companies and for their investors.

These impacts and their associated risks can, to a significant degree, be mitigated through the implementation and further development of best practices. In some areas, best practices can be implemented immediately. In others they will require time and innovation. Of primary importance are:

- Transparency – Increasing transparency, especially regarding fracturing fluid, is of immediate importance. Some U.S. investors and regulators have already raised the bar in this area.
- Baseline water testing – In order to monitor and better understand the impact of hydraulic fracturing on local water quality, baseline testing is essential. The results should be reported to local communities and to regulatory authorities.
- Green Products – Companies should strive to reduce the toxicity of the fracturing fluids that they use in order and lessen the risk of water contamination. This will require innovation.
- Process Changes – These should include green completions (to reduce fugitive emissions), the recycling of flow back water (to reduce pressure on water resources), and well integrity testing (to reduce contamination risks). Innovation is key to this area as well, and investors should be looking for opportunities associated with second- and third-generation fracturing techniques.
- Operational Management – Critical to this area is contractor supervision and auditing. Companies need assurances that their contractors are executing the agreed upon procedures in a responsible manner.
- Community Engagement and Consultation – This needs to begin at an early stage, to be continuous, and to include both households and local government.

Citation: KPMG, Shale Gas Development: *Global Update* (2013)

Topic Area: The Shale Gas Market and Global Development

Jurisdiction: USA, China, Argentina, Australia, Indonesia and UK

Introduction: Shale is fast transforming itself from 'tomorrow's big thing' to become an essential part of the global energy sector. Although the US is still way out in front in terms of commercializing this valuable asset, other markets are playing an accelerated game of catch-up, with a series of discoveries and technological advances. Energy security is the word on every government's lips, with shale promising to bring greater self-sufficiency, significant revenue from industrialization, exporting surplus volumes, and a reduced carbon footprint.

Aims & Research Methods: This report provides an analysis of the opportunities, issues, M&A trends and outlook in the chosen jurisdictions to provide a global outlook of the current Shale Gas industry.

Scope: This report discusses the global shale market and looks at developments in the big three – US, China and Argentina – as well as in Australia, Indonesia and the UK. It provides some compelling insights into an evolving sector as well as some pointers to the future shape of global shale markets.

Conclusions: With a pronounced shift in the US shale market from gas to liquids, it is uncertain when gas prices will rise sufficiently to justify a return to large-scale dry gas extraction. Although the presence of majors such as ConocoPhillips and Exxon indicates confidence in the potential of shale, investors are hoping for a boost in infrastructure development and a favourable tax and regulatory environment to maintain momentum. China is undeniably an up-and-coming player and, with strong government backing, is likely to have a strong influence on global markets within the next five years, and should continue to prove attractive to overseas investors. The future for Argentina is rather less clear cut, and may be dependent upon a more transparent approach to ownership, to reassure business owners. Having enjoyed a natural resources boom over the past two decades, Australia is well-positioned to take advantage of its shale reserves, assuming it can extract gas and liquids cost-effectively. The continued impact of shale dry gas upon global prices will in part be determined by the degree to which it is exported as LNG; some governments may choose to put pressure on their energy industries to retain this critical resource to provide much-needed self-sufficiency as is the case in Indonesia. This factor, along with the speed of recovery of the US industry, may have a significant impact upon the return on investments in dry shale gas.

Citation: Lisa Sumi, *The Regulation of Shale Gas Development: State of Play* (2013) Prepared for Council of Canadians Re: Ontario Energy Board Proceedings *Exhibit L.UGL.COC.2*

Topic Area: Environmental Issues, Regulatory Initiatives, Water Use and Management

Jurisdiction: USA and Canada

Introduction: The present applications before the Ontario Energy Board (the "Board") promise to realize certain benefits such as access to relatively abundant shale gas reserves from the United States, in particular from the Marcellus and Utica shales.

Aims & Research Methods: The purpose of this report is to provide an overview of the potential environmental and regulatory issues that may affect gas production from shale basins in the United States, and in particular, supply from those basins presented as significant future sources of natural gas for the residents of the Ontario and the Greater Toronto Area (the "GTA").

Scope: This report is divided into two sections. The first describes the major environmental challenges facing the shale gas industry today – the seriousness of these impacts underscores the need for determined action by governments to address them. The second describes the extent to which governments have responded to these challenges, and the potential impact of emergent regulatory and economic measures on the pace and extent of shale gas development in the Marcellus and Utica basins.

Conclusions: The key conclusions of this paper are:
1. Information about the environmental and public health impacts of shale gas development continues to grow, revealing a diverse array of very serious affects, including:
•regional water shortages, which may impact the ability of Marcellus operators to obtain the large volume of water needed to drill and fracture wells;
•contamination of drinking water from shale development,
•air pollution, which has affected local and regional air quality and threatens public health;

• the large volume of wastewater generated from shale gas wells, which is already overwhelming existing disposal options; earthquakes, which have been linked to shale gas wastewater disposal via underground injection; and
• toxic and radioactive chemicals in wastes, which are posing disposal challenges and concerns.

2.State regulatory agencies in Pennsylvania, West Virginia and Ohio were ill-prepared for the pace of drilling, and the environmental impacts that accompanied the shale gas boom. Not only were regulations inadequate to protect the environment and public health from shale gas development, but state agencies tasked with overseeing drilling, production and waste disposal were and in many cases remain underfunded and understaffed. Consequently, these states are still in "catch-up" mode, and tightening of regulations can be expected.

3.Both state and federal government continue to develop and strengthen regulations to address some of the impacts, but the large gap between known impacts and existing regulations means more safeguards are needed.

4.Voluntary and regulatory mechanisms to mitigate environmental impacts can impose significant costs on shale gas development. With almost every new regulatory initiative proposed, the shale gas industry has expressed concerns related to the costs of compliance, and has argued that some proposed regulations will result in decreases in drilling. One potential federal regulation related to ozone is said to be the most costly regulation ever proposed for the industry.

5.If governments respond with effective regulatory and economic measures to the environmental challenges facing the shale gas industry, the cost of shale development will certainly rise, and in some cases is likely to become uneconomic. In other cases, the risks associated with shale gas development may be considered too great to allow for any development of this energy resource, and moratoriums now in place in the Marcellus shale may become permanent and spread to other jurisdictions.

Citation: Michael Ratner and Mary Tiemann, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions* (2013) Congressional Research Service

Topic Area: Other Social Issues, Environmental Issues, Fracking Activities

Jurisdiction: USA

Introduction: The United States has seen resurgence in petroleum production, mainly driven by technology improvements—hydraulic fracturing and directional drilling—developed for natural gas production from shale formations. Application of both of these technologies enabled natural gas to be economically produced from shale and other unconventional formations, and contributed to the United States becoming the world's largest natural gas producer in 2009. Use of these technologies has also contributed to the rise in U.S. oil production over the last few years. In 2009, annual oil production increased over 2008, the first annual rise since 1991, and has continued to increase each year since then. Between 2008 and 2012, U.S. annual crude oil production rose by 1.5 million barrels per day, with about 92% of the increase coming from shale and related tight oil formations in Texas and North Dakota. Overall petroleum liquids grew by 2.1 million barrels per day, with much of the increase in natural gas liquids coming from shale gas plays. Other tight oil plays are also being developed, and helped raise the prospect of energy independence, particularly for North America.

Aims & Research Methods: This report focuses on the growth in U.S. oil and natural gas production driven primarily by tight oil formations and shale gas formations. It also reviews selected federal environmental regulatory and research initiatives related to unconventional oil and gas extraction, including the Bureau of Land Management (BLM) proposed hydraulic fracturing rule.

Scope: This report analyses geology, price drives, technical stimulants, fracking activities, other social issues and environmental concerns and responses in the US.

Conclusions: The prospect that by the end of the decade the United States could become a significant exporter of natural gas and the world's leading oil producer is a phenomenal change of circumstances from just a few years ago. The technological advances that drove the changes in the United States have also reversed the global perspective of dwindling oil and natural gas resources, and increased the concern among many about greenhouse gas emissions. Other countries seek to emulate the U.S. success, but have yet to do so. The U.S. oil and gas situation continues to be extremely dynamic, and many questions remain about how the United States will develop its resources.

Many observers, including U.S. government officials, have only recently recognized the tremendous resource size and the benefits that will accrue from developing the resources, as well as the potential risks that may be associated with this development. Even though shale gas development is still considered very new and tight oil production is even newer, the industry has continued to improve its efficiency in extracting the resources, particularly of natural gas. As more industry resources are shifted to tight oil plays, the natural gas sector has had to produce more with less. Some in industry point out that at the beginning of shale gas development about 5% of the resource was able to be extracted; now it is closer to 20%. By comparison, the extraction rate from conventional gas is between 30% and 60% of the resource.

Most concerns surrounding shale gas and tight oil development have involved environmental and human health issues, and particularly concerns over the potential risks to groundwater and surface water resources, and emissions of air pollutants. These concerns have led to calls for greater federal oversight of oil and gas development. Although primary regulatory authority over oil and natural gas exploration and production on state and private lands generally rests with the states, provisions of several federal environmental laws currently apply to certain activities associated with oil and natural gas exploration and production. Moreover, EPA is reviewing other statutory authorities and pursuing new regulatory initiatives, and BLM has proposed revisions to its oil and gas rules to specifically address hydraulic fracturing on federal and Indian lands. A broader concern, particularly from environmental groups, is that the low price of natural gas is having negative consequences for the development and growth in renewable energy sources and nuclear power, potentially resulting in another generation of greenhouse-gas-producing energy sources.

The 113th Congress has held hearings, roundtables, and other discussions on issues associated with unconventional oil and gas development broadly, and on the role of the states specifically. Bills have been introduced to expand and also to constrain federal involvement in oil and gas development involving hydraulic fracturing. In the meantime, the Administration is pursuing actions to broaden federal oversight of this industry sector through administrative means.

Citation: KPMG, *Central and Eastern Europe – Shale gas development "inevitable"* (2012)

Topic Area: Social and Environmental issues

Jurisdiction: EU

Introduction: Many Central and Eastern European countries, especially Poland, Romania and Ukraine, will potentially be important markets for shale gas production in the next decade, as governments struggle with dwindling conventional gas reserves, rising energy demand and an over-dependence on single countries for primary energy needs.

Aims & Research Methods: This report notes, there are a number of environmental (and often social) factors related to the recovery of shale gas that need to be monitored, while local topographical particularities in Europe will also need to be considered, should the development of shale gas resources proceed in earnest within the CEE region. While the public's concern over shale gas exploration and development has – with the exception of Bulgaria – been limited thus far, addressing potential environmental and safety issues will be essential for the industry's development.

Scope: This report analyses Shale Gas in the US and CEE, public acceptance of shale gas, county profiles and economics of Shale Gas.

Conclusions: Unlike in the US, where land owners generally own the rights to minerals on their property, underground reserves in CEE countries are considered to be the sole property of the state; land owners in the region, therefore, are not incentivized to cooperate with exploration companies. On top of paying a royalty to the state, developers have the choice to either pay a rental fee or acquire the land from the land owner, which increases costs and can delay progress with exploration or production activities. Fragmented land ownership can also make this situation even more difficult. In addition to differences in rights ownership, population density within CEE region is generally greater than that of shale formation areas in the US. In Central and Eastern Europe, open agricultural areas are available for exploration, while drilling around buildings, roads, overhead power lines, drinking water production areas, and environmentally protected land is restricted, which are all more difficult to avoid in the region.

Citation: Heather Cooley and Kristina Donnelly, *Hydraulic Fracturing and Water Resources: Separating the Frack from the Fiction* (2012) Pacific Institute

Topic Area: Fracking Activities, Water Use and Management

Jurisdiction: USA

Introduction: Natural gas has been touted by some as a key "bridge fuel" that will transition the United States toward a more low-carbon energy economy. Energy analysts, including the United States Energy Information Administration (U.S. EIA), project that the United States will become increasingly reliant on natural gas. According to U.S. EIA estimates released in January 2012, natural gas production is projected to increase by nearly 30% over the next 25 years, from 22 trillion cubic feet in 2010 to 28 trillion cubic feet in 2035.[1] The growth in natural gas production is driven by a dramatic increase in domestic shale gas production, and by 2021, the United States is projected to be a net exporter of natural gas.

Aims & Research Methods: To better identify and understand what the key issues are in relation to hydraulic fracturing, the Pacific Institute conducted extensive interviews with a diverse group of stakeholders, including representatives from state and federal agencies, academia, industry, environmental groups, and community-based organizations from across the United States.

Scope: This paper provides a short summary of the key issues identified in the interviews and in an initial assessment and synthesis of existing research. It especially examines the impacts of hydraulic fracturing and unconventional natural gas extraction on water resources and identifies areas where more information is needed. Our focus throughout the report is on shale gas, although we discuss other unconventional natural gas sources where information is readily available. For the purpose of this report, we use a broad definition of hydraulic fracturing to include impacts associated with well construction and completion, the hydraulic fracturing process itself, and well production and closure.

Conclusions: Overall, we find that the lack of credible and comprehensive data and information is a major impediment to a robust analysis of the real concerns associated with hydraulic fracturing. Due to the nature of the business, members of the industry have an incentive to keep the specifics of their operations secretin order to gain a competitive advantage, avoid litigation, etc. Additionally, peer-reviewed, scientific information on the process and its environmental impacts is lacking. This hinders a comprehensive analysis of the potential environmental and public health risks and strategies to minimize these risks. While much has been written about the interaction of hydraulic fracturing and water resources, the majority of this writing is either industry or advocacy reports that have not been peer-reviewed (U.S. EPA 2011a). As a result, the discourse around the issue to date has been marked by opinion and obfuscation.

Citation: Kara Rickson, *Coming apart at the seams? Social impact assessment and the coal seam gas controversy in Queensland, Australia* (2012) IAIA12 Conference Proceedings' Energy Future: The role of impact assessment 32nd Annual Meeting of the International Association for Impact Assessment 27 May-1June 2012, Centro de Congress da Alfândega, Porto, Portugal

Topic Area: Other Social Issues, Social Impact Assessments

Jurisdiction: Australia

Introduction: The prospects for the Darling Downs and Maranoa regions in the Australian state of Queensland are riding high. While this is one of the country's most productive farming areas, it is the reserves of coal seam gas (CSG) that represent the biggest source of both promise and conflict. With three newly-approved CSG 'mega-projects', another in development, mining exploration permits covering most of the region, and an export contract of unprecedented magnitude, this part of the Surat Basin is viewed as a critical contributor to future State employment and revenue, as well as the federal government's lower-carbon energy policy. Debates about whether the scale and pace of coal seam gas mining are booming ahead of scientific understanding and legislative protections and putting communities and environments irreversibly at risk have, however, become highly charged. Questions have been raised not only about the safety of cumulative and longer-term impacts on aquifers and agriculture, including on the nation's food security, but also about the very future of Australia's rural and regional communities, environment and economy.

Aims & Research Methods: This paper examines these issues in relation to current and proposed provisions for social and environmental impact assessment.

Scope: Broadly, this paper considers debates about the nature and role of social impact assessment in development decisions, and tensions over the legitimacy and science of assessment that may be fracturing, or becoming further buried, in the seams.

Conclusions: Conflicts over CSG mining have emerged not just between companies seeking to secure a 'social license' with residents at the farm gate and in town halls, but involve a much broader constituency, beyond a 'politics of grievance' (Buttel, 2005). Wider debates over resource use have questioned both the acceptability of risks and the legitimacy invested in authorities to accept them. That there has been the level of conflict within and across regions, political party lines, sectors and communities powerfully suggests that developments are indeed proceeding ahead of adequate SIA requirements, but also that these alone may provide insufficient basis to address such conflicts, the issues at debate, or the differently privileged interests that identify, negotiate or contest them.

Citation: British Geological Survey, *Potential Groundwater Impact from Exploitation of Shale Gas in the UK* (2012) Groundwater Science Programme Open Report OR/12/001

Topic Area: Water Use and Management, Fracking Activities

Jurisdiction: UK and USA

Introduction: Demand for gas in the UK is steadily increasing, North Sea gas reserves are declining and the UK has become a net importer of gas. Shale gas drilling in the UK has been given the go-ahead by MPs in a report looking at the impact it could have on water supplies, energy security and greenhouse gas emissions (Energy and Climate Change Select Committee, 2011). In order to meet demand in the future, energy exploration may be focused on our 'unconventional' reservoirs, including shales (mudstones, claystones, and other fine-grained rocks). Work towards extraction of shale gas began in the UK in August 2010 with the drilling of a 2700 m deep exploratory well to the Bowland Shale at Preese Hall, near Blackpool, NW England. The second phase involving hydraulic fracturing began in Marc h 2011. Work was temporarily suspended on 1 June 2011 after a 1.5 magnitude earth quake was detected. Work began at a second site at Banks, near Southport on 22 August 2011 and at Grange Hill Farm.

Aims & Research Methods: For UK we need to determine whether fields likely to be exploited for shale gas are overlain by significant aquifers. For aquifers at outcrop the vulnerability of groundwater to surface pollution from operations and flow back water can be informed by existing vulnerability mapping and other information. The vulnerability of groundwater to pollution from fracking operations and shale gas requires the determination of the relative depths of groundwater and shale gas reservoirs and the nature of the intervening strata.

Scope: This report is a desk study to evaluate the potential risks to ground water in the UK from exploitation of shale gas. As yet there is little in formation for UK so we need to look to the USA experience for transferable information. The UK may possess considerable reserves of shale gas. Significant areas include the Widmerpool Gulf, near Nottingham, and the Else wick field near Blackpool. Work has begun near Blackpool.

Conclusions:

- The UK may possess considerable reserves of shale gas. Significant areas include the carboniferous strata of the Widmerpool Gulf, near Nottingham, and the Elsewick field near Blackpool. Work to extract shale gas has begun near Blackpool.
- Shale gas is predominantly methane of thermo genic origin with low percentages of C2 and C3hydrocarbons. Its 13C isotopic signature allows it to be distinguished from shallow biogenic methane in the subsurface
- Extraction involved drilling of deep horizontal wells and enhancing the natural permeability of the shale by hydraulic fracturing.
- Groundwater may be potentially contaminated by extraction of shale gas both from the constituents of shale gas itself, from the formulation and deep injection of water containing a cocktail of additives used for hydraulic fracturing and from flow back water which may have a high content of saline formation water. OR/12/001 20
- Fracking chemicals include hydrochloric acid, polyacrylamide, mineral oil, isopropanol, potassium chloride and ethylene glycol and low concentrations of pH buffers, corrosion inhibitors, biocides and gelling agents.
- A wide range of pollutants, including priority substances has been detected in flow back water
- The large volumes of water required may also put pressure on groundwater resources with impacts on other uses and groundwater dependent ecosystems. Reuse of flow back water involves treatment to remove high TDS.
- There are examples of surface water contamination from releases of fracturing water or flow back water. Documented instances of groundwater contamination from the U.S. are all related to the leakage of methane into groundwater.

Citation: Argonne, *Hydraulic Fracturing and Shale Gas Production: Technology, Impacts and Regulations* (2013)

Topic Area: Fracking Activities, Other Social Impacts, Regulation and Chemical Use and Disclosure

Jurisdiction: USA

Introduction: Hydraulic fracturing is a key technique that has enabled the economic production of natural gas from shale deposits, or plays. The development of large-scale shale gas production is changing the U.S. energy market, generating expanded interest in the usage of natural gas in sectors such as electricity generation and transportation. At the same time, there is much uncertainty of the environmental implications of hydraulic fracturing and the rapid expansion of natural gas production from shale plays. The goal of this white paper is to explain the technologies involved in shale gas production, the potential impacts of shale gas production, and the practices and policies currently being developed and implemented to mitigate these impacts.

Aims & Research Methods: The goal of this white paper is to explain the technologies involved in shale gas production, the potential impacts of shale gas production, and the practices and policies currently being developed and implemented to mitigate these impacts.

Scope: This report analyses shale gas hydraulic fracturing, environmental impacts, water quality, regulation and proposed mitigation impacts.

Conclusions: Shale gas production represents a large, new potential source of natural gas for the nation.
Development of this resource is, however, not without risks to natural resources. Potential impacts include the following:

- Greenhouse gas emissions during completion and production activities,
- Air emissions that affect local air quality during completion and production activities,
- Water withdrawals for hydraulic fracturing,
- Induced seismicity from improper management of flow back water,
- Water quality impacts to surface water or aquifer from faulty well design and construction or improper flow back water management, and
- Additional community impacts including noise and light pollution.

Improved science-based assessments of these risks are underway, but early results indicate that the risks can be managed and lowered through existing practices including the following:

- RECs that limit VOC, HAP, and CH_4 emissions and reduce flaring,
- Engineering controls and appropriate personal protective equipment to reduce worker exposure to crystalline silica,

- Reusing flow back water to limit fresh water withdrawal requirements and reduce water management burdens,

- Drilling of multiple wells from a single well pad to reduce the footprint of operations,

- Proper siting, design, and construction of gas production and fluid disposal wells, and

- Groundwater quality monitoring coupled with fracturing fluid chemical disclosures.

With adequate safeguards in place, shale gas can be exploited responsibly in ways that protect both the environment and human health.

Citation: Mary Tiemann, *Hydraulic Fracturing and Safe Drinking Water Act Issues* (2012) Congressional Research Service

Topic Area: Fracking Activities and Chemical Use and Disclosure

Jurisdiction: USA

Introduction: Historically, the Environmental Protection Agency (EPA) had not regulated the underground injection of fluids for hydraulic fracturing of oil or gas production wells. In 1997, the U.S. Court of Appeals for the 11th Circuit ruled that fracturing for coal bed methane (CBM) production in Alabama constituted underground injection and must be regulated under the Safe Drinking Water Act (SDWA). This ruling led EPA to study the risk that hydraulic fracturing for CBM production might pose to drinking water sources. In 2004, EPA reported that the risk was small, except where diesel was used, and that national regulation was not needed. However, to address regulatory uncertainty the ruling created, the Energy Policy Act of 2005 (EPAct 2005) revised the SDWA term “underground injection” to explicitly exclude the injection of fluids and propping agents (except diesel fuel) used for hydraulic fracturing purposes. Consequently, EPA currently lacks authority under the SDWA to regulate hydraulic fracturing, except where diesel fuel is used. (In May, EPA issued draft permitting guidance for use of diesel during fracturing.) As the use of this process has grown, some in Congress would like to revisit this statutory exclusion.

Aims & Research Methods: This report reviews past and proposed treatment of hydraulic fracturing under the SDWA, the principal federal statute for regulating the underground injection of fluids to protect groundwater sources of drinking water. It reviews current SDWA provisions for regulating underground injection activities, and discusses some possible implications of, and issues associated with, enactment of legislation authorizing EPA to regulate hydraulic fracturing under this statute.

Scope: This paper analyses hydraulic fracturing and the regulation of underground injection, legislative regulation and potential implications of fracturing regulation under the SWDA.

Conclusions: Hydraulic fracturing bills introduced in the 112th Congress and previously have generated considerable debate. Many state agencies have argued against regulation of hydraulic fracturing under the SDWA groundwater protection provisions, and note a long history of the successful use of this practice in developing oil and gas resources. Industry representatives argue that additional federal regulation is unnecessary and would likely slow domestic gas development and increase energy prices. At the same time, the amount of natural gas and oil produced from formations that rely on hydraulic fracturing continues to grow. Drilling and fracturing methods and technologies have changed significantly over time as they have been applied to more challenging formations, greatly increasing the amount of water, fracturing fluids, and well pressures involved in oil and gas production operations. The increasing density of wells and geographic expansion of the use of hydraulic fracturing, along with a growing number of citizen complaints of groundwater contamination and other environmental problems attributed to this practice has led to calls for greater state and/or federal environmental oversight of this activity.

Citation: Brandon Murril and Adam Vann, *Hydraulic Fracturing: Chemical Disclosure Requirements* (2012) Congressional Research Service 1-23

Topic Area: Fracking Activities, Chemical Use and Disclosure

Jurisdiction: USA

Introduction: Chemical disclosure laws at the state level vary widely. Of the 15 laws examined in this report, fewer than half require direct public disclosure of chemical information by mandating that parties post the information on the FracFocus chemical disclosure website. The level of detail required to be disclosed often depends on how states protect trade secrets, as these protections may allow submitting parties to withhold information from disclosure at their discretion or to submit fewer details about proprietary chemicals, except, perhaps, in emergencies. Even if a disclosure law does not protect information from public disclosure, other state laws, such as an exemption in an open records law, may do so. States also have varying laws regarding the timing of these disclosure requirements.

Aims & Research Methods: This report provides an overview of current and proposed laws and regulations at the state and federal levels that require the disclosure of the chemicals added to the fluid used in hydraulic fracturing. Appendix A provides a glossary of many of the terms used in this report. Appendix B contains a table summarizing the fracturing chemical disclosure requirements described in this report. For an overview of the relationship between hydraulic fracturing and the Safe Drinking Water Act (SDWA), see CRS Report R41760, Hydraulic Fracturing and Safe Drinking Water Act Issues.

Scope: This report analyses federal proposals and state disclosure laws in regards to trade secret chemical use and disclosure of fracking activities.

Conclusions: Many federal and state legislators and regulatory authorities have adopted or proposed measures that would create new disclosure requirements applicable to the practice of hydraulic fracturing, a natural resource recovery technique that is widely used in the recovery of natural gas from shale formations. The Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board has recommended the public disclosure, on a well-by-well basis, of all of the chemical ingredients added to fracturing fluids—even those ingredients that do not meet OSHA's standards for hazardous chemicals requiring MSDSs. The subcommittee recommended that some protection for trade secrets be provided.

At the federal level, BLM has proposed disclosure requirements that would be applicable for hydraulic fracturing on all lands managed by the agency. Legislation has been introduced in the 112th Congress that would create disclosure requirements for all hydraulic fracturing operations nationally.

Chemical disclosure laws at the state level vary widely. Of the 15 laws examined in this report, fewer than half require direct public disclosure of chemical information by mandating that parties post the information on the FracFocus chemical disclosure website. The level of detail required to be disclosed often depends on how states protect trade secrets, as these protections may allow submitting parties to withhold information from disclosure at their discretion or to submit fewer details about proprietary chemicals, except, perhaps, in emergencies. Even if a disclosure law does not protect information from public disclosure, other state laws, such as an exemption in an open records law, may do so. A few states require the submission of MSDSs for certain chemicals. MSDSs may offer a relatively low level of disclosure, as the most specific details that parties currently must include on the data sheets under OSHA regulations are the chemical or common names of certain hazardous ingredients. With regard to the timing of disclosure, a few state laws require at least some disclosure of information about fracturing fluid chemical composition before fracturing is performed, but these states typically require less detailed information to be provided before fracturing than afterward.

Citation: NSW Government, *Strategic Regional Land Use Policy Fact Sheet Agricultural Impact Statement* (September 2012)

Topic Area: Land Use, Environmental Issues

Jurisdiction: Australia (NSW)

Introduction: An Agricultural Impact Statement is required for:

 All new State Significant mining and coal seam gas development applications that may impact agricultural resources, whether or not they are located on land mapped as Strategic Agricultural Land in a Strategic Regional Land Use Plan; and
 Mining and coal seam gas exploration activities as part of the Review of Environmental Factors (REF).

Scope: This fact sheet analyses and outlines the requirements for the agricultural impact statement regime in NSW.

Conclusions: The Agricultural Impact Statement is a new state-wide requirement for all mining, coal seam gas exploration and production proposals to assess potential impacts of these activities on agricultural resources and businesses. For the first time, this assessment must take place at the very earliest stages of a mining or coal seam gas project to minimise impacts on our valuable agricultural and water resources.

The Agricultural Impact Statement must detail:
 The significance of the agricultural resources – including land and water – and associated businesses in the project area and surrounding locality; and

 The potential impact of the project on agricultural land, water and businesses at a local and regional level.

The requirement for an Agricultural Impact Statement ensures a targeted assessment of the potential impacts of mining and coal seam gas proposals on agricultural land and water. This will form a key component of the assessment process in terms of evaluating and avoiding impacts on and loss of agricultural lands.

Citation: NSW Government, *Strategic Regional Land Use Policy Aquifer Interference Policy* (September 2012)

Topic Area: Aquifer Regulation, Water Use and Distribution, Hydraulic Fracturing Activities

Jurisdiction: Australia (NSW)

Introduction: THE AQUIFER INTERFERENCE POLICY
 Will apply across the State to clarify water licence and impact assessment requirements for aquifer interference activities;
 Ensures equitable water sharing among different types of water users;
 Ensures that water taken by aquifer interference activities is properly licensed and accounted for in the water budget and water sharing arrangements; and
 Enhances existing regulation, resulting in a comprehensive framework to protect the rights of all water users and the environment.

Aims & Research Methods: The Aquifer Interference Policy is a new policy which defines the protection of NSW underground water resources and strikes a balance between the water use requirements of towns, farmers, industry and the environment. A key plank of the NSW Government's Strategic Regional Land Use Policy, the Aquifer Interference Policy details how potential impacts to aquifers should be assessed, and how this information is provided to the relevant planning process, including the Gateway Panel and/or the Planning Assessment Commission.

Scope: This fact sheet analyses and outlines the requirements for the aquifer interference policy regime in NSW.

Conclusions: HOW WILL THIS BENEFIT NSW?
 The community and project proponents will have a better understanding of the considerations against which projects will be assessed.
 The agency assessment of potential impacts on aquifers by State Significant Development and Infrastructure proposals will occur with greater speed, clarity and transparency than in the past

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Citation: Chris Flynn and Matt Baumgurtel, *Coal Seam Gas in NSW: To Be or Not to Be?* Glibert and Tobin (May 2012)

Topic Area: Social and Environmental Issues, Hydraulic Fracturing Activities

Jurisdiction: Australia (NSW)

Introduction: On 1 May 2012, the New South Wales Legislative Council General Purpose Standing Committee no.5 (Committee) released its report (Report**)** on certain environmental, economic and social aspects of the coal seam gas (CSG) industry in NSW. The report contains 35 recommendations for action by the NSW Government (Recommendations).

Aims & Research Methods: The Report proposes comprehensive changes to the regulation and, thereby, the operation of the CSG industry in NSW. Most notably the Report recommends the following:

- new environmental and community consultation requirements are proposed at the exploration license application stage;
- an ongoing comprehensive community consultation regime be established during the exploration and production phases of CSG operations;
- a comprehensive land access arrangement regime with landholders be developed (including the development of a template land access agreement);
- tighter and more robust requirements surrounding water usage, monitoring and storage are imposed on CSG companies (including with respect to aquifers and aquifer interference);
- scrapping the current royalty holiday (and related tied royalty regime) for CSG projects;
- introducing a domestic supply obligation whereby a proportion of gas produced from a project is reserved for specifically domestic consumption;
- continuing the current ban on hydraulic fraccing until the Government considers the assessment currently being undertaken by the National Industrial Chemicals Notification and Assessment Scheme;
- limiting fugitive emissions from CSG projects to an upper limit of 0.1%;
- introducing a robust environmental remediation scheme by way of amendment to the Act likely requiring the posting of higher value, longer term security bonds and a higher standard against which environmental remediation obligations will be measured; and
- the establishment of 2 new Government units for industry oversight.

Scope: This update does not detail every one of those 35 recommendations. Rather, it provides a preliminary overview of a number of the key recommendations made in the Report. It remains to be seen how many, and which, of the Recommendations will be adopted by the NSW Government.

In the meantime, *the Committee recommends that no further production licences are issued in respect of CSG operations before a "comprehensive framework for the regulation of the* *coal seam gas industry is implemented*". The timing and key steps in developing this framework remains unclear.

However, given the early stage of development of the CSG industry in NSW and the need for more information on the environmental and social effects of CSG activities, the Report also recommends that the exploration phase of CSG activities be allowed to proceed, albeit subject to tighter control and regulation.

Conclusions: It is not yet known which, or how many, of the Recommendations will be implemented by the NSW Government. However, each of the Recommendations will affect the operations and economics of CSG companies and projects in NSW. In particular, the extent to which the Government implements each of the Recommendations will determine the extent to CSG companies are required to absorb the additional time and costs which will flow from the Recommendations when undertaking CSG projects.

Increased costs and time delays will primarily arise from the proposed access arrangements that proponents will be required to enter into with landholders. CSG companies will need to ensure that they have effective resources, management and mitigation measures in place to comply with any new conditions in their licences or requirements under law coming out of the implementation of any of the Recommendations. Increased regulatory scrutiny may also expose CSG companies to compliance and reputational risk issues.

Finally, given the Minister's broad powers to refuse exploration licence applications, a CSG company's environmental track record is likely to be a significant factor in its ability to successfully participate in the CSG industry in NSW.

Citation: Environmental Defender's Office NSW, *Mining Law in NSW Discussion Paper* (June 2011)

Topic Area: Regulatory Framework, Environmental and Social Issues

Jurisdiction: Australia (NSW)

Introduction: The regulation of coal mining and coal seam gas ("CSG") extraction in NSW is on an unsustainable path. Many aspects of the regulatory framework are out dated and fail to promote or produce sound environmental outcomes. It is clear that if current mining practices continue, the result will be irreversible damage to this State's long term environmental, social and economic wellbeing. That result is avoidable, however, and changes can be made for the better.

Aims & Research Methods: This paper has been drafted to encourage discussion about the legal framework for mining in NSW, and to promote positive environmental outcomes. It identifies key inadequacies with the current system and makes recommendations for legislative change to make the current processes more sustainable, robust, equitable and transparent. The paper focuses on the Mining Act 1992 (NSW) ("Mining Act") and the Petroleum (Onshore) Act 1991 (NSW) ("Petroleum (Onshore) Act"), as well as the Environmental Planning and Assessment Act 1979 ("EP&A Act"), where many of the environmental gains can be made.

Conclusions: Overall, the EDO supports the development of a regulatory system that is framed – or, from a resource extraction perspective, constrained – by the notion of sustainability. This essentially involves two elements. First, it involves strengthening and operationalising the established principles of ecologically sustainable development (“ESD”) within the legislative framework.

These principles are set out in section 6 of the Protection of the Environment Administration Act 1991 (NSW). In brief they include:
 the precautionary principle
 inter-generational equity
 conservation of biological diversity and ecological integrity, and
 improved environmental valuation, pricing and incentive mechanisms.
Second, and more importantly, it involves seeing ESD as an end to be achieved, as well as the pre-eminent benchmark underpinning decision-making.
Legislative frameworks and policy approaches need to be built from, and reflect, this standpoint on ESD. In turn, the actions of decision-makers need to be judged against it.

Citation: NSW Government, *Frequently Asked Questions Strategic Regional Land Use Policy* (September 2012)

Topic Area: Land Use, Environmental and Social Issues

Jurisdiction: Australia (NSW)

Aims & Research Methods: The Strategic Regional Land Use Policy sets out a range of initiatives to better balance growth in the mining and coal seam gas (CSG) industries with the need to protect important agricultural land and water resources.
For the first time, it maps the State’s most valuable agricultural land and protects it from mining and CSG projects.
Key elements of the policy include:
• Strategic Regional Land Use Plans covering the Upper Hunter and New England North West regions
• Strengthening the regulation of exploration activities
• Establishing the role of a Land and Water Commissioner
• A state-wide Aquifer Interference Policy
• Two Codes of Practice for the CSG industry

Conclusions: The Strategic Regional Land Use Policy sets out a range of initiatives to better balance growth in the mining and coal seam gas (CSG) industries with the need to protect important agricultural land and water resources. For the first time, it maps the State’s most valuable agricultural land and protects it from mining and CSG projects.
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• Establishing the role of a Land and Water Commissioner

• A state-wide Aquifer Interference Policy
• Two Codes of Practice for the CSG industry

Citation: Campbell Macpherson Pty Ltd, *Identification and Review of Standards for Hydraulic Fracturing* (November 2011)

Topic Area: Hydraulic Fracturing,

Jurisdiction: Australian (NSW)

Introduction: While hydraulic fracturing has been used for around 60 years, a survey of literature in English indicates that the few standards, guidelines and codes of practices that exist have only been recently developed. There is no international standard nor is there a single consolidated set of standards in any jurisdiction.

Aims & Research Methods: This report examines the current regulatory framework for coal seam gas in NSW. In essence, the legislation is out dated and inadequate to addressing the demands of an expanding coal seam gas industry. Applying standards for hydraulic fracturing (even if a robust set of standards was available) would probably not address identified risks, meet the Government's call for 'tough new conditions or coal am gas' or allay community anxiety.

Scope: This report analyses Coal Seam Gas in Australia and the United States.

Conclusions: This report suggests a broader solution and the following recommendations have been made:

1. Immediately amend the Schedule of Onshore Petroleum Exploration and Production Safety Requirements to update it and include hydraulic fracturing safety requirements;
2. Liaise with DEEDI Queensland on its Draft Code of Practice for Hydraulic Fracture Stimulation for possible inclusion in the Schedule;
3. Develop a proposal for amendments to the Petroleum (Onshore) Regulation;
4. Develop a proposal for amendments to the Petroleum (Onshore) Act;
5. Develop a 'hydraulic fracturing' section on the Department's website;
6. Develop a workforce plan for the inspectorate.

Citation: Queensland Government, *Guide to Queensland's New Land Access Laws* (November 2010)

Topic Area: Land Access and Land Use

Jurisdiction: Australia (Queensland)

Introduction: Significant growth and expansion in exploration and development of minerals, gas, petroleum and other resources, such as coal seam gas to support the emerging liquefied natural gas industry, presents both opportunities and challenges for the long-term prosperity of Queensland. The Queensland Government is committed to balancing the interests and sustainable growth of the agriculture and resource sectors for the benefit of our State. Both industries, the jobs they create and income they generate, are vital to our economy and regional communities. Natural resources, including underground resources such as minerals, petroleum and coal seam gas, are owned by the people of Queensland and are not the property of individuals or companies.

The Government manages these resources for the benefit of all Queenslanders. The Government has listened and responded to the concerns of the agricultural sector and landholders about access to their land for resource exploration and development.

In May 2008, as part of the Government's response to growth of the resources industry and impacts on the agricultural sector, a Land Access Working Group (LAWG) was established to help improve relationships between the agriculture and resources sectors. The LAWG includes key representatives from both sectors including Agforce, the Queensland Farmer's Federation, Queensland Resources Council and Australian Petroleum Production and Exploration Association.

The LAWG has helped guide the Government's response to these issues and in 2009 assisted with development of the Land Access Policy Framework. This policy framework includes a number of land access reforms including legislative amendments and development of supporting land access documents. New laws strengthening existing land access laws are part of these reforms.

Aims & Research Methods: Significant growth and expansion in exploration and development of minerals, gas, petroleum and other resources, such as coal seam gas to support the emerging liquefied natural gas industry, presents both opportunities and challenges for the long-term prosperity of Queensland.

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Natural resources, including underground resources such as minerals, petroleum and coal seam gas, are owned by the people of Queensland and are not the property of individuals or companies. The Government manages these resources for the benefit of all Queenslanders.
The Government has listened and responded to the concerns of the agricultural sector and landholders about access to their land for resource exploration and development.
In May 2008, as part of the Government's response to growth of the resources industry and impacts on the agricultural sector, a Land Access Working Group (LAWG) was established to help improve relationships between the agriculture and resources sectors. The LAWG includes key representatives from both sectors including Agforce, the Queensland Farmer's Federation, Queensland Resources Council and Australian Petroleum Production and Exploration Association.

The LAWG has helped guide the Government's response to these issues and in 2009 assisted with development of the Land Access Policy Framework. This policy framework includes a number of land access reforms including legislative amendments and development of supporting land access documents. New laws strengthening existing land access laws are part of these reforms.

The key features of the new land access laws are:

- a requirement that all resource authority holders must comply with a single Land Access Code
- an entry notice requirement for 'preliminary activities' i.e. those that will have no or only a minor impact on landholders
- a requirement that a Conduct and Compensation Agreement be negotiated before a resource authority holder comes onto a landholder's property to undertake 'advanced activities' i.e. those likely to have a significant impact on a landholder's business or land use
- a graduated process for negotiation and resolving disputes about agreements which ensures matters are only referred to the Land Court as a last resort
- stronger compliance and enforcement powers for government agencies where breaches of the Land Access Code occur.

In addition to the new laws, the Government has produced a suite of land access documents to support implementation of the new framework. These materials provide information to help landholders and resource authority holders' dealings with land access matters. These documents include:

- a single Land Access Code
- standard agreements to help landholders in land access undertake conduct and compensation negotiations related to land access
- a tip sheet to assist landholders negotiating with resource companies

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Citation: Queensland Government, *Land Access Code* (November 2010)

Topic Area: Land Access and Land Use

Jurisdiction: Australia (Qld)

Introduction: The Queensland Government is committed to balancing the interests of the agricultural and resource sectors to address issues related to land access for resource exploration and development. Good relationships between these groups, assisted by adequate consultation and negotiation, will improve transparency, equity and cooperation across the sectors involved and creates a more level playing field for all. This Land Access Code has been developed by the Queensland Government in consultation with the resource and agricultural sectors through the Land Access Working Group.

Aims & Research Methods: Section 24A of the Petroleum and Gas (Production and Safety) Act 2004 (P&G Act) provides for the making of the Land Access Code by regulation. Section 24A states that 'a regulation may make a single code for all resource Acts (the land access code) that—
(a) states best practice guidelines for communication between the holders of authorities and owners and occupiers of private land; and
(b) imposes on the authorities mandatory conditions concerning the conduct of authorised activities on private land.'' All resources Acts' means the Geothermal Energy Act 2010 (GE Act), Geothermal Exploration Act 2009, Greenhouse Gas Storage Act 2009 (GHG Act), Mineral Resources Act 1989 (MRA), Petroleum Act 1923 (PA1923) and the Petroleum and Gas (Production and Safety) Act 2004 (P&G Act).

In relation to (a) above, Part 2 of this document provides the best practice guidelines for communication between the holders of authorities and owners and occupiers of private land.

In relation to (b) above, Part 3 of this document imposes on the following authorities mandatory conditions concerning the conduct of authorised activities on private land:
(a) geothermal tenures under the Geothermal Energy Act 2010;
(b) GHG authorities under the Greenhouse Gas Storage Act 2009;
(c) petroleum authorities under the Petroleum and Gas (Production and Safety) Act 2004;
(d) 1923 Act petroleum tenures under the Petroleum Act 1923;
(e) exploration permits and mineral development licences under the Mineral Resources Act 1989.

The definitions contained in Part 3, section 11 apply to the entire Land Access Code document. Part 4 of this document provides further details of information sources that may assist parties dealing with land access issues.

Citation: Land Access Review Panel, *Land Access Framework- 12 month review Report of Land Access Review Panel* (February 2012)

Topic Area: Land Access and Land Use

Jurisdiction: Australia (Qld)

Introduction: The panel adopted a two-stage process for stakeholder consultation. Firstly, the Chair wrote to key stakeholders seeking written feedback. This call resulted in 68 responses being received from a variety of stakeholders. Then, after analysing the submissions, the panel identified key stakeholders to meet with in person. Meetings were held in Emerald, Moranbah, Townsville, Mount Isa, Roma, Dalby, Toowoomba and Brisbane. The panel met with over 100 individuals representing peak bodies, community groups, landholders, resource companies, lawyers and other land access professionals.

Aims & Research Methods: From the results of consultation, the panel identified a broad range of land access issues. These have been categorised under the following themes: process complexity; legal and professional representation; diversity in land use and resource activities; conduct and compensation; information and education; technical issues; and out-of-scope of the review issues. Throughout the consultation process, the panel identified that there were a number of key steps common to successful negotiations between landholders and resource companies. The panel has compiled these steps in an 'optimal process' chapter of this report (Chapter 2). In essence, this is a distillation of best practice communication being used by landholders and resource companies. Stakeholders also took the opportunity to express concerns that were not related to land access and were outside the review terms. However, the panel is mindful that these issues are important and considers it appropriate to highlight them in this report.

Conclusions: The panel concluded that while the Land Access Framework has changed the way resource companies must negotiate access with landholders for their activities it has often not improved working relationships. The report includes 12 recommendations developed to address the issues raised during consultation and to reflect best practice engagement in the 'optimal process' chapter of this report. The panel has put together the recommendations in a way that government and other stakeholders can make changes to the Land Access Framework to further improve the way landholders and resource companies interact. These changes are designed to streamline the process where possible, to provide a fully informed platform for negotiating beneficial agreements and to resolve disputes efficiently.

Citation: Queensland Government, Department of Employment, Economic Development and Innovation, *Tips for Landholders Negotiating Agreements with Resource Companies* (November 2010)

Topic Area: Land Use and Land Access, Alternative Dispute Resolution

Jurisdiction: Australia (Qld)

Introduction: If you are a landholder and a resource company has been granted a tenement, licence or authority to carry out activities on your land, this fact sheet may be useful. It provides guidelines to help you undertake negotiations about land access and compensation issues with a company so you can develop and enter into a conduct and compensation agreement with that company.

Aims & Research Methods: Natural resources, including underground resources such as coal, petroleum or coal seam gas, are owned by the people of Queensland and are not the property of individuals or companies. The Queensland Government manages these resources for the benefit of all Queenslanders. New land access laws came into effect on 29 October 2010 for the *Petroleum and Gas (Production and Safety) Act 2004, Petroleum Act 1923, Greenhouse Gas Storage Act 2009* and *Geothermal Energy Act 2010*. This follows their passage through the Queensland Parliament on 19 August 2010 and earlier introduction and debate of draft legislation included in the Geothermal Energy Bill 2010. Land access laws for the Mineral Resources Act 1989 will commence later this year. The new land access laws are vital to achieving a balanced approach to access to private land. They recognise and clarify the rights of tenement or authority holders and landholders in relation to access to private land for resource activities. In terms of access to land for exploration and development, the provision of consistent legislative requirements and processes will facilitate transparency, equity and co-operation across the agricultural and resources sectors.

The new laws set out requirements of resource companies and landholders related to access to private land and compensation. While a company holding a tenure or authority is allowed to explore and produce resources from private land for the area of tenure, affected landholders are entitled to know what activities are being undertaken, have input and receive compensation for those activities.

Under the new laws a resource company has a statutory obligation to:

- consult or use reasonable endeavours to consult owners and occupiers about access, the way in which authorised activities are carried out and compensation
- avoid any unreasonable interference with anyone else carrying out a lawful activity (i.e. landholder)
- comply with the mandatory provisions of the Land Access Code.

Under the land access laws, a company can only come on to your land to carry out authorised activities if it has:

• provided an entry notice at least ten (10) business days prior relating to preliminary activities (activities likely to cause nil or only minor impact on a landholder's business and land use activities)

• for advanced activities (activities likely to have a significant impact):

– entered into a conduct and compensation agreement with you or

– entered into a deferral agreement with you (allowing for a conduct and compensation agreement to be agreed at a later time) or

– applied to the Land Court for a decision about your compensation entitlement.

This document provides general advice regarding landholder obligations, legal, accounting and valuation advice, standard agreements and negotiation terms generally.

Citation: Department of Environment and Heritage Protection, *Oil Shale Development in Queensland* (March 2013) (website)

Topic Area: Oil and Gas Development in Queensland

Jurisdiction: Australia (Qld)

Aims & Research Methods: The environmental performance of Oil Shale mining and processing in Queensland is regulated under the Environmental Protection Act 1994 by the Department of Environment and Heritage Protection. Under the Government's oil shale policy, all oil shale developments will be subject to assessment by environmental impact assessment under either the Environmental Protection Act 1994 or the State Development and Public Works Organisation Act 1971. The Department of Environment and Heritage Protection has produced a report (PDF, 3.3M)* reviewing the environmental performance of the oil shale processing demonstration plant, operated by Queensland Energy Resources Pty Ltd, against the requirements of its Environmental Authority, issued under the Environmental Protection Act 1994. The demonstration plant is located on the Stuart oil shale deposit near Gladstone in Central Queensland.

The EHP report found that the QER's demonstration plant has consistently demonstrated a high level of environmental performance and has complied with the pollutant emission criteria in the Environmental Authority.

Environmental conditions that apply to approve oil shale projects are available. Environmental Authorities currently in force are: Stuart deposits -MIN100479806 (PDF, 1.9M)* and PEN100375209 (PDF, 3.3M)*.

This website provides information regarding licences and permits, management and regulation, coastal management, sustainability, wildlife and ecosystems and heritage.

Citation: CLNG Project, Environmental Impact Statement, *Coal Seam Gas Field Environmental Values and Management of Impacts* (March 2009)

Topic Area: Environmental Issues and Other Social Issues

Jurisdiction: Australia (Qld)

Aims & Research Methods: This report outlines Santos EPA management plan of coal seam gas fields. The report states "to ensure Santos has complied with EPA approvals and that rehabilitation of the CSG fields has been conducted to satisfactory levels, Santos will lodge a "Financial Assurance" form with the EPA. A financial assurance is "a security held to ensure compliance with the conditions of an environmental authority and to meet any costs or expenses (or likely costs or expenses) incurred by the administering authority in taking action to prevent or minimise environmental harm or rehabilitate or restore the environment in relation to the activity for which financial assurance has been given" (EPA, 2008).

During the final relinquishment of tenements (ATPs and PLs) that are no longer producing gas nor have any exploratory value, a final relinquishment report will be required. This report will detail all petroleum activities that occurred, what remedial works where conducted, and the status of the final land use. Prior to relinquishment, Santos takes steps to ensure affected landowners are satisfied with the standard of site rehabilitation undertaken by Santos. In addition, the administrating authority must be satisfied with the standard of rehabilitation before Santos can relinquish the tenement."

Citation: Queensland Government, *Queensland's Booming Coal Seam Gas Industry* (Poster) (2012)

Topic Area: Coal Seam Gas Industry Information

Jurisdiction: Australia (Qld)

Aims & Research Methods: This poster provides general information and statistics regarding the expansion and growth of Queensland's coal seam gas industry.

Citation: Queensland Government, *Standard Conduct and Compensation Agreement* (2010)

Topic Area: Conduct and Compensation Agreement, Land Use, Alternative Dispute Resolution

Jurisdiction: Australia (Qld)

Aims & Research Methods: This document has been developed by the Queensland Government in consultation with landholder groups and groups representing resources explorers and producers. It is intended to represent a fair and balanced approach as between those parties to land access and compensation issues. Parties undertaking negotiations may use this as their conduct and compensation agreement. Alternatively, clauses contained in this document can be modified to meet the specific needs of the parties. In either case any required schedules and annexures should be attached.

Citation: Queensland Government, *CSG Flow Chart* (2012)

Topic Area: Petroleum Lease, Overlapping Tenure, Applications

Jurisdiction: Australia (Qld)

Aims & Research Methods: This flow chart provides information for the application for petroleum leases in overlapping tenure information in correspondence with the *Petroleum and Gas (Production and Safety) Act 2004* (Qld).

Citation: Queensland Government, Department of Natural Resources and Mines, *Coal seam Gas Engagement and Compliance Plan* (2013)

Topic Area: Regulatory Engagement and Complaisance Plan

Jurisdiction: Australia (Qld)

Introduction: The Queensland Government is supporting the development of the Coal Seam Gas (CSG) to Liquefied Natural Gas (LNG) industry in the state. The Government recognises the significant contribution the CSG industry is making to the State's economy with the injection of $60 billion of private investment and new job creation opportunities as part of growing Queensland's four pillar economy. However, the growth of Queensland's CSG to LNG industry needs to be balanced against the interests of rural landholders, regional communities and the environment. The Department of Natural Resources and Mines (DNRM) has a key role to play in supporting the development of the CSG industry for Queensland.

Aims & Research Methods: The overarching purpose of DNRM is to ensure Queenslanders benefit from the sustainable and productive use of the State's natural resources – our land, water and minerals. In relation to CSG, DNRM has a lead role in achieving balance in the access to, and use of Queensland's petroleum and gas resources. Important functions of the department include - management of CSG exploration and production tenures and permits, safety of CSG industry, managing land use, land access on private properties, contributing to the management of groundwater resources, community engagement, regulating the CSG industry operations and provision of expert advice. It is also critical that the rights of landholders and industry are prioritised and are respected by all parties. DNRM works in partnership with other agencies, including the Department of Environment and Heritage Protection (DEHP) and the GasFields Commission Queensland (GFCQ) in managing Queensland's CSG to LNG industry. DNRM will work to ensure the impacts of the CSG to LNG industry are appropriately and effectively regulated and managed throughout the State

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Citation: Queensland Government, Department of Environment and Resource Management, *Coal Seam Gas Recycled Water Management Plan and Validation Guideline* (June 2011)

Topic Area: Water Management and Distribution

Jurisdiction: Australia (Qld)

Introduction: The recycled water provisions for coal seam gas (CSG) water of the Water Supply (Safety and Reliability) Act 2008 (the Act) commenced on 1 December 2010 and are administered by the Department of Environment and Resource Management (DERM). The chief executive of DERM is the regulator under the Act. The primary objective of the Act in relation to CSG water is to protect public health. Under the Act, for a CSG recycled water scheme to supply CSG recycled water (directly or indirectly) either into a water source used as a drinking water supply or directly to a drinking water service provider as a source of drinking water, a responsible entity must have:
• an exclusion decision made by the regulator, or
• an interim CSG Recycled Water Management Plan (RWMP) approved by the regulator or as deemed by sections 641, 642 and 643 of the Act, or
• a full CSG RWMP approved by the regulator.

Aims & Research Methods: This guideline has been developed to provide information to the responsible entity, about preparing an exclusion decision (if applicable) or RWMP where a scheme is proposing to supply either:
• CSG water into a water source used for a drinking water supply by a drinking water service provider; or
• CSG water directly to a drinking water service provider as a source for a drinking water supply. It has been prepared using a modular format. While separate sections within the guideline may appear repetitive, the intent is to provide the responsible entity with all the relevant information in a single location, dependent on the type of exclusion decision application or RWMP being prepared. CSG water has a different public health risk profile compared to other recycled water sources. The principal public health concern is adequate management of the chemical and radiological quality of water including management of long term exposure. To cater for these differences an adaptive CSG RWMP approval regime and this guideline have been developed.

This guideline aims to provide information about:
• exclusion decision applications
• the requirements of the Act and related criteria for different methods of supply to a drinking water service provider
including:
ƒ direct supply of CSG water to a drinking water service provider as a source of drinking water
ƒ direct and indirect supply to a water source used for a drinking water supply by a drinking water service provider
• the adaptive approach to preparing RWMPs including:
ƒ interim RWMP
ƒ full RWMP
• submitting documents for approval by the regulator

• matters considered by the regulator in assessing RWMPs
• seeking amendments to an RWMP
• additional responsibilities of recycled water providers, or scheme managers.
The material in this guideline is indicative of the regulator's policy objectives and the Act's purpose. The regulator may also choose to look at other information, such as industry standards, technical expert advice or other health-based guidance to support policy objectives and the Act's purpose.

Citation: Department of Natural Resources and Mines, *Mediation and Negotiation Options* (2012)

Topic Area: Alternative Dispute Resolution, Land Use and Access

Jurisdiction: Australia (Qld)

Introduction: A conference or alternative dispute resolution (ADR) can be called when parties have not been able to enter into a conduct and compensation agreement at the end of the minimum negotiation period, after a Notice of intention to negotiation an agreement is served. At the expiration of the 20 business day minimum negotiation period, or such longer timeframe as the parties agree, either party may, by a notice (an election notice) to the other party and a relevant or authorised officer, ask for the relevant/authorised officer to call a conference or agree to an ADR process to negotiate a conduct and compensation agreement.

The relevant/authorised officer in most cases will be the local mining registrar from the Department of Natural Resources and Mines (DNRM). If you wish to call an ADR, the process may include conciliation, mediation or negotiation. The facilitator must be independent of either party.

The election notice for an ADR must state that the party giving the notice agrees to bear the costs of the person facilitating the ADR. However, parties may be willing to negotiate this when developing a conduct and compensation agreement. Parties must use reasonable endeavours to finish the process within 20 business days after giving the election notice (the usual period). Either party may within the usual period request the other party to agree to a longer period to finish the process.

Aims & Research Methods: This report outlines the conference and ADR process for negotiation of conduct and compensation agreement and the formal notice documentation.

Citation: Queensland Resources Council, *A New Approach to Overlapping Tenure in Queensland* (May 2012)

Topic Area: Overlapping Tenure

Jurisdiction: Australia (NSW)

Introduction: The current legislative framework for managing overlapping coal and CSG tenure was first introduced in 2004 with the passage of the Petroleum and Gas (Production and Safety) Act 2004 (Qld) ('P&G Act') and associated amendments to the Mineral Resources Act 1989 (Qld) ('MRA') and the Petroleum Act 1923 (Qld) ('Petroleum Act'). In the period since the framework was first introduced, there have been substantial developments in the nature and scope of both the CSG and conventional coal mining industries in Queensland. These developments, to both the technical and economic landscape, have placed pressure on the existing overlapping tenure regime while presenting both industries with a number of concerns and barriers to future development.

In an effort to address a number of these issues, the Queensland Government released the Draft Bill for comment on 20 January 2011. The stated purpose of the Draft Bill was to ensure that the framework for overlapping coal and petroleum tenure adequately supported the establishment of Queensland's CSG to Liquefied Natural Gas ('LNG') industry and optimised the use of the State's coal and CSG resources. There has been mixed reaction amongst the coal and CSG industries to the changes proposed in the Draft Bill, including that:

- the timeframes proposed in the Draft Bill in respect of initial consultation and negotiation between overlapping tenure holders, as well as for potential resolution through the Ministerial Preference Decision process, are too long to achieve project certainty or facilitate timely project development;
- the proposed amendments would fundamentally erode the security of tenure necessary to underpin large, integrated CSG-to-LNG projects through mechanisms (i.e. retention declarations and veto rights for exploration permits for coal ('EPCs') holders) designed to prevent the grant of petroleum leases ('PLs') in circumstances where production would not commence within 2 years of grant; and
- the Draft Bill contains ongoing deficiencies in timing and process clarity, and missed opportunities such as for harmonising safety provisions and optimising the extraction and utilisation of incidental coal seam gas ('ICSG').The Government's intention was to table the Draft Bill in Parliament by July 2011, although this timeframe was delayed to seek a more mutually beneficial and industry supported alternative.

Aims & Research Methods: The purpose of this report is to present a joint industry overlapping tenures framework as an alternative to the January 2011 consultation draft of the Mines and Petroleum Legislation Amendment Bill 2011 ('Draft Bill'). This report has been designed to provide:

- an integrated solution to current deficiencies in the overlapping tenure regime for coal and CSG;
- default principles to encourage negotiated outcomes, which the broad industry believes should underpin an overlapping tenure legislative framework in Queensland, including detailed explanations on the package of principles, as well as the advantages and trade-offs associated with such principles;
- a series of worked examples/scenarios to illustrate the application of the principles;
- suggestions on how those principles may be implemented in practice; and
- status of outstanding issues that will require further work and industry consultation led by the Queensland Government. Section 3.2 of this report provides a useful executive summary of the key principles involved.

Conclusions: QRC anticipates that a further Government-led process of consultation and refinement will take place relating to those sub-sections of the proposed framework which require additional technical detail and scenario testing. It is suggested that there are at least five further steps that will need to be undertaken by the Government with a view to preparing draft legislation for introduction into parliament by the end of 2012.QRC looks forward to working with Government to achieve these steps in a timely and effective manner.

Step 1: Establish the government-industry technical working groups as detailed in section 4.4 of this report to finalise outstanding issues of detail.
Step 2: Work with the QRC and APPEA on the development and implementation of legislative harmonisation changes in the areas outlined in section 4.2 of this report, which may be required for the proposed overlapping tenure framework to operate effectively.
Step 3: Conduct further government-led consultation and refinement of the proposed overlapping tenure framework to enable draft legislation to be prepared.
Step 4: Release draft legislation to industry for comment.
Step 5: Seek to introduce legislation by the end of 2012.

Citation: DEEDI, *Queensland's Coal Seam Gas Overview* (February 2012)

Topic Area: Coal Seam Gas Industry Overview

Jurisdiction: Australia (Qld)

Introduction: Queensland's coal seam gas (CSG) industry has grown rapidly over the past 15 years — the annual number of wells drilled increasing from 10 in the early 1990s to almost 600 in 2010–11.The CSG industry has defied the recent global economic downturn with both exploration and development activity remaining strong. It continues to be at the forefront of Queensland's petroleum industry. The Queensland Government is supporting the growth of the petroleum industry by making available geoscientific information and company exploration data, and coordinating approvals for major petroleum projects.

Aims & Research Methods: In the past five years there has been a growing interest in using Queensland's CSG resources to produce liquefied natural gas (LNG) for export, taking advantage of increasing global demand for gas. Three export LNG projects based on Queensland coal seam gas resources are under construction on Curtis Island near Gladstone with first cargoes expected in late 2014. A further five proposals to develop export LNG projects are under consideration. If all current projects and proposals are developed to full capacity, this would represent a potential LNG export market for the state of more than 50 million tonnes per annum. Current infrastructure consists of more than 4000 kilometres of gas transmission pipelines. Additional pipelines to markets interstate and for supply of gas to the Gladstone LNG plants are planned or under construction. Many Queensland basins are highly prospective for CSG and production in the Bowen (Permian coal measures) and Surat (Jurassic Walloon Coal Measures) basins represents more than 79% of the total gas produced in the state (Figure 1). As at30 June 2011, proved and probable (2P) reserves reached 33 001 petajoules (PJ) (Figure 2, Table 1). In 2010–11, production increased to 234 PJ from 212 PJ in 2009–10 (Figure 3). Production from these sources is expected to supply an increasing proportion of the Queensland and other eastern Australian markets.

Citation: Queensland Water Commission, *Draft Underground Water Impact Report, Stuart Cumulative Management Area, Consultation Draft* (May 2012)

Topic Area: Water Use and Distribution, Groundwater Contamination

Jurisdiction: Australia (Qld)

Introduction: The *Petroleum and Gas (Production and Safety) Act 2004* and *Petroleum Act 1923*authorises petroleum tenure holders to undertake activities related to the exploration for, and production of, petroleum and gas, which includes the right to take or interfere with groundwater. Those groundwater rights exist because water is found in association with petroleum and gas and it is not practicable to manage the water separately. The *Water Act 2000* establishes responsibilities for petroleum tenure holders to monitor and manage the impacts caused by the exercise of these groundwater rights, including a responsibility to make good impairment of private bore water supplies. When water is extracted from a gas well, groundwater levels decline in the area surrounding the well. If there are multiple gas fields adjacent to each other, the impacts of water extraction on groundwater levels may overlap. In these situations, a cumulative approach is required for the assessment and management of groundwater level impacts. In Queensland, where this situation exists, a Cumulative Management Area can be established. Within a Cumulative Management Area the Queensland Water Commission is responsible for assessing impacts and establishing integrated management arrangements in an Underground Water Impact Report. In the Surat and southern Bowen Basins, expansion of coal seam gas production is proposed, involving multiple developers adjacent to one another. As a consequence, the Surat Cumulative Management Area was established on 18 March 2011. As required, the Queensland Water Commission has prepared this draft Underground Water Impact Report for consultation purposes before submitting a final Underground Water Impact Report for approval to the Chief Executive of the Department of Environment and Heritage Protection.

Aims & Research Methods: On approval, the report becomes a statutory instrument under the *Water Act 2000*. Obligations for individual petroleum tenure holders for activities arising from the Underground Water Impact Report will then become legally enforceable. The Department of Environment and Heritage Protection will be responsible for ensuring petroleum tenure holders comply with their obligations.

Conclusions: The Commission will adopt a program of annual reporting to EHP and those reports will be published on the Commission's website. The reports will provide the following information. Petroleum tenure holders have responsibilities under the WMS and SIMS to carry out actions including water level monitoring and to submit monitoring data to the Commission. The trends in the monitoring data will reflect the net effect of impacts from petroleum activities along with other causes such as agricultural use or seasonal conditions. On an annual basis, the Commission will summarise and assess monitoring data. The Commission will obtain from petroleum tenure holders regular updates on changes to their plans for development. On an annual basis, the Commission will run the regional groundwater flow model using the updated estimates of planned production to assess if changes to planned production will cause material change to predicted IAAs and LAAs. Where there is material change, new predictions will be submitted to EHP, along with the summary of monitoring results.

Citation: TressCox Energy and Resources, *Queensland Government Policy on the Management of Water produced from Coal Seam Gas Production* (May 2009)

Topic Area: Coal Seam Gas Production

Jurisdiction: Australia

Introduction: The process of releasing coal seam gas for production involves the extraction of water from the coal seams. Coal seam gas water (CSG water) typically contains high variable concentrations of salts and therefore is of poor quality. The release of CSG water without proper treatment has the potential to cause harm to the environment. Management of CSG water is currently regulated by a number of Acts, including:

- *Petroleum and Gas (Production and Safety) Act 2004;*
- *Petroleum Act 1923;*
- *Environmental Protection Act 1994;*
- *Water Act 2000;*
- *Water and Supply (Safety and Reliability) Act 2008; and*
- *Integrated Planning Act 1997.*

Under the *Environmental Protection Act 1994*, CSG water is defined as a "waste". Disposal of CSG water in excess of 50 tonnes a year requires a company to be a level 1 petroleum authority. However, CSG water may be approved on a case-by-case basis as having a "beneficial use", in which case the regulations on disposal of "waste" no longer apply. The process for approving CSG water for "beneficial use" is contained in the *Environmental Protection (Waste Management) Regulation 2000*.

Disposal of CSG water currently includes injection into natural underground reservoirs or aquifers of equal or lesser water quality, direct or treated use of CSG water, discharge to waters, or evaporation through evaporation ponds.

In order to supply CSG water, the *Water Act 2000* and *Water Supply (Safety and Reliability) Act 2008* requires the supplier to obtain a water licence and register as a water service provider.

Most CSG water is presently disposed of in evaporation (or "environmental") ponds which can range from 1 to 100 hectares in area. At present, limited quantities of untreated CSG water are used for stock watering, coal washing and related petroleum activities. Some producers have trialled "beneficial uses" such as the use of CSG water for town water supplies, as cooling/blowdown water in power stations, for irrigation and for aquaculture. However, There has been widespread concern about the ongoing use of evaporation ponds and the long-term legacy associated with the salt stored in them. Additionally, some landholders, local governments and community groups have expressed concerns about potential groundwater and landscape impacts of CSG extraction and disposal techniques.

Aims & Research Methods: This website provides an update on the Queensland Government Policy Water Plan in Coal Seam Gas Production.

Conclusions: The Queensland Government is seeking to consult with the CSG industry, community groups and stakeholders on a number of issues, including:

- The circumstances under which industry should be required to cooperate to develop and fund a CSG water aggregation and disposal system (or systems) to deal with CSG water which cannot be directly injected or has no immediate customers;
- What remediation action for existing evaporation ponds is reasonable and appropriate; and
- What disposal options are appropriate for the saline effluent resulting from treatment.

Accordingly, while the Queensland Government is not mandating the treatment of water for "beneficial use" (ie., it recognises that CSG water is often extracted in locations where the potential "beneficial uses" are limited) it is likely that the Queensland Government will develop further policy designed to encourage industry to transport CSG water to locations where there are greater "beneficial uses", which may include irrigation, supplements to existing drinking water supplies, or for industrial use. This new policy could therefore be the catalyst for the development of a new CSG water industry in Queensland.

Citation: USQ, Preliminary *Assessment of Cumulative Drawdown Impacts in the Surat Basin Associated with the Coal Seam Gas Industry* (March 2011)

Topic Area: Environmental Impacts

Jurisdiction: Australia (Qld)

Introduction: The coal seam gas (CSG) industry in eastern Australia is experiencing a period of rapid expansion. A major focus of the current development is on the Surat Basin in south-west Queensland. The Surat Basin covers approximately 110,000 km2 and has an estimated 6 billion tonnes of thermal coal resources and more than 18,000 PJ of coal seam gas reserves (DEEDI, 2010). It also has an established agricultural sector including extensive grazing, intensive feedlots and irrigated broad-acre and horticulture crops. CSG recovery has occurred from small scale developments in Queensland for approximately 25 years. Coal seam gas is recovered by drilling extraction wells into the target coal seams. Groundwater is then pumped from the wells to lower the water pressure in the coal seam so that the gas (primarily methane) is released. It is generally not necessary to completely dewater the coal seams to produce the gas. CSG production is therefore dependent on groundwater extraction to facilitate recovery of the gas from the coal seams. The Surat Basin CSG industry produces gas from the Walloon Coal Measures (WCM). The target coals are thin seams within the low permeability, largely siltstone Walloon Coal Measures, and are directly overlain and underlain by low permeability geological units known as aquitards (or confining layers). These aquitards restrict vertical groundwater flow between the coal seams and aquifers which are located both higher and lower in the geological sequence. Despite the low permeability of the aquitards overlying and underlying the Walloon Coal Measures, groundwater extraction to reduce the water pressure in the coal seams may induce some vertical leakage into the coal seams and produce impacts on the surrounding sandstone aquifers.

Regional towns and the agricultural industry within the Surat Basin utilise groundwater from both the sandstone aquifers and, to a much lesser extent, the Walloon Coal Measures. Shallow groundwater aquifers in the area are generally used to provide town supplies and water for irrigation while bores in the Walloon Coal Measures are most commonly used for stock and domestic use. Hence, it is important to understand the potential effects of groundwater depressurisation for CSG extraction on other groundwater users

Aims & Research Methods: During 2010, the four major CSG companies operating in the Surat Basin identified that there was significant community concern regarding the cumulative groundwater impacts of CSG operations in this area. In an industry first, these companies agreed to pool their resources to review the approaches taken to the individual assessments, and provide a preliminary independent assessment of cumulative groundwater impacts associated with CSG operations. The University of Southern Queensland (USQ) was commissioned in September 2010 to manage this study, with RPS Aquaterra engaged to undertake the independent assessment of cumulative impacts, based on information from published impact assessment reports and other information made available to USQ and RPS Aquaterra by the four CSG companies to undertake the study. The overarching aim was to collate and present the existing groundwater modelling data to provide both the Government and the public with a greater level of understanding and confidence regarding the cumulative groundwater impacts from the development of CSG projects within the Surat Basin. This preliminary study was designed to provide a first estimate of impacts based on existing modelling.

Scope: Lease boundaries for the four CSG projects are shown on Figure 2.1.Three of the projects (as presented in EIS or project documentation) are located entirely within the Surat Basin. Santos has proposed developments from coal measures in both the Surat Basin and the Bowen Basin. Origin operates the Spring Gully project in the Bowen Basin under existing environmental approvals. Arrow has also previously recovered CSG from a small-scale project in the Bowen Basin. Although some CSG production has occurred or is proposed from the Bowen Basin, for the purposes of cumulative impact, only the Surat Basin proposals are considered in this report. It is considered appropriate to consider only the Surat Basin in this cumulative impact study, as the intervening aquitards between the Walloon Coal Measures (WCM), which is the target coal unit in the Surat Basin proposals, and the Bandanna Coal Measures (BCM) which is the target unit for CSG production in the Bowen Basin, will effectively keep the two coal measures hydraulically separate. Although it is possible that impacts of the Surat Basin and Bowen Basin developments could mutually interact slightly, it was decided to concentrate only on the Surat Basin developments in this study. It should be noted that there is significant current use of groundwater in the Surat Basin, as well as commercial activity that potentially impacts on groundwater, including:
x Large-scale irrigation use
x Stock and domestic use
x Town water supply
x Industrial use of groundwater
x Coal mining
x Conventional oil and gas production
x Existing CSG production.
It is generally the shallower units that are developed for water use, hence most current use of groundwater occurs in or close to the outcrop areas of the main aquifer units.

Conclusions: This study has collated groundwater information from the four major CSG companies operating in the Surat Basin to provide a preliminary but over-conservative assessment of the groundwater areas expected to be impacted by depressurisation of the Walloon Coal Measures. The Queensland Water Commission has been tasked with assessing the CSG water impacts. However, in conducting this preliminary study it is clear that there are areas where additional research would improve both the identification of the cumulative impact area as well as the robustness of the model predictions regarding timing and scale of impact.

Citation: Department of Environment and Primary Industries, Government of Victoria, *Fact Sheet 3: How is Gas Exploration and Production Regulated?* (2013)

Topic Area: Natural Gas Exploration and Production Regulation

Jurisdiction: Australia (Vic)

Aims & Research Methods: This fact sheet provides information on how natural gas exploration and production is regulated. Onshore gas exploration and production is regulated differently depending on its type. This fact sheet explains regulations concerning coal seam gas, which is regulated by the *Mineral Resources* (*Sustainable Development*) *Act* (MRSDA) 1990. Since 2000, a number of mineral exploration licences have been issued in Victoria for exploration for coal seam gas. To date, no production of coal seam gas has occurred. A number of companies currently have been granted exploration licences for coal seam gas in Gippsland, the Otways and Bacchus Marsh.

Citation: Department of Environment and Primary Industries, Government of Victoria, *Information for landholders and the community* (2013)

Topic Area: Land Use and Access, Mining Licences

Jurisdiction: Australia (Vic)

Aims & Research Methods: This fact sheet provides information regarding land holder rights under the Mineral Resources (Sustainable Development) Act 1990 exploration and mining licensees. The fact sheet explains that additional obligations apply to mining licensees, who must prepare a community engagement (CE) plan documenting the commitments they will make to engage with their community during the life cycle of the project. Furthermore, under the MRSD Act, permission to start work on a mining licence will only be granted once the licensee has obtained the written consent of the landholder. This may involve the making of a compensation agreement with the landholder.

Compensation provisions apply where landholders suffer loss or damage as a result of work on a licence or consequence of the approved work plan. On commencement of activity, exploration and mining licensees are also obliged to: minimise interference with regular landholder activities on the land follow public safety and environment planning regulations maintain in good condition and repair all structures, equipment and property used in connection with minerals exploration and mining operations continue consultation with the local community for the duration of the operation (from exploration through to development, operation, closure and rehabilitation).

Citation: Department of Environment and Primary Industries, *Regulation of the Coal Seam Gas Industry in Victoria* (2013)

Topic Area: Regulation of Victorian Coal Seam Gas Industry

Jurisdiction: Australia (Vic)

Aims & Research Methods: This fact sheet provides information regarding the regulation of mineral resources in Australia. The fact sheet states The Department of Primary Industries regulates the minerals, extractive, petroleum, pipelines and geothermal industries in Victoria and offshore waters. It provides a consistent and transparent exploration and mining management regime, together with environmental standards, monitoring and enforcement that ensure these industries comply with their obligations and meet community expectations. In Victoria, coal seam gas exploration and mining is regulated under the *Mineral Resources (Sustainable Development) Act* 1990 (MRSD Act). The MRSD Act provides a legislative framework for the development and regulation of the mineral exploration and mining industry, including gold, coal, and mineral sands. The MRSD Act addresses licensing and approval requirements, along with other issues such as compensation, rehabilitation and royalties for extractive industries, mineral exploration and development activities. The MRSD Act seeks to encourage an economically viable mining industry which makes the best use of mineral resources in a way that is compatible with the economic, social and environmental objectives of the State. A series of regulations and guidelines also apply to mineral exploration and development activities.

Citation: Department of Environment and Primary Industries, *What is Coal Seam Gas, How is it found and produced?* (2013)

Topic Area: Coal Seam Gas General Information

Jurisdiction: Australia (Vic)

Aims & Research Methods: This fact sheet provides general information on coal seam gas in Victoria, its production and hydraulic fracturing. The fact sheet states there is currently no coal seam gas production in Victoria, nor are there any applications to begin production. A number of exploration licences have been granted, however, while the location of Victoria's coal resources is well known, the amount of associated gas and the feasibility of extraction are uncertain. Nevertheless, the most prospective part of Victoria for coal seam gas is the Gippsland basin, due to its extensive coal resources.
In the event that the production of coal seam gas is feasible and that a proposal to extract the gas met all regulatory requirements, it is estimated that it would take around five or more years for such a project to commence commercial production.

Citation: The Wilderness Society, *Toxic Alert Coal Seam Gas, Fracking and the threat of onshore unconventional gas in WA* (June 2011)

Topic Area: Hydraulic Fracturing

Jurisdiction: Australia (WA)

Aims & Research Methods: The Wilderness Society briefing paper argues all hydraulic fracturing activities are currently regulated under the Petroleum and Geothermal Energy Resources Act 1967 and the Petroleum Act 1967 Schedule of Onshore Petroleum Exploration and Production Requirements 1991. If a project is considered likely to have a significant effect on the environment, the project may be referred to the Environmental Protection Authority for assessment under Western Australia's Environmental Protection Act 1986. The public can refer projects to the EPA for assessment. There are no requirements under the Petroleum and Geothermal Energy Resources Act 1967 for public disclosure of the chemicals that are proposed to be used in hydraulic fracturing. If a project is referred to the Environmental Protection Authority and the level of assessment set for the project is a Public Environmental Review (PER), there would be an opportunity for the public to comment on the proposed project as part of the PER assessment process under Western Australia's Environmental Protection Act 1986. Under the Schedule of Onshore Petroleum Exploration and Production Requirements 1991, the proponent is required to have an approved code of environmental practice for their activities. This code is referred to as an Environmental Management Plan (EMP) which is assessed by the Department of Mines and Petroleum, not by the EPA or Department of Environment and Conservation (DEC). The Environmental Protection Authority has no regulatory framework or legislation regarding hydraulic fracturing in Western Australia. The Department of Mines and Petroleum has no laws or regulation for protection of landowner's groundwater use should fracking

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Citation: Government of Western Australia, *Information Regarding Activities Targeting Shale and Tight Gas Resources* (2012)

Topic Area: Shale and Tight Gas Activities

Jurisdiction: Australia (WA)

Aims & Research Methods: This table outlines information regarding Perth and Canning Basin Leases, Wells, Targets and Fracturing Activities Information.

Citation: WA Government, Department of Mines and Petroleum, *Tight Gas in Western Australia, White Paper* (March 2009)

Topic Area: Tight Gas Activities and Regulation

Jurisdiction: Australia (WA)

Introduction: Western Australia has abundant large reserves of easy-to-access gas and it is a vital energy source, fuelling around 60 per cent of the State's electricity generation. Gas underpins the State's manufacturing, processing and mining industries.

However, the State's gas reserves are largely located in the far north of the State and the bulk of Western Australia's domestic demand for gas emanates from the south-west region. The south-west region is therefore dependent on the majority of its gas demand being met chiefly by two suppliers, remotely located, which supply gas through a single pipeline. The vulnerability of Western Australia's economy to this arrangement was most recently demonstrated in June 2008 with the Varanus Island gas pipeline explosion.

It is therefore important to develop a variety of energy supply options including alternatives such as gas from tight gas fields in the south-wet region of Western Australia. Gas resources currently viewed as "tight gas" in the South West region of the State could potentially hold enough gas to satisfy much of the State's needs far into the future.

Aims & Research Methods: The purpose of this White Paper is twofold. Firstly, it aims to increase understanding of what tight gas is and its potential significance in meeting Western Australia's energy needs. Secondly, the White Paper discusses Western Australia's current onshore petroleum royalty system. This discussion highlights the need for an appropriate royalty system to handle the cost characteristics of tight gas projects and proposes application of a five per cent ad valorem wellhead royalty rate for projects which meet a definition of tight gas that is acceptable to Government. Included in this section is a summary of fiscal measures introduced overseas for tight gas projects where such projects have been operating for many years.

The White Paper also outlines how the recommended ad valorem rate for tight gas projects can be implemented under the *Petroleum and Geothermal Energy Resources Act 1967*.

Conclusions: Western Australia has the most energy intensive economy of all States with significant resource processing activities underpinning much of the State's employment base. The State's economic development is threatened if its existing level of domestic gas demand is not met with sufficient supplies.

The bulk of Western Australia's domestic demand for gas emanates from the south-west region and is met chiefly by two suppliers. These are located in the far north of the State and supply through a single pipeline. The vulnerability of Western Australia's economy to this arrangement was most recently demonstrated in June 2008 with the Varanus Island gas pipeline explosion. It is therefore important to develop a variety of energy supply options and alternatives such as gas from tight gas fields in the south-wet region of Western Australia.

Gas resources currently viewed as "tight gas" in the South West region of the State could potentially hold enough gas to satisfy much of the State's needs far into the future.

Tight gas developments have significantly higher drilling and recovery costs compared to conventional gas projects. This has been recognised overseas where special royalty arrangements have been put in place to encourage development of unconventional gas fields. However, Western Australia's current petroleum royalty system cannot handle the cost characteristics of tight gas projects. Without implementing from scratch a totally new petroleum royalty regime, the most practical approach is to apply a five per cent royalty rate within the existing wellhead system. A five per cent royalty rate applied to a gas project that meets the definition of tight gas is comparable to the ten per cent rate currently applied to a conventional gas field.

The lower rate of five per cent rate can be readily implemented by the Minister for a primary licence under section 52(1) of the PGERA. It will be necessary though to amend the PGERA to enable the Minister to determine a lower royalty rate for tight gas projects when they apply for a secondary licence. This amendment can be carried out through the *Petroleum and Energy Legislation Amendment Bill* (PELA).

Citation: WA Energy Research Alliance, *Innovative Solutions for the Global Energy Industry* (May 2010)

Topic Area: Energy Regulation

Jurisdiction: Australia (WA)

Introduction: The Western Australian Energy Research Alliance (WA:ERA) is an alliance between the leading research institutions of CSIRO, Curtin University of Technology (Curtin) and The University of Western Australia (UWA), combining state-of-the-art facilities and multi-disciplinary expertise to deliver technology-based solutions to the global energy industry.

Aims & Research Methods: While Western Australian gas resources are plentiful, they possess many unique characteristics that make their development challenging.

Accessing gas found in deeper waters in a commercially viable manner brings with it the need for greater efficiencies – the application of world-leading subsea technologies, the design of equipment that is compact and energy efficient, and the utilisation of optimum processing and low emissions technologies.

WA: ERA scientists and researchers have a competitive edge to develop strong relationships and align research priorities with the needs of companies leading the Western Australian gas industry, through WA: ERA's geographic proximity to significant gas reserves and the multi-dimensional capacity and expertise delivered through its alliance members.

Curtin scientists possess a diverse suite of capabilities from skills in process intensification, which involves the development of reactors that are smaller, lighter, faster, and more energy efficient, to corrosion and reliability engineering and expertise in computational fluid dynamics.

At UWA, scientists experiment to optimise each and every aspect of the gas processing journey, from well-head to plant, in the knowledge that small improvements can make large differences particularly in relation to cost and carbon dioxide capture.

CSIRO's investment in state-of-the-art laboratory and infrastructure for technologies include the nation's first synthetic fuels research facility, and the hydrates flow loop, Australia's only gas-dominant flow loop. Researchers investigate methods to prevent flow disruptions in subsea pipelines, particularly blockages from gas hydrate crystals which form at high pressure and low temperature.

Conclusions: This report concludes by reporting the successes in geological storage of carbon dioxide. Continuing to provide the world with increasing amounts of energy in an emissions-constrained global environment is an ongoing challenge for the petroleum industry. Carbon dioxide storage, one of a number of technology options that could potentially reduce greenhouse gas emissions, carries strong synergies with oil and gas technologies, processes, environments and capabilities. The existing relationships between WA: ERA and the petroleum industry provide a significant springboard for the extension of carbon storage research in support of emissions reduction. WA: ERA scientists have participated in major commercial carbon capture and storage (CCS) projects internationally, including Sleipner, Weyburn, Gorgon, and In Salah, and are active in the global network of CCS research. They have already demonstrated significant expertise in optimising the potential for CO2 underground storage through applied research under the auspices of the

Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC) Otway Project, Australia's largest CO2 storage project, and continue to play an important role in the project.

Citation: ERCB Investigation Report Red Deer Field Centre, *Midway Energy Ltd. Hydraulic Fracturing Incident: Interwellbore Communication* (January 13 2012)

Topic Area: Hydraulic Fracturing Incidents

Jurisdiction: Canada

Introduction: On January 13, 2012, hydraulic fracturing operations conducted by Midway Energy Ltd. (Midway)1 at surface location Legal Subdivision (LSD) 3, Section 16, Township 35, Range 3, West of the 5th Meridian (Midway well) affected a nearby producing oil well operated wild Stream Exploration Inc. (Wild Stream)2 at surface location LSD 06-09-035-03W5M (Wild Stream well). This resulted in a release of hydraulic fracturing and formation fluids (crude oil, produced water, and natural gas) at the surface of the Wild Stream well.

Aims & Research Methods: This report analyses and provides an overview of the incident, cause of Well Control Incident, release clean-up, ERCB Investigation, information submitted by Wild Stream, investigation findings, company actions, ERCB actions and follow up.

Conclusions: Midway was clearly aware of the existence and operating status of the Wild Stream well as well as its proximity to the Midway well. At the time of the incident, Midway maintained an internal protocol which, if followed, would have spaced the fractures at least 135 m from the nearest well. Midway did not follow its own internal protocol in this case. The ERCB finds that, had Midway used its modelling and calculations, followed its own internal protocol, and notified Wild Stream of its fracturing operations, the incident may have been prevented altogether or the impact may have been reduced.

The ERCB finds that, had Midway notified Wild Stream of its intentions, Wild Stream would have had the opportunity to

- shut in its nearby wells,
- ensure its operators were aware of the activities, allowing them to pay closer attention to any operational anomalies at nearby wells or facilities, or
- influence Midway to modify its fracturing operations so as to prevent or mitigate any impacts on its wells and facilities.

Despite these findings, the ERCB has concluded it would not be appropriate to issue enforcement action against Midway for failing to notify Wild Stream of its fracturing operations. This is because, at the time of the incident, there were no existing regulatory requirements governing spacing of fracturing operations in relation to nearby wells or requiring notification of licensees of nearby wells of impending fracturing operations.

Citation: ERCB, *Draft Directive Hydraulic Fracturing* (2012)

Topic Area: Hydraulic Fracturing

Jurisdiction: Canada

Introduction: Hydraulic fracturing is a well-stimulation process in which a fluid, a proppant, and additives are pumped under high pressure into a hydrocarbon-bearing formation. The fluid pressure creates fractures in the formation and the fluid transports the proppant into the fractures. The proppant keeps the fractures open and allows the hydrocarbons to flow from the formation to the wellbore. The additives serve various purposes, such as reducing friction, preventing the growth of microorganisms, and inhibiting corrosion within the wellbore. After the fracturing process is complete, the fracturing fluids and hydrocarbons are produced at the surface.

Hydraulic fracturing provides access to hydrocarbon resources that otherwise may not have been recoverable. The use of hydraulic fracturing is expected to increase as the technology improves and conventional hydrocarbon deposits are depleted.

Aims & Research Methods: This directive sets out the ERCB's requirements for managing the risks associated with hydraulic fracturing operations. This directive does not apply to thermal wells approved under *Directive 051: Injection and Disposal Wells – Well Classifications, Completions, Logging, and Testing Requirements*.

These requirements are intended to

- prevent the loss of well integrity at a subject well (a well in relation to which a licensee proposes to conduct hydraulic fracturing operations),
- reduce the risks of interwellbore communication between a subject well and an offset well,
- maintain well control at an offset well in the event of interwellbore communication with a subject well,
- prevent impacts to nonsaline aquifers,
- prevent impacts to water wells, and
- prevent surface impacts.

Conclusions: This directive rescinds both *Directive 027: Shallow Fracturing Operations – Restricted Operations* and *Bulletin 2012-02: Hydraulic Fracturing; Interwellbore Communication between Energy Wells*. This directive includes:

- new requirements to prevent the loss of well integrity at a subject well (Section 2),
- new requirements for a licensee to assess, plan for, and mitigate the risks of interwellbore communication with offset wells (Section 3),
- new requirements to protect nonsaline aquifers from hydraulic fracturing operations at depths less than 100 metres (m) below the base of groundwater protection (Section 4),

- increased vertical setback distances for hydraulic fracturing operations near water wells (Section 5),
- increased vertical setback distances for hydraulic fracturing operations near the top of the bedrock surface (Section 6),
- pumping volume restrictions and exemptions to setback distances for nitrogen fracturing operations for coal bed methane (Section 7),
- new notification requirements to ensure that licensees notify the ERCB (a) prior to commencing hydraulic fracturing operations and (b) in the event that hydraulic fracturing operations have caused an unintended communication event with an offset well or a nonsaline aquifer (Section 8), and
- new requirements for continual improvement (Section 9).

Citation: BC Oil and Gas Commission, *Investigation of Observed Seismicity in the Horn River Basin* (August 2012)

Topic Area: Seismicity and Hydraulic Fracturing

Jurisdiction: Canada

Introduction: This report provides the results of the BC Oil and Gas Commission's (Commission) investigation into amomatious seismicity within geographically confined and remote areas in the Horn River Basin between April 2009 and December 2011. The investigation was commenced immediately after the Commission became aware of a number of anomalous, low-level seismic events which were recorded by Natural Resources Canada (NRCan) near areas of oil and gas development. Only one of the events under investigation had been reported by NRCan as "felt" at the earth's surface.

Aims & Research Methods: In undertaking the investigation, the Commission notes that more than 8,000 high-volume hydraulic fracturing completions have been performed in northeast British Columbia with no associated anomalous seismicity. None of the NRCan reported events caused any injury, property damage or posed any risk to public safety or the environment. The investigation was completed by the Commission's geological and engineering staff within the Resource Development department, and they benefited from consultation with NRCan, the University of British Columbia and the Alberta Geological Survey. Data was obtained from numerous sources including open source information as well as proprietary data acquired by oil and gas companies working near the area of the investigation.

Conclusions: The investigation has concluded that the events observed within remote and isolated areas of the Horn River Basin between 2009 and 2011 were caused by fluid injection during hydraulic fracturing in proximity to pre-existing faults. The Commission makes seven recommendations based on the investigation, which include the submission of microseismic reports, establishment of a notification and consultation procedure; studying the relationship of hydraulic fracturing parameters on seismicity, and upgrading and improving B.C.'s seismograph grid and monitoring procedures. Improvements to the seismographic grid network have already begun through funding provided by Geoscience BC. The upgraded grid will provide improved monitoring for induced seismicity and will form the basis for the monitoring, detection, notification and consultation procedure.

In addition, the Commission has initiated a broader study with the University of British Columbia to examine factors related to the extent, magnitude, impact and control of induced seismicity in northeast B.C. The intent of this research is to provide insights into predicting the location and magnitude of seismic events based on hydraulic fracturing parameters and geomechanics and to establish protocols for prediction, detection, monitoring and mitigation of these events.

Citation: National Energy Board, *A Primer for Understanding Canadian Shale Gas* (November 2009)

Topic Area: Shale Gas in Canada

Jurisdiction: Canada

Introduction: The National Energy Board (NEB or the Board) is an independent federal agency that regulates several aspects of Canada's energy industry. Its purpose is to promote safety and security, environmental protection and efficient energy infrastructure and markets in the Canadian public interest within the mandate set by Parliament in the regulation of pipelines, energy development and trade. The Board's main responsibilities include regulating the construction and operation of interprovincial and international oil and gas pipelines as well as international and designated interprovincial power lines. The Board regulates pipeline tolls and tariffs for pipelines under its jurisdiction. In terms of specific energy commodities, the Board regulates the exports and imports of natural gas as well as exports of oil, natural gas liquids (NGLs) and electricity. Additionally, the Board regulates oil and gas exploration, development and production in Frontier lands and offshore areas not covered by provincial or federal management agreements. The Board's advisory function requires keeping under review matters over which Parliament has jurisdiction relating to all aspects of energy supply, transmission and disposal of energy in and outside Canada.

The NEB monitors energy markets to objectively analyse energy commodities and inform Canadians about trends, events, and issues. The Board releases numerous research reports. This report is a briefing note – a brief report covering one aspect of energy commodities. Specifically, this report examines the different aspects of shale gas development to aid in the public understanding of this emerging resource.

Aims & Research Methods: In a relatively new development over just the past few years, shale formations are being targeted for natural gas production. Based on initial results, there may be significant potential for shale gas production in various regions of Canada, including traditional areas of conventional production like Alberta, British Columbia, and Saskatchewan, and non-traditional areas like Quebec, Nova Scotia, and New Brunswick. However, there is much uncertainty because most Canadian shale gas production is currently in experimental or early developmental stages. Thus, its full potential will not be known for some time. If exploitation proves to be successful, Canadian shale gas may partially offset projected long-term declines in Canadian conventional natural gas production.

This emerging resource can be considered a technology driven play as achieving gas production out of otherwise unproductive rock requires technology-intensive processes. Maximizing gas recoveries requires far more wells than would be the case in conventional natural gas operations. Furthermore, horizontal wells with horizontal legs up to two kilometres in length are widely used to access the reservoir to the greatest extent possible. Multi-stage hydraulic fracturing, where the shale is cracked under high pressures at several places along the horizontal section of the well, is used to create conduits through which gas can flow. Micro-seismic imaging allows operators to visualize where this fracture growth is occurring in the reservoir. However, as a technology driven play, the rate of development of shale gas may become limited by the availability of required resources, such as fresh water, fracture proppant, or drilling rigs capable of drilling wells several kilometres in length. There are some environmental concerns with the specialized techniques used to exploit shale gas. There is potential for a heavy draw on freshwater resources because of the large quantities required for hydraulic fracturing fluid. The land-use footprint of shale gas development is not expected to be much more than the footprint of conventional operations, despite higher well densities, because advances in horizontal drilling technology allow for up to ten or more wells to be drilled and produced from the same well site. Finally, there is potential for a high carbon footprint through emissions of carbon dioxide (CO2), a natural impurity in some shale gas. Proposals have been made for carbon capture and storage as a remedy.

Conclusions: It appears that there is potential for 30 1012m3 (1000 Tcf) of shale gas in place within Canada if not more (Table 1). Assuming a 20 per cent rate of recovery, there would be enough recoverable gas to comprise more than one-third of Canada’s estimated ultimate potential for all conventional natural gas resources or almost two thirds of currently remaining ultimate conventional resources. High uncertainty, because gas shales are still in the initial stages of evaluation across Canada, precludes calculating more rigorous resource estimates for Canada at the current time.

Furthermore, the relative economics of shale gas development also has significant uncertainty. The resource will only be developed if it is profitable, which means the price of gas derived from other sources, like conventional gas, frontier natural gas, and liquefied natural gas (LNG), will need to be higher than the full cycle production cost of shale gas. Currently, only the Montney and Horn River Basin gas shales can be said to have “proof of concept” through numerous production tests after horizontal drilling and hydraulic fracturing and only the Montney currently has what can be called significant amounts of production. The Utica Shale has only had limited production from three hydraulically fractured horizontal wells, making it too early to declare “proof of concept”. Production of gas from shallow, vertical wells drilled in Colorado Group shales appears to be limited to the Wildmere area of Alberta to this point. The Horton Bluff Group shales of the Canadian Maritimes are very much in the early evaluation and testing stage.

Shale gas may be a key component of supply that will allow Canada to sustain its own domestic requirements for natural gas far into the 21st Century. Other sources of this natural gas may include other resource plays (including coal bed methane, tight sandstones and tight carbonates) or future production from Canada’s frontier areas in the offshore and in the north. It is even possible that shale gas could allow Canada to become a net exporter of LNG: recently, Apache Corporation and EOG Resources, both active in the Horn River Basin, signed memorandums of understanding to supply natural gas to a proposed LNG liquefaction terminal in British Columbia. However, ultimately, the pace of development of Canadian shale gas may be constrained by the availability of required resources, such as fresh water, fracture proppant, or drilling rigs capable of drilling wells several kilometres in length.

Finally, there are some environmental concerns with development of shale gas in Canada. Little is known about what the ultimate impact on freshwater resources will be. The land-use footprint does not appear to be of significant concern beyond conventional operations, despite higher well densities, because advances in drilling technology allow for ten or more horizontal wells to be drilled from the same well site. Furthermore, potential growth in CO2 emissions from shale gas is being addressed with proposals for carbon capture and sequestration. Still, it is very early to come to any conclusions about how development of this potentially large resource will impact the environment. Ongoing development of this emerging resource is likely to provide additional public data that will enable improved estimates of the contribution of shale gas to Canadian natural gas supply. Thus, the NEB will continue to monitor its progress.

Citation: ERCB, *What is Shale Gas? An Introduction to Shale-Gas Geology in Alberta* (2008)

Topic Area: Shale Gas

Jurisdiction: Canada

Introduction: Shale gas exploration and production is in its infancy in Alberta, so currently there is limited data to estimate the shale gas resource potential in the province. Knowledge obtained from American projects indicates that shale gas has the potential to add substantially to Alberta's resource and reserve base. In this report we define resources as 'the maximum gas in place, without regard to the technology necessary to extract gas nor the present price of the gas.' Reserves are defined as 'an estimation of how much can be produced at the current price with present technology.' Resources assigned to shale gas projects in the United States are in the range 35–250 Tcf for each project (Curtis, 2002; Faraj et al., 2004), with recoverable reserves being about 5%–20% of resources, given the present state of technology. The resource potential of Alberta shale gas is immense (*see* Section 4); Alberta may contain as many as 15 formations that exhibit shale gas potential, with multiple shale gas pools, in a spatial sense, potentially associated with many of the formations. In general, shale gas projects involve drilling many low-flow-rate wells (e.g. 560–8400 m3/d; 20– 300 mcf/d) that decline slowly and produce for 2–4 decades or more (Curtis, 2002). More rarely, the initial flow rate may be very high (e.g., 28 000–280 000 m3/d; ~1–10 mmcf/d); however this rate generally declines to a low-flow-rate within a few months or years (Bowker, 2007).

Aims & Research Methods: The purpose of this report is to define and describe gas shales and discuss Alberta's potential for shale gas production. Shale is traditionally regarded as a potential source rock and seal/cap rock for conventional hydrocarbon reservoirs. More recently, shale has been recognized as a potential unconventional reservoir for hydrocarbons, although with lower permeability and a larger content of organic matter than conventional reservoirs. In a shale reservoir, gas typically occurs in two modes: adsorbed on organic matter within the shale bed in a similar manner to coal bed methane, and as free gas in porosity within the shale matrix, similar to conventional reservoirs. The low permeability of shale reservoirs dictates that specialized completions techniques are necessary to enable production.

This report discusses relevant geological and geochemical criteria required for viable shale gas plays, including the type, amount and maturation of organic matter within a shale bed, gas contents and permeability. The nature of the reservoir, including mineralogy, fractures, porosity and permeability will determine suitability for different completions technologies and influence drainage area from a wellbore. Numerous shale plays in the United States are in production. A selection of plays is discussed as possible analogues for Alberta shale gas potential. Similarities and differences, with emphasis on geological, geochemical and mineralogical components are presented to highlight the potential for Alberta shale gas production.

Scope: This report is organized in the following manner:

• Section 2 discusses fundamental geological and geochemical aspects of shale that are relevant to Alberta shale gas development.

• Section 3 reviews geochemical and geological aspects of four main shale gas producing areas in the United States and suggests analogues for these plays in Alberta based on our knowledge of the Western Canada Sedimentary Basin (WCSB) and our own recent data collection and analysis.

• Section 4 summarizes some of the published resource estimates for Alberta.

• Section 5 summarizes some of the current shale gas projects in the WCSB.

Conclusions: At present, the most notable areas drilled for shale gas in the WCSB are in northeast British Columbia (B.C.) where the Muskwa Formation in the Horn River Basin has gained considerable attention along with the Montney Formation in east-central British Columbia. Horizontal and vertical drilling is on-going in these formations and gas production testing has yielded considerable success. Initial gas flow rates announced in the Muskwa are comparable to the prolific Barnett shale gas field in the U.S.A.; although production facilities in the area are being built so no extended production data is publically available. Horizontal drilling in the Montney Formation has resulted in numerous published examples of economic success with some fields literally abutting the B.C.-Alberta border. Reports on the shale gas potential of the Montney and Muskwa formations in B.C. can be found on the British Columbia Ministry of Energy, Mines and Petroleum Resources website (http://www.empr.gov.bc.ca/OG/oilandgas/petroleumgeology/UnconventionalOilAndGas/Pages/Shale.as px#studies). In Alberta, there is Montney 'shale' gas wells drilled, but the number of wells drilled is not to the extent seen in British Columbia. With respect to water resources, the Ground Water Protection Council (GWPC; www.gwpc.org) of the U.S.A. recently published a report entitled 'Modern Shale Gas Development in the United States: A Primer'(http://www.gwpc.org/elibrary/ documents/general/Shale%20Gas%20Primer%202009.pdf).

According to the authors, the primer discusses the "regulatory framework, policy issues, and technical aspects of developing unconventional shale gas resources," including water use and environmental aspects related to horizontal drilling and hydraulic fracturing.

In conclusion, Alberta has numerous packages of thick shale that have characteristics suitable for shale gas generation and production. Although shale gas production in the U.S.A. is well established, preliminary results in Alberta suggest that shale gas has the potential to contribute to Alberta's gas resource base.

Citation: Solander Ecological Research Ltd Victoria BC, *Assessment Methods for Application to Northeastern British Columbia* (January 2013)

Topic Area: Shale Gas Assessment

Jurisdiction: Canada

Introduction: Watersheds within northeastern British Columbia occupy a diverse biogeophysical region. The Liard River basin (LRB) is located in the Northern Boreal Mountains ecoprovince, the Horn River (HRB) and Cordova (CB) basins lie in the Taiga Plains ecoprovince, and much of the Montney basin (MB) is located in the Boreal Plains ecoprovince, with the exception of areas west and south of the basin, which lie in the Sub-Boreal Interior ecoprovince (British Columbia Ecoregion Classification; Demarchi 2011). The LRB lies east of the northern Boundary Ranges of the Coast Mountains, west of the Alberta Plateau, and south of the Taiga Cordillera of the Mackenzie Mountains. The general character of the LRB is mountains and plateaus separated by wide valleys and lowlands. Lowland areas are often occupied with wetlands, small lakes, and meandering streams, and valley bottoms in the mountains are often filled with glacial debris, in the form of kame deposits, till plains and moraines. Major tributaries of the Liard River include the Fort Nelson and Petitot basins, which are mid-alpine basins dominated by boreal forests and wetlands. Vegetation in the Upper and Central Liard basins is mostly white and black spruce dominated boreal forests with high alpine tundra vegetation in the upper reaches. Sub-arctic forest and alpine tundra dominate the Lower Liard. The HRB and CB lie to the east of the northern Rocky Mountains, and are characterized as extensions of the Alberta Plateau, with large lowland areas eroded by the Liard River and its main tributaries, the Fort Nelson and Petitot rivers, and by higher uplands adjacent to the Rocky Mountain Foothills. The Fort Nelson and Petitot rivers are incised as much as 150 m below the general level terrain of the lowland, which lies near 450 m elevation. Black spruce bogs and wetlands are extensive. Intermittent areas of permafrost also occur. Here the climax forest is white and black spruce, however, the frequency of wildfires across this landscape means that trembling aspen forests are common, often with balsam poplar and paper birch. At the higher elevations of the Muskwa Plateau, a cold subalpine forest, the Spruce - Willow - Birch Zone, is established.

The MB is located on the Alberta Plateau, east of the Rocky Mountains, south of the Fort Nelson Lowlands. The plateau is eroded by the Peace River and its tributaries. The upland surface lies between 900 m and 1,200 m above sea level rising to 1,500 m on the northern boundary. The basin consists of plateaus, plains, prairies, and lowlands, and is generally an area of low relief away from the deeply eroded riverbeds. Poor drainage dominates much of the upland surface, where there are large areas of muskeg, and meandering streams. Several rivers, such as the Moberly, Pine, Kiskatinaw, Halfway, and Beatton have cut through the upland surface into the soft shale bedrock leaving steep-sided canyons. Vegetation in MB is dominated by the Boreal White and Black Spruce Zone, aspen parkland occurs in the Peace River Lowland and muskeg occurs throughout most of the upland surface. On the low ridges east of the Rocky Mountain Foothills, the Engelmann Spruce - Subalpine Fir Zone occurs south of the Peace River, and the Spruce - Willow - Birch Zone occurs north of the Halfway River.

Aims & Research Methods: The purpose of this report is to provide a recommendation and supporting rationale to the Canadian Association of Petroleum Producers (CAPP) for a method or set of methods to determine environmental flows for streams in northeastern British Columbia, specifically the Montney, Cordova, Liard and Horn geologic basins (Figure 1). The shale gas deposits of northeastern British Columbia are receiving a great deal of interest by petroleum producers, and natural gas production in the region is projected to increase substantially over the next few years. There are a number of activities associated with exploration and extraction that require the use of water, including seismic exploration, road and pad construction, drilling, well completion, transportation and pipelines, and hydraulic fracturing, with the latter comprising the largest component of water use. Although companies are able to recycle and reuse some water, there is a substantial need for water if the industry expands as predicted.

Conclusions: The methods described here are recommendations that allow for a risk assessment of water withdrawals in northeastern BC. Although we believe there are benefits and strengths in the assessment approach, there has been only limited input and discussion with regulators. Additional input and discussion will undoubtedly be required if this proposal for a standard setting technique is to be adopted by government. Possible methodological challenges include verification of data requirements and outputs, monitoring and revising decisions based on the standard (i.e., adaptive management), and future revisions of the method based on new information. We recommend coordinating an agency review of the method and possibly a third-party peer review to support the agency review. It may be beneficial to review the method and results in a workshop setting. Furthermore, we note that MOE are undertaking their own efforts at developing a risk framework for water withdrawals.

We must also emphasize that the methods proposed here do not provide a holistic account of all environmental needs. Unlike other desktop methods that provide a one size fits all solution to water withdrawals, our approach provides a risk assessment framework for understanding risks of different withdrawal scenarios, especially for withdrawals that are fairly small. More complex environmental concerns (e.g., hydrology, geomorphology, biology, water quality, and connectivity) are likely to arise as withdrawals increase. The fish performance measures are good representations of important aspects of environmental flow needs, but as risk increases, information needs may also increase. Therefore, additional site-specific investigations may be required to support large withdrawals, particularly when flows are naturally very low.

Citation: Energy News Bulliten, *All about the Community* (July 2011)

Topic Area: Community engagement

Jurisdiction: Australia

Introduction: Community engagement should be a key focus of the coal seam gas sector, according to some of the speakers at the inaugural Queensland Gas Conference and Exhibition to be held in Brisbane from August 16-17.

Summary: Dart Energy chief executive officer Robert de Weijer, Queensland government LNG Enforcement Unit head Andrew Brier and Surat Basin Engagement Group chair John Cottter all believe better engagement with farming and community groups is essential to the future of the sector. “Some of the things that are now happening, such as the Surat Basin Engagement Group, which is bringing together industry and the local communities, should have been done a couple of years ago,” Cotter said. “This process, and events such as QGCE, are certainly changing and educating people’s views, giving them all a better understanding of what each party is about – and taking into account, for example, that the gas companies knew nothing about how farmers worked either. “The mystery has got to be taken out of it, there's got to be very transparent and open scrutiny, there's got to be understanding, which will start to build trust between all parties involved.” Cotter added the industry had to make clear the benefits that the CSG-to-liquefied natural gas sector could bring by repopulating and reinvigorating rural communities. "With this we can ensure there is infrastructure and facilities, like health and education, and sporting facilities and roads and services in those communities, which service all levels, both the rural sector [and] the resource sector."

Brier said the main issue for industry and government regulators was the need to get the message out there about what existed now – the rights and regulations with regard to landholders, the community and gas exploration companies. "Anything like QGCE which helps to do this, in a forum which actually helps people get all sides of the arguments and hear them all in one place, I think it's going to be extremely beneficial," he said. He added a lot of the anger from the community was from misinformation. "Having said that though, I think that some landholders have genuine concerns about what the effects of coal seam gas may be on their livelihoods and lifestyle," Brier said. "It's just unfortunate that these rational people with real concerns are getting a bit lost in some of the noise and misinformation that is out there at the moment." Brier noted that while the government had a role in explaining the regulations and rights for people who may be impacted by CSG activities, the industry also needed to explain how it worked, what the concerns were, and how they were managing the impacts.

"There are some properties and businesses out there who have benefited from the CSG industry, and both companies and landholders will tell you of areas where it has worked well," he said. "If we can get that mistrust and misunderstanding dealt with, and we get a good dialogue occur, then we are likely to get where we need to be."

Conclusions: Dart Energy chief executive officer Robert de Weijer, Queensland government LNG Enforcement Unit head Andrew Brier and Surat Basin Engagement Group chair John Cottter all believe better engagement with farming and community groups is essential to the future of the sector. "Some of the things that are now happening, such as the Surat Basin Engagement Group, which is bringing together industry and the local communities, should have been done a couple of years ago," Cotter said. "This process, and events such as QGCE, are certainly changing and educating people's views, giving them all a better understanding of what each party is about – and taking into account, for example, that the gas companies knew nothing about how farmers worked either. "The mystery has got to be taken out of it, there's got to be very transparent and open scrutiny, there's got to be understanding, which will start to build trust between all parties involved." Cotter added the industry had to make clear the benefits that the CSG-to-liquefied natural gas sector could bring by repopulating and reinvigorating rural communities. "With this we can ensure there is infrastructure and facilities, like health and education, and sporting facilities and roads and services in those communities, which service all levels, both the rural sector [and] the resource sector."

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Citation: Bill Babcock ConcoPhillips Director Global Resource Plays, *Issues Involved in Initiating Shale Gas Exploration Activities in Poland* (2011)

Topic Area: Shale Gas Exploration Activities in Poland

Jurisdiction: Poland

Aims & Research Methods: This presentation explores regulatory issues in shale gas development of Poland.

Conclusions: Investors need regulatory certainty Shale gas developments represent multi-billion dollar investments and continue for decades Processes need to be: Clear and non-discriminatory Timely and repeatable across large operations Promote innovation and new investment Cost base is critical Requires development of a competitive service sector capable of coping with large parallel operations Requires free movement of goods and services Gas Market potential Appropriate regulatory environment could make Poland gas trading hub

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Citation: Global Trade.net, *Regulations for the Shale Gas Mining- Extraction of Natural Gas in Poland* (2011)

Topic Area: Regulation of Shale Gas Development in Poland

Jurisdiction: Poland

Introduction: Poland is considered to be one of the European countries with the largest potential of recoverable shale gas deposits; estimates range between 1400 – 3000 billion cubic meters. The process of Polish shale gas deposit exploration has begun, with leading U.S. and international oil and gas company participation. The Ministry of Environmental Protection has already issued over 90 concessions for shale gas exploration, including 50 for U.S. companies (Exxon Mobile, Chevron, Marathon Oil, EurEnergy, and Conoco Phillips). Poland is facing a boom in shale gas exploration and production drilling operations, and appropriate regulations should be undertaken in order to facilitate the flow of necessary equipment and qualified engineering staff from abroad and U.S.

Aims & Research Methods: Poland's current legal framework regime for oil and gas exploration is generally favourable. The Geological and Mining Law of 1994 with further amendments, describes conditions for conducting the activities of exploration, operation, production and storage of natural resources in Poland, including oil and gas, and shale gas in specific.

The law can be viewed at
http://www.mos.gov.pl/g2/big/2009_06/5d34ad61445fce2a93d0c4e5906e4aa6.pdf

Article 68 of the Geological and Mining Law addresses the regulation of mining professions and the requisite qualifications for these professions. The law states that mining plant operations (including oil and gas) may be conducted only under the management and supervision of personnel possessing proper qualifications. The Minister of Economy is responsible for: 1) the specification of general and professional qualifications required for these personnel; 2) the creation of a list of positions for mining plants which are to be held by persons with professional qualifications, and 3) definitions for these types of qualifications. These issues are regulated by the Minister of Economy Ordinance of 2002 on Mining Profession Qualifications (Journal of Laws no 84, position 755).

According to above law, managerial positions are defined as “the manager of the mining plant and managers of the particular mining plant sections”. The supervisory positions include supervisors at the high, medium and low levels of plant operations. The general qualifications specified by the law that refers to all mining plants are as follows: written and spoken knowledge of Polish language, knowledge of subject type of mining plant operations to the extent necessary to perform managerial or supervisory duties. The general professional qualification requirements for all mining plants include: graduation from an adequate technical school verified by a diploma from the school and the completion of professional training in mining plant operation according to the duration and technical requirements specified for that particular position.

Conclusions: The list of managerial and supervision professions in the oil and gas exploration and production (including shale gas) that are currently regulated in Poland includes: shot fired, explosive materials disposer, drilling rig operator, operator of cement aggregates and equipment for oil and gas exploitation intensification, and welder. The special qualification requirements that refer to the above professions are as follows: graduation from a school specific to skills required and verified by a graduation diploma, adequate work experience, special training course completion, and age and health condition requirements. The qualifications of operation managers and supervisors in the underground mining plants (including shale gas) are ascertained by the President of the State Mining Authority (WUG). In order to perform duties of operation manager or supervisor, the person must possess a special certificate issued by WUG that ascertains his or her qualifications for this position. The recipient of this certification must pass an oral exam in Polish in front of the special commission. In order to be qualified for the exam, the applicant must apply to WUG, complete the required forms and attach documentation attesting to his or her educational and professional experience. U.S. engineering personnel who would like to work in Polish mining operations should follow this procedure, pass the exam in Polish and receive a WUG certificate. Qualifications of foreign mining operation specialists (except EU) are not acknowledged in Poland.

Citation: F.V Jones, M.D Zimmerman, W. Heinz, ERM Southwest Inc, *Managing Environmental Risks from Shale Gas Exploration- Applying Lessons Learned in the US to New Ventures in Poland* (2011) SPE 140864 Society of Petroleum Engineers

Topic Area: Shale Gas Environmental Risks

Jurisdiction: Poland

Introduction: Outside of the US, unconventional gas resources like shale gas have not been intensively studied or explored until recently. This paper describes the specific environmental risks and potential social impacts of shale gas exploration and how lessons learned from the US shale gas programs can be transferred to new ventures in Poland and other European countries.

Aims & Research Methods: This paper discusses these potential issues and provides a review in tabular form along with potential mitigation and management programs, which have been successfully applied by operators in US shale gas programs. The ability to identify the potential impacts and then develop focused mitigation programs is a key factor in developing a well-rounded SHE program and facilitate acceptance of shale gas exploration in Poland and Europe.

Conclusions: The mitigation and management programs outlined are important elements of a well-rounded Environmental Management Plan, which helps facilitate acceptance of shale gas exploration in Poland. By adopting lessons learned from the US, a painful and in most cases expensive repetition of errors can be avoided. The stimulations Operations of operators on neighbouring concessions and related incremental environmental risks and combined regulatory and social license to operate, requires an exchange of information and collaboration, happening during the day to day business, we would highly recommend that the operators start to combine their efforts in facilitating and maintaining public acceptance of their activates, and thus jointly secure their licenses to operated.

Although in Poland shale gas exploration is currently strongly supported by the public acceptance in conjunction with the wish to become self-sufficient and eliminate the dependency on the Russian gas supply, this will likely change when the downsides in form of actual or potential environmental impacts become more visual. This change should be proactively managed by implementing the referred management plans including action plans for failures, spills and accidents, and by pro-actively involving and informing the public, community representative sand other stakeholders about the current situation, about planned activates and related impacts and risks. It is also recommended that operators proactively address critical questions, that are not yet raised in Poland, but which will certainly be raised in the near future.

Citation: *Gas Strategies, Shale gas in Europe: A Revolution in the Making?* (2010)

Topic Area: European Shale Gas Development

Jurisdiction: EU

Introduction: Where might European shale gas reserves lie? The prospective areas lie, unsurprisingly, where companies have announced shale exploration initiatives:

- At the margins of the North Sea, in the east of the UK and in the Netherlands
- In Poland, particularly in the Baltic Basin in the north of the country where both
- ConocoPhillips and ExxonMobil have interests
- In several regions in France, particularly the Paris basin but also in Languedoc Roussillon, the
- Cevennes mountains and the Savoie region near the Swiss border
- In Southern Sweden in the Cambrian Alum Shale – Shell has drilled the first core well and

- plans to drill two more wells during 2010
- In Hungary and Austria, with OMV planning its first well in the Vienna Basin this year
- In Romania, where Shell is studying prospects
- Outside the narrow confines of the EU in Turkey and particularly the Ukraine

Aims & Research Methods: Without question, one of the big gas news stories of the last couple of years has been the so-called "shale gas revolution". A dramatic rise in US shale gas production has been one of the factors which have boosted US gas production to record levels and led to continuing weak gas prices. Even more dramatic than the increase in production have been the revisions of estimates of US domestic gas resources, which have been sufficiently dramatic for a flock of commentators to talk about shale ushering in a new era of cheap gas, with the potential to revolutionise the US energy scene, boosting energy security and providing a transition to a low-carbon economy. And now the interest in shale is turning in earnest to Europe, precipitating what some observers have called a "land-grab" for potential shale gas acreage. But, despite this optimism, Europe has yet to produce any shale gas and even on the most optimistic projections, shale will not make any impact on European gas production for some years, perhaps a decade. So how excited should we be about the prospects for shale gas production in Europe? In this article we look at the potential and some of the obstacles companies will face in exporting the US shale gas revolution to Europe.

Conclusions: Even if drilling results from these areas are promising, several obstacles lie in the way of efforts to commercialise shale gas in Europe. The most obvious of these is economics. Shale gas wells have lower productivity than conventional wells and, moreover, their production declines very rapidly in the first couple of years. This means drilling a larger number of wells than for conventional gas and, with the requirement for horizontal drilling and hydraulic fracturing, these are relatively expensive wells. Just how expensive shale gas is to produce will technically depend on the shale characteristics. There are also differences of opinion on the true cost of shale gas production, with shale gas promoters claiming costs in the best US plays of $5/MMBtu and below while sceptics suggest that true costs may be $7/MMBtu or more. In a European context these figures look good compared with the current price of gas bought on long-term oil price-linked contracts (the average German import price was running around $8.50/MMBtu in February) but maybe not so good compared with traded gas prices (NBP was around $5.30/MMBtu in February).

Cost is, however, not the only issue. The environmental impact of shale gas production is becoming an ever more contentious issue in the US. The key concern seems to be the risk of contamination of water supply aquifers by the chemicals used in hydraulic fracturing. Very large quantities of water, potentially millions of gallons of water per well are needed for fracturing operations, and chemicals are added to the water to improve performance. Both the sourcing of such large quantities of water and the risk of migration into water supplies pose environmental issues. And while shale gas promoters say that there are no known incidents of contamination of water supply from hydraulic fracturing, concerns have been sufficiently strong for New York state, for example, to essentially impose a moratorium on shale gas drilling near a watershed that supplies drinking water to New York City (See March issue of Gas Matters – A blip for US shale gas production). Environmental concerns of this sort may well be even greater in more densely-populated Europe, and the playing-out of the environmental issues will be a key factor to watch in assessing the potential of shale gas in Europe. Even if the geological, environmental and economic hurdles can be overcome, it will take a considerable effort to mobilise the resources needed to make the dream of a European shale gas boom come true. Currently Europe lacks the service industry that would be necessary for a spurt in shale gas activity – there are far fewer land-based drilling rigs available in Europe than in the US, for example. This can be overcome with time but might be a constraint on the rate – and cost – of development. Shale gas certainly has the potential to make a major impact on European gas supply. Whether it will be a "gamechanger" is rather less certain. What does seem sure, however, is that 2010 will see several European shale gas plays tested for the first time, and by the end of this year we may have a better idea of "Doctor Drill's" preliminary opinion on the matter.

Citation: House of Commons, *Energy and Climate Change Committee, Shale Gas Fifth Report of Session* 2010-12 (10 May 2011) (Volume I: Report, together with formal minutes, oral and written evidence)

Topic Area: Shale Gas Resource development in the UK and EU

Jurisdiction: UK

Introduction: Shale gas resources in the UK could be considerable—particularly offshore—but are unlikely to be a "game changer" to the same extent as they have been in the US, where the shale gas revolution has led to a reduction in natural gas prices. UK domestic shale gas resources could be used to increase our self-reliance, but they are unlikely to have as large an impact on our security of supply due to the limited extent of the resource. Elsewhere in Europe the impact of shale gas could be considerable; for example, Poland has potentially large shale gas resources, and the development of a Polish shale gas industry could reduce the extent to which Poland relies on imported natural gas. It is important for the UK to monitor the development of the fledgling shale gas industry in Poland, in terms of both our own prospects and the evolution of national and EU regulation in reaction to the development.

Aims & Research Methods: In this Report we consider the prospects for shale gas in the UK, the risks and hazards associated with shale gas, and the potential carbon footprint of large-scale shale gas extraction. We also consider the implications for the UK of large-scale shale gas production around the world. The report continues with an analysis of the prospects for shale gas in both the UK and abroad and the likelihood of rapid depletion of reserves. Chapter Four examines the policy implications for the Government of the establishment of a shale gas industry in the UK, and the regulatory challenges to be faced by the Department of Energy and Climate Change and its agencies. Chapter Five analyses the environmental risks associated with shale gas, including water and air contamination. Finally, in Chapter Six we consider the potential carbon footprint of shale gas and the implications of this for the UK's emissions and climate change targets.

Conclusions: The process of hydraulic fracturing has been described as "old as Moses" and certainly has been used in the petroleum industry for decades. However, it is only in the last decade that we have seen the effects of shale gas exploration and production on a large scale, as the combination of hydraulic fracturing and directional drilling have made the resources economically viable. Unconventional gas is just "natural gas" from a different type of rock. Whilst the term "unconventional" refers to the type of reservoir in which the gas is found, the techniques for accessing it are the same as you would use for a conventional well. Shale gas exploration is still in its infancy in the UK and the rest of Europe, which gives us the opportunity to learn from US experience and make regulations that are evidence based. While hydraulic fracturing itself poses no direct risk to underground water aquifers, there is a risk of contamination through a failure in the integrity of the well, but these risks are no different than those encountered when exploiting oil and gas from conventional reservoirs. We are, however, concerned about the large volume of water and chemical additives required for hydraulic fracturing each well, and the large volumes of waste water generated, especially as commercial shale gas production requires so many more wells than conventional gas.

As shale gas exploration progresses in Poland, the UK needs to work with the rest of Europe to ensure that shale gas policy and regulation is not driven primarily by concerns about energy security. In regions already experiencing water stress—the number of which might increase as a result of climate change—the water required by hydraulic fracturing could exacerbate the situation. The volume of waste water generated must not outpace the capacity and capability of treatment facilities to deal with it nor with the availability of disposal sites. The industry should recycle as much of the waste water generated as practicable.

The UK could have a large amount of shale gas offshore, and we encourage the Government to incentivise exploration of this potential resource. However, estimates of the UK's onshore shale gas resources suggest that there will not be a "shale gas revolution" in the UK based on domestic resources alone—nevertheless, they could make us more self-sufficient by reducing our reliance on imported natural gas. If significant amounts of shale gas enter the natural gas market it will disincentives investment in renewables and other lower carbon technologies. The UK Government needs to manage this risk in order to achieve its aim of generating more electricity from renewable sources.

The Government needs to be cautious in its approach to natural gas as a transition fuel to a low carbon economy. Although emissions from gas power plants are less than from coal, they are still higher than many lower carbon technologies. The main component of natural gas is methane, which is a greenhouse gas far more potent the carbon dioxide. However, the main source of this methane would be through leaks (or so-called "fugitive emissions") from the well and/or pipelines, which can be easily minimised through appropriate regulation and enforcement. Furthermore, the emergence of shale gas—and the likelihood that it will lead to the increased use of gas in power plants—means that we need to pursue with increased urgency the development of carbon capture technology suitable for gas as well as coal.

Citation: House of Commons, *Energy and Climate Change Committee, Shale Gas Fifth Report of Session* 2010-12 (10 May 2011) (*Volume II Additional written evidence*)

Topic Area: Shale Gas Resource development in the UK and EU

Jurisdiction: UK

Aims & Research Methods: Volume II presents additional written evidence supplementary to Volume I including:

1 World Coal Association Ev w1

2 Martin Quick Ev w6

3 National Grid Ev w7

4 Campaign to Protect Rural England Ev w8

5 Scottish & Southern Energy Ev w9

6 Scotia Gas Networks Ev w11

7 Ofgem Ev w13

8 Shell International Ltd Ev w19

9 Prof Stevens, Chatham House Ev w24

10 CNG Services Ltd Ev w28

11 The Co-operative Group Ev w32

12 Philip Mitchell Ev w36

13 Friends of the Earth Ev w38

14 ExxonMobil Ev w40

Citation: German Advisory Group Institute for Economic Research and Policy Consulting, *Non-Conventional Gas Regulation in Europe: Implications for Ukraine* (2011)

Topic Area: Gas Regulation in Europe

Jurisdiction: Ukraine

Introduction: Non-conventional gas resources may play an essential role in Ukrainian energy policy in the next decades. The exact amount of economical extractable reserves is unknown. It is undisputed that the development of exploration and following production of nonconventional gas in Ukraine will need further time and will not take place before 2020. The development of a stringent legal frame for a contemporary exploration today will establish the basis for an efficient and accepted use of the given opportunity in the future. After witnessing a non-conventional gas boom in the United States, a use of this resource for stabilising European decreasing production of conventional natural gas is in discussion for several years. Currently, neither a progress in exploration is visible nor a production in Europe. However, non-conventional gas emerges as a new opportunity for European primary energy supply. How this opportunity will be used is vague today. We will give an overview on the current discussion and the (weak) legal basis in the EU27 and in some Member States, and we will highlight in chapter 2 why the development of nonconventional gas production lies behind the progress of the United States.

Ukraine may benefit from two possible developments: (1) Non-conventional gas can be used for own national energy consumption and may reduce import dependency. (2) The EU27 may become a market for Ukrainian non-conventional gas. It is uncertain today, which development will take place and the future of non-conventional gas will be influenced mainly by the development of the global gas market and gas price and European gas demand. Therefore, we will give an overview of actual demand scenarios for the EU27 in chapter 3. Furthermore, in chapter 4 an overview of the need for environmental regulation regarding the exploration and production of non-conventional gas is given. Moreover, we will highlight the environmental concern on this technic and we will highlight how existing regulations in the EU27 is applicable on non-conventional gas production. In chapter 5 we make some recommendations how Ukraine may develop the regulation basis for the use of non-conventional gas resources.

Aims & Research Methods: Non-conventional gas may become a significant part of national energy supply in Ukraine in the next decades. Thereby, this type of resource can be applied as complement to national conventional natural gas and may be used as a substitute in the long run. The utilisation of given non-conventional potentials in Ukraine requires elaborating a long-term strategy, which takes into account the economic and technical challenges and the extensive environmental hazards. A clear regulatory framework is necessary for the attraction of investments, for creating public acceptance, and for an economical use of natural finite resources. We revise the EU progress regarding non-conventional gas regulation, and introduce the existing regulatory framework in the EU27 and in the Member States since they might be useful for Ukraine. In view of the European development it emerges that regulations are necessary regarding

(1) mining, (2) property rights, (3) fresh water use, (4) habitat and biodiversity hazards,

and (5) waste management. Whether non-conventional gas will play the predicted dominant role in European and Ukrainian energy supplies will mainly be influenced by the development of gas prices and the technical progress in non-conventional gas production, which reduces costs. The further European demand on natural gas (conventional and possibly non-conventional) will influence the technical progress of mining, the amount of firms in the sector, and thereby gas prices. Obviously, the European overall gas demand resp. the share of natural gas in the energy mix (as discussed in section 3) will have a major impact on how much non-conventional gas will be demanded. This gas demand also depends on further steps regarding European climate targets, global energy price development, cost of drilling and several environmental issues regarding non-conventional gas. Furthermore, the uncertainties related to nuclear power plants' safety represent a major challenge for the European energy resp. electricity strategy. Environmental hazards are one major obstacle in the development of non-conventional production in Europe. Public acceptance is mainly influenced by concerns about water pollution and habitat destruction. Strict environmental rules for non-conventional production in Ukraine can help to reduce risks and to ensure public acceptance, which has a positive impact on investors' reputation and thereby investors' decisions.

Conclusions: This report recommends the following Ukrainian policies on non-conventional gas: (1) Observe the international progresses and learn from successes and failures, (2) Perform a fundamental investigation of national reserves, (3) Develop the basis of a regulatory frame for exploration and production of non-conventional gas resp. clarify if existing regulations on conventional gas is applicable for non-conventional gas production, (4) Improve the legislative framework for foreign investments attraction to non-conventional sector for participation in knowledge and technology transfer, (5) Establish the legislative framework for public participation process.

Citation: The Polish Institute of International Affairs, *Norway: A Model for Shale Gas Exploration and Production in Poland?*, Bulletin No. 120 (196) (September 2010)

Topic Area: Exploration and production (E&P) of gas

Jurisdiction: Poland and Norway

Introduction: The Norwegian model of exploration and production (E&P) of gas can to a limited extent be implemented in Poland. The external limitations stem, first, from the differences in the profitability of natural and shale gas, and, second, from the restricted possibility of introducing Norwegian interventionist measures due to EU regulations and liberalisation of the European gas market. On the other hand, the Norwegian model highlights the challenges connected with resource management, and these challenges should be taken into account even at the early stage of the E&P.

Aims & Research Methods: For the time being, the amount and accessibility of shale gas reserves in Poland remain uncertain, but it is nonetheless worthwhile to examine the successful Norwegian model of natural resource management to highlight the challenges involved in the E&P of gas. This model is based on economic and legal actions of the state aimed at minimising the negative consequences for the economy often associated with resource production (the so-called "resource curse") and at safeguarding a managed distribution of profits among citizens. Prospects for the adoption of the Norwegian model of E&P of gas are examined below by comparing the economic and legal elements of the model with the current situation in Poland.

Conclusions: Although the Norwegian model cannot be directly implemented in Poland, it highlights the needs to ensure the transparency of and control over the actions of foreign investors by imposing high environmental standards or a twofold system of high taxation and tax incentives. It also shows that in the long run investments in the development of the national education and research as well as a strong position of the national gas player, are economically viable. In view of the forecasted increase in gas demand in Europe and the EU's low-emission energy policies, Poland should come up with a long-term resource management strategy as soon as its deposits of shale gas are confirmed. Until then, it would be worthwhile to enhance contacts and coordination between the local and central authorities. Surprisingly, the EU gas market liberalisation process need not hinder the consolidation of energy players, but shale gas E&P could change Poland's position in the EU forum from a supporter of liberalisation to an advocate of consolidation. On the other hand, Poland will not become "the Norway of the South" in a fortnight. Global oil and gas prices are among the factors that should reckoned with, while the long tradition of Norwegian state intervention in the economy has made it easier to reach a consensus on the implementation of interventionist measures there. Last but not least, Norway has consistently followed the welfare state model. The tradition of a managed distribution of energy profits was applied to the development of hydropower in the early 20th century, while in Poland's case the launch of a comparable system would evoke the still-vivid memories of the inefficiency of the socialist system.

Citation: Orlen, *Shale Gas Basic Information* (July 2010)

Topic Area: Shale Gas Generally

Jurisdiction: Global

Introduction:

• Depending on the nature of rock where hydrocarbons accumulate, deposits are divided into conventional and unconventional. Production of unconventional gas is more expensive and more challenging in terms of technology.

• Unconventional gas resources include shale gas, tight gas, coal bed methane, and gas hydrates.

• Given the current level of technology, it is possible to produce gas from unconventional resources commercially.

Aims & Research Methods: Polski Koncern Naftowy ORLEN intends to actively participate in projects involving exploration for unconventional gas in Poland. This plan is among the Group's strategic priorities. ORLEN Upstream, the Group's company responsible for upstream projects, has already commenced exploration in five licence areas in the Lublin region.

This Report has been prepared as the first attempt in Poland to compile in a systemicway the available knowledge and information on shale gas exploration and production. We aim to provide all interested parties with reliable and complete information on shale gas and PKN ORLEN's activities in this area.

The first section of this Report outlines the basic characteristics of shale gas, such as its geological origin, extraction technology, commerciality criteria, and – what stirs the greatest hopes and emotions in Poland – the potential economic and political impact of its production. The first country to launch commercial production of shale gas was the United States, therefore a whole chapter is devoted to this market. Shale gas currently accounts for approximately 14% of the U.S.'s total natural gas production. As estimated by the U.S. Department of Energy, a majority (60%) of recoverable gas resources is stored in unconventional reservoirs (shale gas and tight gas).

The final section of this Report examines the prospects of unconventional gas exploration and production in Poland. The estimates of potential shale gas resources published to date have provided a strong stimulus for the imagination. However, it should be remembered that the process of appraisal of potential shale gas reserves in Poland is only at a starting point.

This Report points out to both opportunities and potential barriers for the development of shale gas exploration in Poland, including geological, economic and administrative factors. It must be emphasised, however, that even if only the most conservative estimates of unconventional gas reserves in Poland prove correct, those resources – if their production turns out economically viable – may be sufficient to change the Polish natural gas market.

Conclusions: The ongoing improvement of production technologies has enabled access to unconventional gas resources present in source rocks. Whether Poland is going to see a gas revolution depends chiefly on the geological conditions. At this point it is difficult to estimate the actual size of Poland's shale gas resources and commerciality of shale gas production. First results will be known in the next four or five years, when operators complete the work under exploration and appraisal licences granted to them by the Ministry of the Environment. Polish government is offering licences on exceptionally favourable terms as an incentive for research on unconventional gas resources. Such an approach is driven by the strategic objective of ending Poland's reliance on foreign sources of natural gas in the future.

Shale gas will not change Poland's and the region's energy landscape instantaneously. As in the case of all commodity and energy revolutions, changes occur slowly, but shale gas development offers huge opportunities for a permanent shift in the Polish and European energy sectors. Poland stands a chance of becoming fully independent on natural gas imports, and Polish companies – a chance of improving their international standing.

Citation: Exen, SSW, Warsaw Consultants, *Poland Shale: A Playbook for Oil and Gas Majors Navigating Poland's Upstream Environment* (2011)

Topic Area: Regulatory landscape and the potential for community engagement to improve operational efficiency in Poland

Jurisdiction: Poland

Introduction: The upstream energy industry has undergone a dramatic transformation in the last few years. Excess capacity, dwindling demand and low prices of natural gas have put a strain on oil & gas companies as their margins have contracted and competition for high quality gas nassets has increased. Energy policy-related uncertainties, geopolitical complexities and ever-present environmental concerns add further pressure on energy majors. Yet, despite the current turmoil, long-term energy demand is set to grow substantially.

Aims & Research Methods: Rapid technological advances and the resultant explosion in shale gas production are partly to blame for the current over-supply. The US Energy Information Administration puts the global technically recoverable shale gas resource estimate at some 188 trillion cubic metres. As a country highly dependent on natural gas imports, Poland faces an unprecedented opportunity to shift its internal gas balance, and by doing so alter its status to that of a major European gas producer. With an estimated 5.3 tcm of technically recoverable shale gas reserves, Poland is rapidly becoming a significant point on the global energy map. And given Polish legislators' intense drive towards achieving greater energy security by increasing the diversity of energy sources, it is becoming clear that Poland's shale plays present an appealing opportunity for IOCs. In this document, we take an in-depth look at Poland's upstream environment and recommend an optimal country-facing strategy for new entrants. We examine the regulatory landscape and the potential for community engagement to improve operational efficiency, win support from local stakeholders and drive the value of global shale gas players.

As we write these words, the story of Poland's shale is beginning to unfold. BNK Petroleum Inc. has recently announced that the Lebork S-1 well has logged thick shales. Well completion and first fracture stimulations are expected to take place in the third quarter of 2011. And adding to the already impressive roster of major gas operators present in Poland, Nexen Inc. has just agreed to acquire a 40% working interest in 10 of Marathon Oil Corporation's 11 concessions.

Conclusions: Since one of the fundamental issues for global energy companies is achievement of appropriate local stakeholder buy-in, it is vital to localise universal corporate and social policies and procedures and adapt the CSR effort to the new operating environment. This toolkit element comprises Poland-specific documentation relating to local community engagement drafted in collaboration with the IOC's corporate communications department and public affairs advisors. As with most unfamiliar markets, adapting global CSR initiatives to the Polish environment requires a custom strategy. To maintain standardised global practices, the local CSR and community engagement function – and local documentation in particular – must be developed in accordance with globally-accepted standards, such as the Environmental, Social and Governance (ESG) format and the Oil & Gas Industry Guidance on Voluntary Sustainability Reporting drafted by the International Petroleum Industry Environmental Conservation Association and the American Petroleum Institute. At the same time, such documentation must adhere to local practices and address the expectations of various audiences including local communities, land owners, local authorities, suppliers and so on. Developing local CSR documentation is a crucial step in the process of initiating and conducting meaningful dialogue with local communities and other stakeholder groups over the life of a project. Another key challenge faced by energy majors entering CEE markets is Europe's E&P technology lag. According to data from Baker Hughes Rotary Rig Counts, Europe currently has some 110 drilling rigs in operation, compared with around 1 850 rigs in the US alone. Included in the E&P repository is localised documentation relating to the operation, inspection and maintenance of E&P equipment, processes, hazards, management systems and emergency response procedures.

With the impending transfer of US shale-drilling technology, there is increased need for technical documentation which is accurate and consistent with both US standards and local practices. Without a clearly defined local document strategy, global gas majors face efficiency losses and rising operating costs, as well as a substantial escalation of health and safety threats.

The local document strategy as regards E&P, environmental protection and HSE must take into account US industry best practices. When localising and authoring technical documentation, particular emphasis should be placed on applying globally-accepted terminology, such as that found in API standards and specifications, ISO standards for the oil & gas industry and the Gold Book.

Over time, the E&P repository develops into a comprehensive technical resource tailored to the Polish market, enabling safe and smooth upstream operations, efficient collaboration with local oilfield services companies and suppliers, as well as streamlining of local workforce development and training efforts. Enabling efficient cross-border communication in such a highly specialised industry as energy is no easy feat. As is the case with other emerging markets, the Polish upstream environment covers a variety of stakeholder groups.

Each audience requires a different type of content, thus necessitating the adoption of a customised approach, both with regard to translating, localising and creating documents and to addressing stakeholders in general. Whether handled internally or outsourced, the document management function must include a fool-proof quality assurance procedure, preferably based on ISO 9001, to ensure that information is transparent, consistent and easily understood by various audiences. A sound document strategy encompasses regulatory, CSR and E&P activity areas and satisfies stringent global data security, archiving and quality standards.

Given the relative obscurity of Polish energy industry standards as a whole, and technical documents and terminology in particular, producing and localising high quality technical documentation may prove a truly daunting task without significant involvement from a local partner with deep energy industry expertise and well-established connections with experts from organisations such as Poland's Oil and Gas Institute, the Polish Geological Institute and the Central Mining Institute. In any event, having a properly defined document strategy and access to local expert knowledge enables IOCs to focus on core operations, increases productivity and drives performance.

Citation: Schonherr Review, *Legal Developments in the Energy Practice* (June 2011)

Topic Area: Legal Developments in the Energy Practice

Jurisdiction: EU

Aims & Research Methods: All that's missing is the President's signature for the new geological and mining law to come into force in Poland. The new law will make administrative proceedings more effective, introduce modern regulations, simplify procedures for entrepreneurs, and fully implement directive 94/22/EC on the conditions for granting and using authorisations for the prospection, exploration and production of hydrocarbons. Some provisions of the new law are significant in relation to mining deposits of shale gas in Poland, estimated as the largest in Europe.

The focus of the Romanian renewable energy sector has lately been on the outcome of the EU Commission's authorisation of the support scheme regulated by Law No. 220/2008 on the promotion system for energy generated from renewable sources. The uncertainty surrounding the support scheme has led to a slowdown of investments in renewable energy projects. In view of the process of getting the support scheme authorised by the EU Commission, the Government proposed a draft emergency ordinance to amend Law No. 220/2008. This draft is currently being subjected to public debate.

Citation: Matt Ridley, *The Shale Gas Shock* (2011)

Topic Area: Shale Gas

Jurisdiction: Global

Introduction: Shale gas is proving to be an abundant new source of energy in the United States. Because it is globally ubiquitous and can probably be produced both cheaply and close to major markets, it promises to stabilise and lower gas prices relative to oil prices. This could happen even if, in investment terms, a speculative bubble may have formed in the rush to drill for shale gas in North America. Abundant and low-cost shale gas probably will – where politics allows – cause gas to take or defend market share from coal, nuclear and renewables in the electricity generating market, and from oil in the transport market, over coming decades. It will also keep the price of nitrogen fertiliser low and hence keep food prices down, other things being equal. None the less, shale gas faces a formidable host of enemies in the coal, nuclear, renewable and environmental industries – all keen, it seems, to strangle it at birth, especially in Europe. It undoubtedly carries environmental risks, which may be exploited to generate sufficient public concern to prevent its expansion in much of western Europe and parts of North America, even though the evidence suggests that these hazards are much smaller than in competing industries. Elsewhere, though, increased production of shale gas looks inevitable. A surge in gas production and use may prove to be both the cheapest and most effective way to hasten the decarbonisation of the world economy, given the cost and land requirements of most renewables.

Aims & Research Methods: 1. The detection and exploitation of shale gas has been described as nothing less than a revolution in the world energy industry, promising to transform not only the prospects of the gas industry, but of world energy trade, geopolitics and climate policy. Production of 'unconventional' gas in the U.S. has rocketed in the past few years, going beyond even the most optimistic forecasts. It is no wonder that its success has sparked such international interest… A few years ago the United States was ready to import gas. In 2009 it had become the world's biggest gas producer. This is phenomenal, unbelievable. -- Anne-Sophie Corbeau, International Energy Agency.

2. The claim made by shale gas‘s champions is that, in defiance of early scepticism, shale gases proving to be:

• ubiquitous, with the result that it promises to be developed near to markets rather than in places where it happens to be abundant, like oil;

• cheap, with the result that it promises gradually to take market share from nuclear, coal and renewable energy and to replace oil in some transport and industrial uses;

• environmentally benign, with the result that it promises to reduce pollution and accelerate the decarbonisation of the world economy.

3. This report considers these claims and assesses them against various counter-claims. It finds that although there are considerable uncertainties that make hyperbole unwise, shale gas will undoubtedly prove to be a significant new force in the world energy scene, with far-reaching consequences.

Conclusions: The dominant fuel in the world fuel mix has gradually shifted from wood to coal to oil over the past 150 years, with gas the latest fuel to grow rapidly. At this rate gas may overtake oil as the dominant fuel by 2020 or 2030. The consequence of this succession is that the carbon hydrogen ratio in the world fuel mix has been falling steadily, because the ratio of carbon to hydrogen atoms is about 10-to-1 in wood, 2-to-1 in coal, 1-to-2 in oil and 1-to-4 in gas. On its current trajectory, the average ratio would reach 90% hydrogen in 2060, having been 90% carbon in 1850. Jesse Ausubel of Rockefeller University describes this phenomenon as follows: When my colleagues Cesare Marchetti, Nebojsa Nakicenovic, Arnulf Grubler and I discovered decarbonisation in the 1980s, we were pleasantly surprised. When we first spoke of decarbonisation, few believed and many ridiculed the word. Everyone ‘knew‘ the opposite to be true. Now prime ministers and presidents speak of decarbonisation. Neither Queen Victoria nor Abraham Lincoln decreed a policy of decarbonisation. Yet, the energy system pursued it. Human societies pursued decarbonisation for 170+ years before anyone noticed. -- Jesse Ausubel, International Journal of Nuclear Governance, Economy and Ecology, 200764.

88. Consequently, although increased energy use means that carbon dioxide emissions are rising all the time, the world is nonetheless slowly decarbonising. A sudden and forced acceleration of this decarbonisation is what environmentalists and many politicians are demanding in the name of climate change policy. The argument is that the cost of waiting for decarbonisation to happen of its own accord is higher than the cost of replacing existing fuels with low-carbon alternatives.

89. However, few of the low-carbon alternatives are ready to take up the challenge on a scale that can make a difference. Nuclear is too slow and costly to build; wind cannot provide sufficient volume of power or reliability; solar is too expensive; biofuel comes at the expense of hunger and high carbon dioxide emissions. All except nuclear (and to a lesser extent solar) require unacceptably vast land grabs. Diverting 5% of the entire world grain crop into the US ethanol program in 2011 will displace just 0.6% of world oil use65; getting 10% of Denmark‘s electricity from wind has saved no net carbon emissions (because of the need for inefficient back-up generation)66.

90. The world would do well to heed the advice of Voltaire and not make the best the enemy of the good. Rapid decarbonisation using renewables is not just expensive and environmentally damaging, it is impossible. However, switching as much power generation from coal to gas as possible, and as much transport fuel from oil to gas as possible, would produce rapid and dramatic reductions in carbon dioxide emissions. Just as genetically modified crops called the bluff of the organic movement, by demonstrating both better crop protection and better environment protection, so abundant gas is calling the bluff of the renewable energy movement by demonstrating both better economic efficiency and better carbon reduction. Yet Europe turned its back on GM crops when they ran into sudden and coordinated environmental opposition based on the precautionary principle that a new technology might be worse than an existing one. Meanwhile GM soya went on to give South America a competitive advantage in the world market in animal feed and GM maize gave North America a competitive advantage in human food. So, likewise, it is entirely possible that Europe may choose to excuse itself from the shale gas revolution and put itself at a competitive disadvantage in the electricity, transport, chemical and fertiliser industry, as well as finding decarbonisation harder.

92. If Europe and the wider world are bent on cutting carbon emissions, they would be foolish to ignore the claims of shale gas, at least until superior versions of nuclear or solar power are developed later in the century67. Fortunately, this strategy is also the most affordable.

Citation: World Energy Council, *Survey of Energy Resources: Focus on Shale Gas* (2010)

Topic Area: Shale Gas

Jurisdiction: Global

Introduction: Today, the global energy industry is facing a growing number of uncertainties, including price volatility, rising demand and increasing costs which are leading to greater pressures for energy producers and consumers alike. Furthermore, almost a quarter of the world population has no access to modern energy and little hope of joining the world's energy consumers any time soon. It is clear that the current energy system is unsustainable. Can shale gas induce badly needed changes?

In its quest for secure, sustainable and affordable supplies of energy, the world is turning its attention to "new" and promising energy resources. Shale gas is one of them, and it has been making headlines in the past couple of years. It seems to be abundant and globally available. Massive recoverable deposits of shale gas have been identified in North America, where the first commercial gas well was drilled nearly two hundred years ago, in 1821.

Aims & Research Methods: The energy sector around the world is undergoing major changes resulting from increasing competitive pressures and concerns about costs, security of supply and the environment. At the same time, 1.6 billion people, almost a quarter of the world population, do not have access to commercial energy and the need for energy infrastructure investment is huge. The energy challenges are not the same in all regions. While rapidly burgeoning economies in the developing world are focusing on expanding energy access to support their economic growth and provide basic energy services to their citizens, industrialised countries are focusing on securing energy supplies in a competitive environment and in a publicly and environmentally acceptable way. In recent years, shale gas has been making headlines as a potential solution for many of the energy-related challenges, in particular in the United States. A number of studies on shale gas have been conducted, the majority focusing on the assessment of the resource base and the role of emerging technologies, which can significantly increase the current reserve estimates.

The World Energy Council has just completed work on its 22nd Survey of Energy Resources and based on this work, it was decided to produce a "Focus on Shale Gas" report to provide a fact-based and forward-looking contribution to the on-going discussion about shale gas. An ad-hoc team of experts led by Richard Davis of RTI International included Vikram Rao of RTEC (former Chief Technology Officer of Halliburton) and Carl Bauer of C.O. Bauer Consulting (former Director of the U.S. National Energy Technology Lab). The Survey of Energy Resources joint-editors Judy Trinnaman and Alan Clark, and RTI International experts James Trainham and David Myers contributed their insights. The project was managed by Elena Nekhaev, WEC Director of Programmes.

Conclusions: It can take decades to realise all the consequences of the increased production and use of shale gas on natural gas markets, in particular. There are a number of uncertainties which can have a significant impact on the future of shale gas. Given the fact that there are still significant producing reserves of conventional natural gas around the world, there may not be sufficient incentive, on a regional basis, to identify or exploit unconventional natural gas in the near term. It may also be the case that the amount of energy needed to produce unconventional gas is considerably higher than for conventional gas. Developing nations will also face the challenge of the cost and time to develop both the resource and infrastructure as economic returns will be initially small.

It is impossible to put a numeric value on security of supply, but replacing oil imports from politically sensitive parts of the world by domestic shale gas production is perhaps the main driver in the United States. It would seem that although shale gas holds much promise, the eventual course of its development cannot be predicted at present. Helge Lund, Chief Executive of Statoil, was quoted by the Financial Times in FT.com in March 2010 as saying „it is far too early to conclude whether shale gas will make as much of an impact outside the US as it has done inside the US‟.

Citation: Global Energy Strategies, James Slutz, *Eastern European Unconventional Gas Regulatory Processes* (September 2010)

Topic Area: Gas Development in Poland

Jurisdiction: Poland

Aims & Research Methods: This presentation outlines the challenges to gas development in Poland as follows:

Lack of rigs and qualified personnel to enable efficient development.

Lack of gas shale specific infrastructure: an opportunity for service companies and subcontractors. but will slow development -shale gas development is highly dependent on technology -cost and recovery maximization.

Polish license needed for imports of equipment. Length of process, transparency

Expert staff requires local licensing

Installation licensing required for certain equipment

Change of leadership in Poland -risk of backtracking on commitments to foster development in shale gas

Conclusions: Government Actions Needed:

- Simplifying licensing requirements for imports, personnel and installation
- Liberalization of gas sector, reducing influence of state firms and thus conflicts of interest with the regulator.
- Removing allocation of gas transportation quotas by state -another conflict of interest with state firms.
- Increasing gas storage capability

Citation: APPEA, *Chemicals that may be used in Australian CSG Fraccing Fluid* (2012)

Topic Area: Chemical Use and Disclosure

Jurisdiction: Australia

Aims & Research Methods: This table outlines the permissible chemicals that may be used in CSG fracking in Australia.

Citation: Queensland Government, *Coal Seam Gas Recycled Water Management Plan and Validation Guidelines: Including Exclusion Decision Application Guideline* (June 2011) (Consultation Draft)

Topic Area: Water Use and Recycled Water

Jurisdiction: Australia (Qld)

Introduction: The recycled water provisions for coal seam gas (CSG) water of the *Water Supply (Safety and Reliability) Act 2008* (the Act commenced on 1 December 2010 and are administered by the Department of Environment and Resource Management (DERM). The chief executive of DERM is the regulator under the Act.

The primary objective of the Act in relation to CSG water is to protect public health. Under the Act, for a CSG recycled water scheme to supply CSG recycled water (directly or indirectly) either into a water source used as a drinking water supply or directly to a drinking water service provider as a source of drinking water, a responsible entity must have:

• an exclusion decision made by the regulator, or

• an interim CSG Recycled Water Management Plan (RWMP) approved by the regulator or as deemed by sections 641, 642 and 643 of the Act, or

• a full CSG RWMP approved by the regulator.

Aims & Research Methods: This guideline has been developed to provide information to the responsible entity, about preparing an exclusion decision (if applicable) or RWMP where a scheme is proposing to supply either:

• CSG water into a water source used for a drinking water supply by a drinking water service provider; or

• CSG water directly to a drinking water service provider as a source for a drinking water supply.

It has been prepared using a modular format. While separate sections within the guideline may appear repetitive, the intent is to provide the responsible entity with all the relevant information in a single location, dependent on the type of exclusion decision application or RWMP being prepared. CSG water has a different public health risk profile compared to other recycled water sources. The principal public health concern is adequate management of the chemical and radiological quality of water including management of long term exposure. To cater for these differences an adaptive CSG RWMP approval regime and this guideline have been developed.

This guideline aims to provide information about:

• exclusion decision applications

• the requirements of the Act and related criteria for different methods of supply to a drinking water service provider

including:

 direct supply of CSG water to a drinking water service provider as a source of drinking water

 direct and indirect supply to a water source used for a drinking water supply by a drinking water service

provider

• the adaptive approach to preparing RWMPs including:

 interim RWMP

 full RWMP

• submitting documents for approval by the regulator

• matters considered by the regulator in assessing RWMPs

• seeking amendments to an RWMP

• additional responsibilities of recycled water providers, or scheme managers.

The material in this guideline is indicative of the regulator’s policy objectives and the Act’s purpose. The regulator may also choose to look at other information, such as industry standards, technical expert advice or other health-based guidance to support policy objectives and the Act's purpose.

Citation: Mary O'Kane, *Initial report on the Independent Review of Coal Seam Gas Activities in NSW* (July 2013)

Topic Area: CSG Activities

Jurisdiction: Australia (NSW)

Introduction: This report draws on five months of information gathering, stakeholder meetings, interviews, community consultations, site visits, and technical paper preparation. In undertaking this review I sought the independent advice of several experts whom I commissioned to provide reports on a range of topics relevant to CSG activities in NSW including water, geology, CSG operational processes, and health and environmental impacts. I also sought the views of the community-at-large through the good offices of the Land and Water Commissioner, Mr Jock Laurie, through meetings with community representatives in Sydney and the regions, and by calling for public submissions to inform the Review. The Review received more than 230 responses.

Aims & Research Methods: The independent review of coal seam gas (CSG) activities in NSW by the NSW Chief Scientist & Engineer commenced in late February 2013. This is the initial report of the Review, which was requested by July 2013.

Based on consultations and submissions to date, the Review makes a small number of recommendations aimed at improving the information available to the community and assisting the Government to build confidence that it has the intention and capacity to oversee a safe CSG industry.

CSG is a complex and multi-layered issue which has proven divisive chiefly because of the emotive nature of community concerns, the competing interests of the players, and a lack of publicly-available factual information.

The debate has been fuelled by unanswered concerns surrounding landholders' legal rights, land access and use; human health; the environment, particularly relating to impacts on water; engineering and operational processes; and industry regulation and compliance. These issues remain matters of contention.

The challenges faced by government and industry are considerable and a commitment from all parties will be required to improve the existing situation and build trust with the community.

From a technical and scientific standpoint, many challenges and risks associated with CSG are not dissimilar to those encountered in other energy and resource production, and water extraction and treatment.

Some challenges are well defined and can be effectively managed through high standards of engineering and rigorous monitoring and supervision of operations.

Other challenges relating to long-term and cumulative environmental impacts are less obvious and require a commitment to significant and ongoing research, as well as a consequent evolution of engineering practice.

This initial report aims to explore the many issues of community concern – drawing on material learned through listening to stakeholders and applying an evidence-based approach to problems.

Conclusions: Based on the work done to date by the Review, this report recommends the NSW Government commit to adopting a vigilant, transparent and effective regulatory and monitoring system to ensure the highest standards of compliance and performance by the CSG industry.

As a first step, the Government needs to institute a strong and sophisticated policy for data collection and data handling, and establish a whole-of-environment data repository.

The Government should also implement stronger conditions around the training of CSG operators, and champion further research on the unanswered questions around the science of CSG.

There is, however, more work to do.

Based on preliminary investigations, the Review will continue the industry compliance study and the study of best practice in unconventional gas extraction technologies and regulation. It will also commission studies on risk and on exposure pathways for chemicals and contaminants. In addition, the Review has identified areas around land owner compensation, company insurance and operator penalties which could be strengthened and, as such, has commissioned further legal work in these areas.

The issue of CSG in NSW is a very tough one with many complicated parts. A commitment to sound policy implementation based on highly developed data and further research to fill the knowledge gaps will be essential.

Citation: USQ, *Preliminary Assessment of Cumultaive Drawdown Impacts in the Surat Basin Associated with the CSG Industry* (March 2011)

Topic Area: Drawdown Impacts in the Surat Basin

Jurisdiction: Australia

Introduction: The coal seam gas (CSG) industry in eastern Australia is experiencing a period of rapid expansion. A major focus of the current development is on the Surat Basin in south-west Queensland. The Surat Basin covers approximately 110,000 km2 and has an estimated 6 billion tonnes of thermal coal resources and more than 18,000 PJ of coal seam gas reserves (DEEDI, 2010). It also has an established agricultural sector including extensive grazing, intensive feedlots and irrigated broad-acre and horticulture crops. CSG recovery has occurred from small scale developments in Queensland for approximately 25 years. Coal seam gas is recovered by drilling extraction wells into the target coal seams. Groundwater is then pumped from the wells to lower the water pressure in the coal seam so that the gas (primarily methane) is released. It is generally not necessary to completely dewater the coal seams to produce the gas. CSG production is therefore dependent on groundwater extraction to facilitate recovery of the gas from the coal seams. The Surat Basin CSG industry produces gas from the Walloon Coal Measures (WCM). The target coals are thin seams within the low permeability, largely siltstone Walloon Coal Measures, and are directly overlain and underlain by low permeability geological units known as aquitards (or confining layers). These aquitards restrict vertical groundwater flow between the coal seams and aquifers which are located both higher and lower in the geological sequence. Despite the low permeability of the aquitards overlying and underlying the Walloon Coal Measures, groundwater extraction to reduce the water pressure in the coal seams may induce some vertical leakage into the coal seams and produce impacts on the surrounding sandstone aquifers. Regional towns and the agricultural industry within the Surat Basin utilise groundwater from both the sandstone aquifers and, to a much lesser extent, the Walloon Coal Measures. Shallow groundwater aquifers in the area are generally used to provide town supplies and water for irrigation while bores in the Walloon Coal Measures are most commonly used for stock and domestic use. Hence, it is important to understand the potential effects of groundwater depressurisation for CSG extraction on other groundwater users.

Aims & Research Methods: During 2010, the four major CSG companies operating in the Surat Basin identified that there was significant community concern regarding the cumulative groundwater impacts of CSG operations in this area. In an industry first, these companies agreed to pool their resources to review the approaches taken to the individual assessments, and provide a preliminary independent assessment of cumulative groundwater impacts associated with CSG operations.

The University of Southern Queensland (USQ) was commissioned in September 2010 to manage this study, with RPS Aquaterra engaged to undertake the independent assessment of cumulative impacts, based on information from published impact assessment reports and other information made available to USQ and RPS Aquaterra by the four CSG companies to undertake the study. The overarching aim was to collate and present the existing groundwater modelling data to provide both the Government and the public with a greater level of understanding and confidence regarding the cumulative groundwater impacts from the development of CSG projects within the Surat Basin. This preliminary study was designed to provide a first estimate of impacts based on existing modelling.

The key objectives of this preliminary study were to:

- Determine the Groundwater Areas expected to be impacted by depressurisation of the Walloon Coal Measures by the four major CSG company projects in the Surat Basin; and,
- Compile a package of information and data to be provided to the QWC to assist its modelling consultants in developing a regional groundwater model for the Surat Basin.

Integral to the second task was a comparison of the conceptual models used by the CSG companies, and presentation of recommended parameters and features for a regional model of the Surat Basin CSG developments which could be used to:

- Describe the current extent of knowledge of the groundwater conditions in the Surat Basin;
- Incorporate existing groundwater uses, as well as the proposed large scale CSG developments in the Basin;
- Represent the main hydrological processes, both natural and anthropogenic, to allow assessment of the impacts of all activities on the basin water resource; and

- Provide a basis for the development of a regional groundwater model by the Queensland Water Commission (QWC), based on the best possible combination of industry experience and knowledge.

It should be noted that the individual projects' scenario modelling used in this study was undertaken separately by the companies and has not considered mutual interactions in terms of the rates of water extraction by the other companies. Hence, the sum of the predicted water production rates is expected to overstate the total water production for the four projects when operating simultaneously, and consequently the cumulative impacts are likely to be less than those presented in this report.

Scope: Lease boundaries for the four CSG projects are shown on Figure 2.1.Three of the projects (as presented in EIS or project documentation) are located entirely within the Surat Basin. Santos has proposed developments from coal measures in both the Surat Basin and the Bowen Basin. Origin operates the Spring Gully project in the Bowen Basin under existing environmental approvals. Arrow has also previously recovered CSG from a small-scale project in the Bowen Basin.

Although some CSG production has occurred or is proposed from the Bowen Basin, for the purposes of cumulative impact, only the Surat Basin proposals are considered in this report. It is considered appropriate to consider only the Surat Basin in this cumulative impact study, as the intervening aquitards between the Walloon Coal Measures (WCM), which is the target coal unit in the Surat Basin proposals, and the Bandanna Coal Measures (BCM) which is the target unit for CSG production in the Bowen Basin, will effectively keep the two coal measures hydraulically separate. Although it is possible that impacts of the Surat Basin and Bowen Basin developments could mutually interact slightly, it was decided to concentrate only on the Surat Basin developments in this study. It should be noted that there is significant current use of groundwater in the Surat Basin, as well as commercial activity that potentially impacts on groundwater, including:

- Large-scale irrigation use
- Stock and domestic use
- Town water supply
- Industrial use of groundwater
- Coal mining
- Conventional oil and gas production
- Existing CSG production.

It is generally the shallower units that are developed for water use, hence most current use of groundwater occurs in or close to the outcrop areas of the main aquifer units.

Conclusions: This study has collated groundwater information from the four major CSG companies operating in the Surat Basin to provide a preliminary but over-conservative assessment of the groundwater areas expected to be impacted by depressurisation of the Walloon Coal Measures. The Queensland Water Commission has been tasked with assessing the CSG water impacts. However, in conducting this preliminary study it is clear that there are areas where additional research would improve both the identification of the cumulative impact area as well as the robustness of the model predictions regarding timing and scale of impact.

Citation: Centre for Community and Business Research, *Economic Impact of the Eagle Ford Shale* (May 2012)

Topic Area: Socio-Economic Issues of Gas Production

Jurisdiction: USA (Texas)

Introduction: The Eagle Ford Shale is a hydrocarbon producing formation that is a source rock for Austin Chalk which is approximately 4,000 to 14,000 feet below the surface. The core focus of this drilling activity is between 10,000 and 12,000 feet below surface. This discovery is of significant importance in that the formation contains both natural gas and oil deposits. The projections put forth in the initial study completed in February 2011 were conservative based on limited information available at the time. Since then, production conducted in 2010 has far exceeded the expectations outlined in the initial report due to rapidly evolving business activity. Indeed, activity in the Eagle Ford Shale has expanded at an unprecedented rate, and the increase in production from 2010 to 2011 has been accompanied by equally significant increases in permitting, well drilling and completion, residential and commercial construction, pipeline construction, and numerous other support activities. This report serves to provide an overview of all activity related to the Eagle Ford Shale play and its economic impact.

Aims & Research Methods: In addition to updates to the impact figures detailed in the 2011 Eagle Ford Shale Report, this report will include vignettes in which CCBR staff members interviewed individuals affected by the increased activity and production in the Eagle Ford Shale region. These vignettes serve to bring home the economic impacts from many different individual perspectives in terms of direct effects (drilling, transport, refining), indirect effects (construction and energy service companies) and induced effects (restaurants, hotels, stores, etc.). Also included in this report are recommendations for improved governance, detailing strategies that communities may consider in order to develop in a sustainable and economically solid manner. These strategies are included in the discussions of the following topics:

• Revenue and investment strategies

• Medium and long-term planning – land use, capital outlays, sustainable infrastructure (medical facilities, improved aesthetics, elimination of blight, public attractions to build community desirability, etc.), and general liability

• Strong institutional management

• Engaged citizens

• Fiscal discipline

• Commitment to ongoing education/working smarter/learning from past mistakes

Formation of linkages and alliances, and engagement of other Eagle Ford Shale communities and higher education institutions Small business is an arena that has been particularly affected by the Eagle Ford Shale play. A small business section is included in this report to highlight the unique opportunities and challenges that small businesses, both previously existing and new, have and will encounter in the Eagle Ford Shale region. The transportation section of this report will address the challenges in infrastructure and also will lay a foundation for future transportation studies in the region. Environment, water, housing, and public health and safety are also highlighted and discussed within this report.

In order to estimate the impacts, CCBR again used the input-output software IMPLAN.5 This software allows for the measurement of direct, indirect, and induced impacts from the operations of the firms in the Eagle Ford Shale. The direct impacts include the actual production and employment by the firms operating in the shale. The indirect impacts include the revenue and personnel expenses of the suppliers while the induced impacts include expenses of the workers. The software organizes the information based on data from the Bureau of Economic Analysis (BEA) and several other federal and state agencies. The IMPLAN model was adjusted to avoid double counting the impacts of several related industries in the same area.

Scope: This study will use 2011 as the baseline case for information on production, drilling, and related activities, to help interpret the rapid changes occurring in the region. This study also has been adjusted to focus specifically on the impacts of 14 producing counties that are of particular interest in the Eagle Ford Shale development area: Atascosa, Bee, DeWitt, Dimmit, Frio, Gonzales, Karnes, La Salle, Live Oak, Maverick, McMullen, Webb, Wilson, and Zavala. In addition, significant non-production activity is occurring in 6 peripheral counties and is included in the analysis: Bexar, Jim Wells, Nueces, San Patricio, Uvalde and Victoria.

Conclusions: Further research will be needed to answer a multitude of questions that will arise throughout the ongoing development of the Eagle Ford Shale region. The projections provided within this report are conservative. As production continues to grow in the area, updated research will be needed in order to maintain an accurate pulse of the changes in activity and production.

When permitting, drilling, completion and production activities all increase between two- and six-fold within one year, it is important to maintain updated figures in order to be able to more closely predict future production. As individual cities and counties grow both in terms of oil and gas activity and in terms of overall community and economic development, continued research will be useful on the individual city and county level to maintain informed strategic focus and decision-making. Tracking local economic indicators will be a critical component to smart, sustainable development on the local level. Transportation studies will continue to be an important component of research for the Eagle Ford Shale region going forward. As production increases and continues for what may potentially turn into several decades of high activity, local roads will require repair and improvement. Major interstate routes to surrounding locations will continue to experience increased traffic, resulting in far-reaching transportation impacts. Workforce development assessments are a useful component of further research. The demand for high-wage and high skilled jobs is increasing, and can be met by the local labour force only if the appropriate training is available to local residents and the workforce is attaining the skills necessary to be competitive in these fields. Ongoing development of relevant training opportunities for local residents will be an important component of this, and research serves as a necessary foundation for approaching workforce development in an efficient and effective manner.

Housing studies are an important component of further research, as we seek to understand how current housing shortages affect price, demand, and commuting patterns, and how communities should plan their short- and long-term housing construction so as to achieve the most sustainable level of community growth and economic development. A housing study is currently being compiled by the College of Architecture at the University of Texas at San Antonio, which will begin to answer some of these questions in greater detail. Finally, cluster development studies are an important direction for further research. South Texas has an opportunity to develop industry clusters in the areas of oil and gas production and its support industries, as well as in areas of technology. Some of the current technologies being developed have been discussed in this report; bringing more research and development companies to the area and providing educational opportunities in this area may help south Texas develop this important related industry cluster.

Citation: Andrew A. Michta, *Shale Storm* (2012)

Topic Area: Hydraulic Fracturing

Jurisdiction: Poland

Introduction: A silent global shale gas revolution has been underway since 2001, thanks to improvements in hydraulic fracturing technology, or “fracking”, which uses large amounts of compressed water, sand and a small amount of chemicals to free natural gas from its geophysical reservoirs. Over the past decade, U.S. energy companies have leveraged “fracking” to increase domestic unconventional gas production from 1 percent of all gas extracted in 2001 to over 20 percent today. By 2035, almost half of all U.S. natural gas output is projected to come from shale. With shale deposits distributed generously worldwide, Europe is beginning to catch the trailing edge of this game-changing moment in global energy production. Today the European Union is engaged in a crucial debate over whether and how to tap into its own shale deposits, which contain more than 17.5 trillion cubic meters (and with the recent discovery of a new major deposit in the United Kingdom, possibly as much as 22 trillion).

Aims & Research Methods: This article reviews Poland’s shale gas reserves and the hydraulic fracturing methods needed to release gas in reserves.

Conclusions: Shale gas exploration in Poland has entered a decisive stage. The next 18 months will determine whether energy companies will prove able to demonstrate the presence of sufficient gas in their exploratory wells, clearing the way for the production phase. The first-yield assessments of the wells are projected to come in mid- 2012, a few short months away. Ten years ago the United States energy industry began to redefine the country’s energy equation by investing heavily in shale gas production back home. Though sceptics initially dismissed U.S. efforts as either quixotic or unimportant, the ripple effect of those decisions is now being felt across the globe, shaking up conventional assumptions about energy sources and growth prospects and ultimately holding the potential to redefine power relationships among major states. Today, with unconventional gas deposits widely available not only in North America and Europe but worldwide, and with the demand for cheap energy to feed the emerging markets’ explosive growth unabated, the global energy game is changing faster than many thought possible only a decade ago. A shale storm is brewing; best be prepared when it hits.

Citation: Marek Nawalany, *Surface Waters and Groundwater in Poland- Challenge to Improve the Status and Capacity of Water Resources of Poland* (2012)

Topic Area: Water Use and Distribution

Jurisdiction: Poland

Aims & Research Methods: This presentation examines water use and the water strategy of surface and groundwater in Poland.

Conclusions:

1.Water policy at the national level will be

planned coherently with the National Development Plans

checked against international agreements(e.g. *Water Framework Directive*)

created and coordinated by KZGW(*National Board of Water Management*; to be created soon, hopefully) via legal means and financial mechanisms -Sectorial and Regional Operational Programmes

enhanced through introduction of a legal framework for Private-Public Partnership(PPP*)*

2.Water policy at the regional level will be

executed coherently with the Regional Development Plans

financially supported by the *EC Programmes*e.g. Cohesion Program, Framework Programs FP7,... programmes related to the Technology Platforms (e.g. WSSTP) and PPP(if introduced)

coordinated, monitored and executed by RZGWthrough legal means and financial mechanisms ofSectorialand Regional Operational Programmes

3.Water policy at the regional level requires

changes in law allowing for non-conflicting collaboration of State and Self-governing Administrations on water policies

creation and empowering of KZGW(*National Board of Water Management*)

recognizing crucial role of RZGW in within the water region by both administrations

4. Capacity of water resources in Poland cannot be increased substantially due to natural constraints however the status and the effective use of water resources can be enhanced/improved by introducing structural changes and taking actions.

5.To this end, water related plans, programs and private, national and European sources of financing are indispensable and welcome.

Citation: Philippe and Partners, *Final Report on Unconventional Gas in Europe* (November 2011)

Topic Area: Unconventional Gas Regulation

Jurisdiction: EU

Introduction: Firstly, this analysis is based on a survey of relevant national laws and regulations. For performing this survey, we prepared a legal questionnaire to the attention of national correspondents in the four Member States.

Secondly, this analysis is based on structured interviews with companies and public authorities.

Aims & Research Methods: The European Commission (the "Commission") selected the Brussels-based law firm Philippe & Partners to carry out the study "*EC TENDER TREN/R1/350-2008 lot 1 on Unconventional Gas in Europe*" (the "Study"). The main purpose of the Study is to analyse how the relevant applicable European legal framework, including environmental law, is applied to the licensing/authorisation and operational permitting for prospection, exploration and production/exploitation of shale gas based on a sample of four Member States, i.e. Poland, France, Germany1 and Sweden.2 It is, however, not purpose of the study to assess whether Member State legislation based on EU legislation has been properly transposed.

This study focuses on shale gas exploration, because shale gas is the type of unconventional gas most discussed and contentious currently. Also, compared to tight gas and coal bed methane, relatively less experience exists in Europe for shale formations as new source of natural gas. The focus on exploration is due to the stage of projects in Europe. No commercial scale shale gas exploitation has taken place yet and it is only expected in a few years' time. Nevertheless, this study also takes into account a possible future production phase and especially analyses legal issues especially related to the transfer from exploration to production stage.

2. As regards areas of law to be studied, the focus is the "core" licensing and permitting process. Given the importance of environmental law in the area of shale gas exploration and production, it is included as an integral part of the study. However, within the scope of this study it is not possible to perform a thorough assessment of the appropriateness of the EU environmental legislation. Nevertheless, the present report describes and analyses EU environmental legislation which was assumed to be of most relevance for shale gas projects,3 especially as regards its interface with the "core" licensing and permitting processes. Thereby it contributes to further efforts to assess the appropriateness of the EU legal framework especially with a view to a future production phase and the challenge to ensure a high level of protection for the environment and public health while enabling shale gas production in Europe, which would be beneficial from a security of supply point of view.

3. The present study does not address issues such as access rights to the gas infrastructure/network or other competition issues.

Conclusions: From our point of view an adequate regulatory framework for early exploration (seismic/test drilling) activities exists taking into account all scrutinised laws and regulations. 324. The activities relating to exploration/exploitation of shale gas are already subject to EU and national laws and regulations, e.g.:

- The grant of authorisations for exploration/production is covered by the Hydrocarbons Directive;

- Water protection is covered by the Water Framework Directive the Groundwater

Directive and (regulating a potential source of water contamination) the Mining Waste Directive;

- The use of chemicals is covered by REACH and administered by the ECHA;

- Protection of Nature 2000 areas for the sake of safeguarding biodiversity within the EU is regulated by the Habitats Directive and the Wild Birds Directive;

- The requirement of an E.I.A. as well as public access to environmental information is laid down by general environmental legislation (the E.I.A.-Directive and European legislation implementing the Aarhus-Convention);

- Operators may be subject to liability for damages under the Environmental Liability Directive and the Mining Waste Directive. Most of these Directives have been implemented into the national law of the scrutinised Member States. In the rare case of non-implementation, other national regulations exist governing the concerned activity and/or transposition is imminent. As mentioned above, most of the relevant EU regulations use flexible mechanisms (see e.g. E.I.A. Directive), allowing the Member States to adjust their legislation to regional or local specifics of shale gas exploration and potentially exploitation. Neither on the European level nor on the national level have we noticed significant gaps in the current legislative framework, when it comes to regulating the current level of shale gas activities. However, this is no reason for complacency, since this assessment explicitly refers to the current level of experience and scale of operations as can be expected during the exploration phase. As the US example indicates, commercial scale shale gas exploitation would involve operations on much larger scale. Especially, related potential cumulative impacts need to be further investigated to provide a basis for a more thorough assessment of the appropriateness of the regulatory framework(s) – both on EU as well as on Member State and/or regional level.

However, as we will see it below, some adjustments to legislation should be further considered in order to improve its appropriateness and practicability with a view of regulating shale gas activities.

325. In some of the scrutinised Member States, legal uncertainty surrounds the regulation on shale gas activities. In North Rhine Westphalia, as well as on the federal German level, studies on the impact of shale gas activities are pending. In North Rhine Westphalia, companies cannot proceed with their activities, as long as the outcome of the study is not known. In France, an act has been adopted prohibiting all exploration activities by means of hydraulic fracturing, until the impact of hydraulic fracturing on public and environment is properly being assessed. This Prohibition Act is problematic from a legal and from a practical point of view. Since it has resulted in the announced abrogation of three shale gas authorisations, it may be seen as a serious threat to a reasonable legal security investors might expect from an authorisation granted legally by an administrative authority. Moreover, the

notion of hydraulic fracturing has not been defined properly, leaving the door open for different interpretations. Pending studies in Germany as well as the French Prohibition Act with a questionable rationale have a negative impact on ongoing and future investments of companies being or willing to be involved in shale gas activities.

326. Legislation may need to be more adjusted to the way in which a shale gas project develops. Often, exploration projects start on a very small scale, without a relatively low potential impact on environment and public in the concerned areas. However, if exploration results appear to be positive, the dimensions of such a project can develop into larger scale operations with a higher potential impact on environment and public in the concerned areas. Our analysis reveals that this change in dimensions is not always dealt with in the most appropriate way. In most scrutinised Member States, neither an E.I.A.-assessment nor consultation of the public (mostly in the framework of an E.I.A.) is required for starting exploration activities. This may be due to the fact that the existing explicit E.I.A.-thresholds are not met by the exploration activities. At the moment where the project is still small scale and thus easy "reversible", consultation of the concerned public is not necessarily foreseen and hence has no say in the decision to allow/refuse its start. It is exactly at this stage that public participation is required the most. Informing the public by means of publications in Official Journals or local newspapers has a limited effect, if the reactions thereon cannot be taken into account in the procedures leading to the grant of authorisations and/or permits.

327. We have noticed that Member States as Germany and France are aware of this weakness in their national legal framework. As we are finalising this report, they are undertaking actions to remedy this lack of public consultation and E.I.A. for exploration activities. In France, inclusion of a public participation mechanism in the procedure leading to the grant of an exploration authorisation is being considered in the framework of the restructuration of the Mining Code. In Germany, the Land of North Rhine Westphalia has filed a motion to make the E.I.A.-requirement compulsory for all hydrocarbon activities involving hydraulic fracturing. Regardless the explicit thresholds foreseen in the E.I.A.-Directive, Member States have all the means to adjust E.I.A. requirements according to their needs.

328. However, a discussion on an appropriate application of the instrument of Environmental Impact Assessment should not be limited to the issue of thresholds. Sweden and Poland already have a more flexible regime in place. Instead of a rigid system oriented on thresholds according to Annex I of the E.I.A.-Directive only (i.e. the 500k m3/day threshold), Poland also uses the "screening procedure" according to annexes II and III of the E.I.A.-Directive to decide on a case by- case basis. In Sweden the possibility for local governments to demand an E.I.A. can contribute to improved local acceptance of projects.

329. As it appears many times in this report, exploration/exploitation of shale gas activities requires the regulation of numerous aspects e.g. in the field of environment, chemicals, civil law, law on worker's health and safety. This leads to the situation where a diversified regulatory framework, requiring the involvement of different authorities, is applicable to shale gas activities. In order to lower the burden on the operators and the involved authorities as well as to ensure a coherent procedure, the core authorisation and permitting procedures on the one hand and the environmental procedures and other permitting procedures on the other hand could be more integrated, as is already the case in Germany and Sweden. Such an integrated approach can take the form of holistic procedures wherein a limited number of authorities deal with all hydrocarbon-related activities, and not several independent authorities treating the different issues separately. Such an overall approach also can be realised by means of a coordination mechanism, allowing different authorities to keep their

competences. They then would have to submit their analysis to one coordinating authority who takes into account these different assessments for deciding upon the grant of an authorisation and/or a permit (cf. one-stop-shop, as is the case in Germany). Such an approach has its pros and cons for companies. On the one hand, they would not have to deal with different authorities with potentially contradicting verdicts. On the other hand a more fragmented administrative structure may increase their influence on the permitting procedure by assuming a kind of coordination role between the different involved authorities. This could be of benefit to companies, especially if they have an advantage as regards knowledge on shale gas projects compared to the public authorities. The ideal scenario would consist of a combination of the best of both worlds. Highly specialised organisations, having their own competence and making their own analysis, who will then be submitted to a coordinating body taking into account these detailed assessment in the core procedure and are then responsible to grant (or refuse) the authorisation and/or permit. It is also advisable to have in this coordinating organ, civil servants who specialised in the field of shale gas and to provide appropriate training.

Citation: UK Government, *Environmental legislation applicable to the onshore hydrocarbon industry (England, Scotland and Wales)* (2012)

Topic Area: Environmental Laws

Jurisdiction: UK

Aims & Research Methods: This table outlines EC Legislation, Associated UK Legislation, Main Requirements and Regulator in the hydrocarbon industry of the UK.

Citation: EIA/ARI World Shale Gas and Shale Oil Resource Assessment, *Poland* (2012)

Topic Area: Resource Assessments

Jurisdiction: Poland

Introduction: Poland has some of Europe's most favourable infrastructure and public support for shale development. The Baltic Basin in northern Poland remains the most prospective region with a relatively simple structural setting. The Podlasie and Lublin basins also have potential but are structurally complex, with closely spaced faults which may limit horizontal shale drilling. A fourth area, the Fore-Sudetic Monocline in southwest Poland, is less recognized but has non-marine coaly shale potential similar to Australia's Cooper Basin.

Aims & Research Methods: With an established onshore conventional oil and gas production industry as well as recent experience with coal bed methane exploration, Poland offers Europe's best prospects for developing a viable shale gas/oil industry. Shale leasing and development in Poland began in 2007 when the Ministry of Environment implemented highly favourable policies for shale gas development, including a simple tax and royalty fiscal system.

The current investment terms for shale gas development include a 1,200-km2 maximum block size, minimal signature fees of 50 Euros/block, freedom from mandatory government back-in rights, and reduced production royalties of \$0.06/Mcf and \$1.60/bbl. The typical shale contract comprises an initial 5-year exploration period, which can be extended, followed by a 30-year production period. Industry's response has been strong: over 100 shale gas exploration licenses have been awarded, covering more than 35,000 km2, no less than one-third of the country's area.

However, more recently the government is discussing modifications to the shale fiscal terms which may increase profit taxes on shale gas production to 40% or more, while establishing a government-owned entity to gain a minority equity stake in shale gas development projects. These changes, if implemented, could significantly reduce industry investment in shale exploration at a time of disillusionment with early well results.

The initial results from some 30 vertical and two horizontal shale wells have been less successful than hoped. Production rates and reservoir quality have been lower than expected, with one operator testing ~4% porosity and ~40% clay content in several wells. Hydraulic fracturing operations to stimulate production from the shale also have been sub-par. However, as exploration continues, operators may successfully identify the geologic sweet spots, while service companies are likely to improve their implementation of North American drilling and stimulation technology.

Citation: AEA, *Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe* (August 2012)

Topic Area: Hydraulic fracturing activities

Jurisdiction: EU

Introduction: Exploration and production of natural gas and oil within Europe has in the past been mainly focused on conventional resources that are readily available and relatively easy to develop. This type of fuel is typically found in sandstone, siltstone and limestone reservoirs. Conventional extraction enables oil or gas to flow readily into boreholes.

As opportunities for this type of domestic extraction are becoming increasingly limited to meet demand, EU countries are now turning to exploring unconventional natural gas resources, such as coal bed methane, tight gas and in particular shale gas. These are termed 'unconventional' resources because the porosity, permeability, fluid trapping mechanism, or other characteristics of the reservoir or rock formation from which the gas is extracted differ greatly from conventional sandstone and carbonate reservoirs.

In order to extract these unconventional gases, the characteristics of the reservoir need to be altered using techniques such as hydraulic fracturing. In particular high volume hydraulic fracturing has not been used to any great extent within Europe for hydrocarbon extraction. Its use has been limited to lower volume fracturing of some tight gas and conventional reservoirs in the southern part of the North Sea and in onshore Germany, the Netherlands, Denmark and the UK.

Preliminary indications are that extensive shale gas resources are present in Europe (although this would need to be confirmed by exploratory drilling). To date, it appears that only Poland and the UK have performed high-volume hydraulic fracturing for shale gas extraction (at one well in the UK and six wells in Poland); however, a considerable number of Member States have expressed interest in developing shale gas resources. Those already active in this area include Poland, Germany, the Netherlands, the UK, Spain, Romania, Lithuania, Denmark, Sweden and Hungary.

Aims & Research Methods: This report sets out the key environmental and health risk issues associated with the potential development and growth of high volume hydraulic fracturing in Europe. The study focused on the net incremental impacts and risks that could result from the possible growth in use of these techniques. This addresses the impacts and risks over and above those already addressed in regulation of conventional gas exploration and extraction. The study distinguishes shale gas associated practices and activities from conventional ones that already take place in Europe, and identifies the potential environmental issues which have not previously been encountered, or which could be expected to present more significant challenges.

The study reviewed available information on a range of potential risks and impacts of high volume hydraulic fracturing. The study concentrated on the direct impacts of hydraulic fracturing and associated activities such as transportation and wastewater management. The study did not address secondary or indirect impacts such as those associated with materials extraction (stone, gravel etc.) and energy use related to road, infrastructure and well pad construction.

The study has drawn mainly on experience from North America, where hydraulic fracturing has been increasingly widely practised since early in the 2000s. The views of regulators, geological surveys and academics in Europe and North America were sought. Where possible, the results have been set in the European regulatory and technical context.

The study includes a review of the efficiency and effectiveness of current EU legislation relating to shale gas exploration and production and the degree to which the current EU framework adequately covers the impacts and risks identified. It also includes a review of risk management measures.

Conclusions: It is recommended that consideration is given to research recommendations made by SEAB (2011a NPR) which would be relevant to hydraulic fracturing in Europe:

- The use of micro-seismic monitoring in relation to hydraulic fracturing

- Determination of the chemical interactions between fracturing fluids and different shale rocks

- Induced seismicity triggered by hydraulic fracturing

- Development of less environmentally hazardous drilling and fracturing fluids

- Development of improved casing and cementing methods.

It is recommended that a readily accessible database on hydraulic fracturing fluid composition is developed for European high volume hydraulic fracturing projects (developing a recommendation presented to the European Parliament, Lechtenböhmer et al., 2011 NPR p61). To be valuable, completion of the database would need to be a requirement for all high volume hydraulic fracturing activities, and it should be fully searchable by geographic location and by chemical species/additive name. This would be useful for regulators and would also be of interest to researchers and local communities.

The SEAB (2011a NPR p20) recommends that research should be carried out into the risks and causes of methane migration into groundwater from shale gas extraction. This was supported by an academic consultee, who also recommended research into the potential health effects of chronic exposure to methane via ingestion (Academic sector consultation response 2012 NPR).

Further consideration and research pertain to the long-term fate of hydraulic fracturing fluid remaining in the shale gas formation during the production and post-closure phases, for instance in relation to provisions of the Carbon Capture and Storage Directive (2009/31/EC).

Based on the discussion of potential impacts of high volume hydraulic fracturing in Chapter 2, further research is recommended into the potential for increased risk of methane migration to groundwater with air drilling compared to drilling using liquid muds. It is recommended that further research is carried out into well cementing methods and practices for HVHF. It is recommended that further research is carried out into the risks which could not be classified based on the available information:

- Potential impacts on biodiversity due to cumulative development in the European context
- Frequency of surface spillages during hydraulic fracturing
- Potential frequency and significance of road accidents involving trucks carrying hazardous substances in support of HVHF operations
- Noise impacts due to flaring, and associated controls
- Risks of groundwater contamination following abandonment
- Land take following abandonment
- Risks to biodiversity following abandonment

It is recommended that further research is carried out to improve the viability of techniques for recycling of wastewater, to ensure that wastewater recycling can be applied in Europe, and to enable a higher proportion of wastewater to be recycled in this way.

The Pennsylvania Governor's Marcellus Shale Advisory Commission recommended the development of voluntary ecological initiatives within critical habitats that would generate mitigation credits which are eligible for use to offset future development. It is recommended that the applicability of similar initiatives in Europe should be investigated.

Citation: Baker and McKenzie, *Shale Gas—Global Environmental Law and Regulation* (February 2013)

Topic Area: Environmental Regulation of Shale Gas

Jurisdiction: Global

Introduction: The shale gas production boom contributed to a significantly larger natural gas inventory and lower natural gas prices across the United States in 2012. According to the US Energy Information Agency, the average wholesale natural gas price fell by almost a third last year and total dry natural gas production for the Lower 48 states rose to an average of

63.6 billion cubic feet per day.1 While these developments are having significant effects across the domestic energy, manufacturing and transport sectors, the federal government is still struggling to get its bearings creating uncertainty about the specter of federal regulation.

Last year, the Environmental Protection Agency ("EPA") and the Department of the Interior ("DOI") developed the first federal rules to deal specifically with hydraulic fracturing operations, and then promptly pulled the rules back for further review in the first month of 2013, after industry strongly opposed the new regulatory programs. In addition to EPA's announced massive, multi-year study on the impacts of hydraulic fracturing on drinking water—which still appears to be idling somewhere just past its initial scoping stage—EPA, DOI and the Department of Energy ("DOE") are now leading a federal inter-agency effort to conduct "policy relevant" research on shale gas development. Federal agencies remain in an information gathering phase, with respect to both the potential environmental impacts of new drilling methods, as well as their own statutory authority to regulate in this area. EPA, in particular, has been beset by petitions for rulemaking under existing environmental statutes, and has now granted a petition committing the Agency to develop rules requiring disclosure related to fracturing fluid additives under the Toxic Substances Control Act ("TSCA").

The increase in shale gas production has also created an opportunity for increasing US exports of liquefied natural gas ("LNG"). Fifteen applications for LNG export approvals to non-Free Trade Agreement countries are currently pending before DOE. As part of the required environmental review of these applications under the National Environmental Policy Act ("NEPA"), the Sierra Club, and more recently, EPA, have commented that "programmatic" environmental impact statements ("EIS") should be conducted in order to consider the cumulative environmental effects of all of the pending export proposals, as well as the indirect, upstream impacts associated with potential related increases in natural gas production (discussed further below).

As natural gas increasingly becomes a primary fuel for power generation and industrial operations, as well as an option for transport applications in the US, demands for improved data, lifecycle analyses and programmatic EISs on the fuel, will similarly rise. The state of New York's programmatic EIS on hydraulic fracturing—now nearing its 4th year without completion—is one example of this process at the state level. Likewise, the expanding federal inter-agency research agenda on hydraulic fracturing is taking on the characteristics of a programmatic EIS on the drilling method.

Companies with on-the-ground technical expertise on the various aspects of natural gas production may wish to consider engaging in the discussion and study of shale gas production lifecycle impacts. Lifecycle impacts attributed to shale gas could serve as the basis for further regulation of the industry, or be used as data inputs for other environmental policies such as fuel standards, or even a potential national Clean Energy Standard, that focus on comparing and contrasting lower carbon fuel choices.

Aims & Research Methods: This newsletter outlines key environmental regulatory and litigation issues impacting the shale oil and gas and hydraulic fracturing industry around the world.

Citation: Janez Potocnik, Note for the Attention of Mr Matthias Groote, Chair of the Envi Committee, European Parliament (January 2012)

Topic Area: Environmental Regulation applicable to Shale Gas Projects

Jurisdiction: EU

Aims & Research Methods: The exploration and exploitation of unconventional hydrocarbons, notably shale gas, is an emerging topical issue for Europe. These projects use advanced technologies such as horizontal drilling and high volume hydraulic fracturing.

Although such projects are still at the phase of exploration and some years away from commercial production, hydraulic fracturing is taking place at present, attracting increasing attention from media and stakeholders. In this context, several Members of the European Parliament have addressed questions to the European Commission concerning the applicable EU environmental legislation in this field.

To this end, the present note aims to inform you as well as the members of your committee about the EU environmental legal framework applicable to the above projects, and to provide the European Commission's views regarding the correct interpretation of that legal framework. The enclosed technical and legal papers serve only for clarification purposes and do not create any new rules of law.

Conclusions: The European Commission's preliminary analysis, based on the available technical information, suggests that interactions of the above processes with environmental media are likely to be complex and cross-cutting in nature. Of concern are potential risks related notably to surface and groundwater, the use of chemicals, waste management practices, as well as impacts to land, biodiversity and air quality.

Citation: European Parliament, Directorate-General for Internal Policies, *Policy Department Economic and Scientific Policy* (2011)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: EU

Introduction: This study gives a survey of unconventional hydrocarbon activities and their potential environmental impacts. The focus is on future activities in the European Union. The assessments of this study concentrate predominantly on shale gas, briefly touching shale oil and tight oil. The first chapter gives a short survey of the characteristics of production technologies, mainly the process of hydraulic fracturing. This is followed by a brief review of experiences from the USA as this is the only country where hydraulic fracturing has been applied increasingly at large scale since many decades.

The second chapter concentrates on the evaluation of greenhouse gas emissions associated with natural gas produced with hydraulic fracturing methods. Existing assessments are reviewed and extended by an own analysis.

The third chapter reviews the legislative framework at EU level relevant for hydraulic fracturing. After reviewing the legislative framework covering mining laws, the focus lies on directives protecting the environment and human health. The legislative deficits concerning the potential environmental impacts of hydraulic fracturing are outlined and discussed.

The fourth chapter gives resource assessments and discusses the possible impact of shale gas extraction on European gas supply. For that reason experiences from US shale gas production are analysed and the common characteristics of production profiles are used to sketch a typical shale development. Concerning European gas production and demand, the probable role of shale gas extraction is discussed in relation to present production and supply with extrapolations to the next decades.

The final chapter draws conclusions and gives recommendations on how to deal with the specific risks of hydraulic fracturing.

Aims & Research Methods: This study discusses the possible impacts of hydraulic fracturing on the environment and on human health. Quantitative data and qualitative impacts are taken from US experience since shale gas extraction in Europe still is in its infancy, while the USA have more than 40 years of experience already having drilled more than 50,000 wells. Greenhouse gas emissions are also assessed based on a critical review of existing literature and own calculations. European legislation is reviewed with respect to hydraulic fracturing activities and recommendations for further work are given. The potential gas resources and future availability of shale gas is discussed in face of the present conventional gas supply and its probable future development.

Conclusions: At a time when sustainability is key to future operations it can be questioned whether the injection of toxic chemicals in the underground should be allowed, or whether it should be banned as such a practice would restrict or exclude any later use of the contaminated layer (e.g. for geothermal purposes) and as long-term effects are not investigated. In an active shale gas extraction area, about 0.1-0.5 litres of chemicals are injected per square metre. This holds even more as the potential shale gas plays are too small to have a substantial impact on the European gas supply situation. The present privileges of oil and gas exploration and extraction should be reassessed in view of the fact that the environmental risks and burdens are not compensated for by a corresponding potential benefit as the specific gas production is very low.

RECOMMENDATIONS

- There is no comprehensive directive providing for a European mining law. A publicly available, comprehensive and detailed analysis of the European regulatory framework concerning shale gas and tight oil extraction is not available and should be developed.

- The current EU regulatory framework concerning hydraulic fracturing, which is the core element in shale gas and tight oil extraction, has a number of gaps. Most importantly, the threshold for Environmental Impact Assessments to be carried out on hydraulic fracturing activities in hydrocarbon extraction is set far above any potential industrial activities of this kind, and thus should be lowered substantially.

- The coverage of the water framework Directive should be re-assessed with special focus on fracturing activities and their possible impacts on surface water.

- In the framework of a Life Cycle Analysis (LCA), a thorough cost/benefit analysis

could be a tool to assess the overall benefits for society and its citizens. A harmonized approach to be applied throughout EU27 should be developed, based on which responsible authorities can perform their LCA assessments and discuss them with the public.

- It should be assessed whether the use of toxic chemicals for injection should be banned in general. At least, all chemicals to be used should be disclosed publicly, the number of allowed chemicals should be restricted and its use should be monitored. Statistics about the injected quantities and number of projects should be collected at European level.

 Regional authorities should be strengthened to take decisions on the permission of projects which involve hydraulic fracturing. Public participation and LCA assessments should be mandatory in finding these decisions.

 Where project permits are granted, the monitoring of surface water flows and air emissions should be mandatory.

 Statistics on accidents and complaints should be collected and analysed at European level. Where projects are permitted, an independent authority should collect and review complaints.

 Because of the complex nature of possible impacts and risks to the environment and to human health of hydraulic fracturing consideration should be given to developing a new directive at European level regulating all issues in this area comprehensively.

Citation: European Commission, *Statement on the use of hydraulic fracturing ("fracking") in the European Union* (November 2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: EU

Introduction: Hydraulic fracturing has taken place in Europe, especially in the context of tight gas production and in offshore projects, mostly in vertical wells as well as in the framework of shale gas exploration projects in a few Member States. Two Member States have prohibited the use of hydraulic fracturing practices for hydrocarbons exploration and exploitation (Bulgaria, France) and some have set up temporary moratoria (e.g. the Netherlands). A number of Member States have initiated, or are about to initiate reviews of the appropriateness of their national legislation (e.g. Denmark). The European Commission takes note of the concerns and views expressed by many of you with regard to potential climate and environmental risks related to hydraulic fracturing activities.

Aims & Research Methods: Under the current EU legal framework, it is up to the Member States to ensure, via appropriate assessment, licensing, permitting as well as monitoring and inspection regimes, that individual hydrocarbons projects (including those using hydraulic fracturing practices) comply with EU's legislation. This includes, *inter alia*, provisions on the protection of health and the safety of humans and environment pertaining notably to the completion of environmental impact assessments, the protection of surface and groundwater, the management of waste from extractive industries, the registration, evaluation and authorisation of chemicals as well as to environmentally protected areas.

Conclusions: But the European Commission obviously has to ensure that EU environmental rules are adequate for this relatively new activity of "fracking". That is why it has set up (in 2012) a technical working group of Member States on environmental aspects of unconventional fossil fuels to exchange information about project developments, potential environmental risks and applicable technical and regulatory practices. More information on: http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetail&groupID =2671 At the beginning of September 2012 the Commission published three new studies on unconventional fossil fuels, in particular shale gas. The studies look at the potential effects of these fuels on energy markets, the potential climate impact of shale gas production, and the potential risks shale gas developments and associated hydraulic fracturing may present to human health and the environment. More information on: http://ec.europa.eu/environment/integration/energy/unconventional_en.ht. In the meantime, we have initiated work to propose before the end of 2013 an adequate risk management framework for unconventional fossil fuels, in particular shale gas developments in Europe. We are currently assessing what form such framework should take. See http://ec.europa.eu/atwork/pdf/forthcoming_cwp_initiatives_2013_en.pdf (item n°41). Regarding requests that the Commission intervenes in order to stop shale gas activities, the Commission is not endowed with such competence. Nor can it decide on an EU-wide moratorium.

Citation: CMS, CMS Shale Gas update – *UK, Algeria, Argentina, Canada, China, India, Poland, South Africa, Ukraine and USA* (2012)

Topic Area: Shale Gas Practices

Jurisdiction: Global

Aims & Research Methods: This report provides an update on shale gas practices, including hydraulic fracturing in the UK, Algeria, Argentina, Canada, China, India, Poland, South Africa, Ukraine and USA.

Citation: DAFF, *National Food Plan Green Paper 2012* (2012)

Topic Area: National Food Policy

Jurisdiction: Australia

Introduction: Australia's food system is complex and diverse. A National Food Plan will establish an integrated approach to food-related policies and programs for the benefit of food businesses and consumers and underpin the vision of Australia being a reliable, sustainable, productive and resilient supplier of nutritious and affordable food. Australia has one of the best food systems in the world. Our current policies, programs and regulations affecting the food system broadly deliver a good mix of economic, environmental and social benefits for the Australian community. However, there is room for improvement. Strengthening these arrangements through the development of the National Food Plan will help Australia's food system respond to new opportunities and challenges. The Australian Government is currently progressing major reforms directly related to food in the areas of nutrition, biosecurity, water, drought preparedness and agricultural chemical use. The National Food Plan will build on these reforms. There are also a number of other policy processes under way including the White Paper on Australia in the Asian Century, the Prime Minister's Taskforce on Manufacturing, the Food Processing Industry Strategy Group and the Parliamentary Working Group on Water, Soil and Food. These will inform and complement the National Food Plan and ensure Australia's food system remains a focus for government decision-making, now and in the future.

Aims & Research Methods: Australia's food system is being shaped by global and local forces such as world population growth, changes in consumption preferences, different economic growth rates among countries, climate change, limits to natural resources, and rising health issues due to poor dietary intake. Over the coming decades these forces will provide significant opportunities but also present some challenges for businesses involved in producing, moving and selling food—and for all of us as food consumers. Australia has a strong, safe and stable food system and Australians enjoy high levels of food security. Australia currently produces far more food than it consumes. We also have the capacity to increase food production in response to market signals and take advantage of growing markets in Asia. Australia is well placed to take advantage of these opportunities because of our key strengths that include our proximity to emerging markets in Asia; our abundance of productive land; a largely pest-and-disease-free biosecurity status; a record of rural innovation; and a skilled and capable workforce.

Conclusions: The National Food Plan's key outcome is to ensure Australia has: *a sustainable, globally competitive, resilient food supply, supporting access to nutritious and affordable food.* To achieve this outcome the Australian Government intends to focus its efforts on seven objectives:

1. Support the global competitiveness and productivity growth of the food supply chain, including through research, science and innovation.

2. Reduce barriers food businesses face in accessing international and domestic markets.

3. Contribute to economic prosperity, employment and community wellbeing in regional Australia.

4. Identify and mitigate potential risks to Australia's food security.

5. Maintain and improve the natural resource base underpinning food production in Australia.

6. Reduce barriers to a safe and nutritious food supply that responds to the evolving preferences and needs of all Australians and supports population health.

7. Contribute to global food security. The green paper has been developed around these seven objectives to explain current policies and to help identify potential policy gaps and possible actions the government might take. It takes into account feedback received from hundreds of stakeholders in response to the *Issues paper to inform development of the national food plan*.

Citation: DECC, *Shale Gas Background Note* (2012)

Topic Area: Shale Gas

Jurisdiction: Global

Introduction: Shale is a sedimentary rock that is predominantly comprised of very fine-grained clay particles deposited in a thinly laminated texture. These rocks were originally deposited as mud in low energy depositional environments, such as tidal flats and swamps, where the clay particles fall out of suspension. During the formation of these sediments, organic matter is also deposited, which is measured when quoting the Total Organic Content (TOC). Deep burial of this mud results in a layered rock called "Shale", which actually describes the very fine grains and laminar nature of the sediment, not rock composition, which can therefore differ significantly between shales.

Aims & Research Methods: This factsheet has been prepared for DECC by Dr C. Green of G Frac Technologies Ltd to assist understanding by non-specialists of the independent experts' report about the induced seismicity during hydraulic fracturing at the Preese Hall site, Lancashire, NW England.

Scope: This fact sheet provides information relating to, hydraulic fracturing, unconventional gas and well design.

Citation: Timothy Consdidine, Robert Watson, Nicholas Considine and John Martin, *Environmental Impacts during Marcellus Shale Gas Drilling: Causes, Impacts, and Remedies* (2012)

Topic Area: Drilling Activities

Jurisdiction: USA

Introduction: The development of shale gas through hydraulic fracturing has awakened what some have described as an American energy renaissance. Shale gas formations thought to be economically unrecoverable as recently as a decade ago now provide nearly 25 percent of our nation's total natural gas supply. According to the Energy Information Administration's reference case forecast of April 2011, natural gas production from shale formations will comprise 46.5 percent of total U.S. dry gas production in 2035. The investments under way for developing these shale resources are generating tens of thousands of jobs, billions in state and local tax revenues, and hundreds of billions in direct economic activity. Indirect benefits to oil and gas suppliers, to U.S. manufacturers that utilize natural gas as a feedstock, and to consumers enjoying lower electricity and heating bills multiply the already substantial direct economic gains. In short, the incentives for states to encourage and facilitate development are substantial.

Aims & Research Methods: But surprisingly little comprehensive analysis exists to quantify the success or failure of states in effectively and safely managing natural gas development. Without such information, it is very difficult for regulators, elected officials, and citizens to engage in productive dialogue around natural gas development and the process of hydraulic fracturing. Whether considering regulatory changes in a state where development is already under way, or debating the permitting of natural gas development where it has not yet occurred, quantifying measurements of success are necessary for building consensus and making sound decisions. To address this question, this study provides a detailed analysis of notices of violations (NOVs) from the Pennsylvania Department of Environmental Protection (PA DEP) from January 2008 through August 2011, categorizing each violation. Of the 2,988 violations, 1,844, or 62 percent, were for administrative or preventative reasons. The remaining 38 percent, or 1,144 NOVs, were for environmental violations. The number of these environmental violations, however, is a misleading metric because an individual event may be associated with multiple environmental violations. As such, the 845 unique environmental events considered in this study were associated with 1,144 NOVs. To produce an accurate accounting of the environmental impacts of these 845 unique events, this study defines major and non-major environmental events through a detailed examination of NOV records. Major environmental events are defined in this study to include major site restoration failures, serious contamination of local water supplies, major land spills, blowouts and venting, and gas migration. Our evaluation of NOV records identified 25 such events. In all but six cases, the resulting environmental impacts from major events have been mitigated.

Non-major environmental events concern site restoration, water contamination, land spills, and cement and casing events that do not involve what is classified as having major environmental impact. Many of the NOVs in this category, while resulting in measurable pollution, were rather minor, involving, for example, a gallon of diesel fuel or antifreeze spilled on the ground. The 820 non-major events identified, comprise the overwhelming majority of environmental NOV's issued by the PA DEP, as shown in figure ES 1. Significantly, the incidence of polluting environmental events declined 60 percent between 2008 and August 2011, from 52.9 percent of all wells drilled in 2008 to 20.8 percent through August 2011 (Figure ES2). On this basis, the Marcellus industry has cut its incidence of environmental violations by more than half in three years, a rather notable indicator of improvement by the industry and oversight by the regulators.

Conclusions: Since 2008, more than 3,533 Marcellus wells have been drilled in Pennsylvania from more than 100 drilling rigs. This study assesses the effectiveness of the state's regulations in mitigating environmental impacts associated with the development of Marcellus Shale in Pennsylvania by surveying records of notices of violations from the Pennsylvania Department of Environmental Protection (PA DEP) from January 2008 through August 2011. The major findings are as follows:

• Of the 2,988 notices of environmental violations (NOVs), the majority (62 percent) are administrative violations or violations issued to prevent pollution from occurring. The remaining citations (38 percent) were in response to an event that impacted the surrounding environment.

• Of the 845 incidents that caused measurable amounts of pollution, 820 were classified as non-major, and only 25 involved major impacts to air, water, and land resources. This implies that over the 44 months surveyed, there was a [0.7 percent] probability of a major environmental event.

• Of the 25 problematic incidents that involved major environmental impacts, six cases did not have their environmental impacts completely mitigated.

• Both the number of environmental violations and subsequent environmental events that caused some physical impact on the environment steadily declined over the past four years, in conjunction with action by state regulators. Notably, the percentage of wells resulting in a major environmental event declined significantly; an indicator that the attention of regulators was focused on the areas of greatest concern. The foregoing suggests that surface activity, rather than the drilling or development process itself, remains the greatest ongoing risk. The findings are significant as they illustrate how the PA DEP has been able to effectively manage the brisk pace of unconventional gas development, while preserving the economic opportunity that development has afforded the community. Pennsylvania provides a strong metric to gauge the regulatory proposal being proposed for New York State. Our research classifying the 25 major events that occurred in Pennsylvania with the 2011 New York SGEIS guidelines demonstrates that each of these specific events would be avoided or mitigated under New York State's regulatory framework currently in place.

Citation: GEAS, *Thematic Focus: Resource Efficiency, Harmful Substances and Hazardous Waste* (November 2012)

Topic Area: Hydrological fracturing techniques

Jurisdiction: Global

Introduction: Hydrological fracturing techniques have made accessible vast unconventional gas reserves. However, observed impacts on the environment and human health raise legitimate public concerns. The potential climate benefits of coal-to-gas substitution are both less clear and more limited than initially claimed. The question of whether to allow or ban gas fracking needs to be carefully assessed by relevant authorities. A review of current related policies and regulations is critically needed.

Aims & Research Methods: Hydrologic fracking may result in unavoidable environmental impacts even if UG is extracted properly, and more so if done inadequately (EU, 2011). Even if risk can be reduced theoretically (IEA, 2011), in practise many accidents from leaky or malfunctioning equipment as well as from bad practises are regularly occurring. This may be due to high pressure to lower the costs or to improper staff training, or to undetected leaks leading to contamination of the ground water (EU, 2011).

Existing laws and regulations of the mining activities often do not address specific aspects of hydraulic fracturing. For governments who choose this path, UG will require dedicated regulations (EU, 2011).

The debate on UG exploitation cannot be disassociated from a “comeback” of fossil fuels. UG is and will be produced by the same actors. Although only very recent, the history of UG exploitation already includes 12 instances of water contamination, leakages to soil, wide-scale land clearing and negative health impacts. Furthermore, increased extraction and use of UG is likely to be detrimental to efforts to curb climate change. Given the increased demand for fossil energy, the UG may be used in addition to coal, rather than being a substitute. Even under the optimistic assumption of the substitution of coal by UG, UG will likely have a limited reduction impact on 21st century global warming. The claim that UG can reduce GHG emissions is conditional on whether UG, over its entire life-cycle, is demonstrated to have a much lower GWP than coal (Howarth, 2011; Jiang, 2011; Hayhoe et al, 2002 ; Wigley, 2011; Hultman et al., 2011; Burnham et al.,2011; IEA, 2011; EU, 2011).

Conclusions: Given the ever-increasing demand for energy, UG use is likely to grow. With large gas reserves and the comparative advantage of using existing infrastructures, equipment and networks from the oil and gas industry (drilling equipment, pipelines, thermal power stations, etc.) UG will remain a tempting power source for the industry and for some governments who want to decrease their foreign dependency on energy. However it will face strong opposition given low public acceptance in certain places. As a non-renewable source of energy, UG remains a stop-gap measure in the transition to a low carbon future. In order to develop energy plans that maximize benefits and minimize harm, other forms of energy will also be needed (McKay, 2008).

Finally, injecting toxic chemicals in underground restricts later use of the contaminated layer (e.g. for geothermal purposes) and long-term effects are not investigated (EU, 2011). New technologies and or energy supplies, such as biofuels or UG, are often greeted as a panacea, but under further investigation are revealed to be less ideal than originally thought. Further research and appropriate, transparent and well-enforced regulation are all critical to possible development of the unconventional gas industry.

Citation: EIA, *World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States* (April 2011)

Topic Area: Shale Gas

Jurisdiction: USA

Introduction: The use of horizontal drilling in conjunction with hydraulic fracturing has greatly expanded the ability of producers to profitably produce natural gas from low permeability geologic formations, particularly shale formations. Application of fracturing techniques to stimulate oil and gas production began to grow rapidly in the 1950s, although experimentation dates back to the 19th century. Starting in the mid- 1970s, a partnership of private operators, the U.S. Department of Energy (DOE) and the Gas Research Institute (GRI) endeavoured to develop technologies for the commercial production of natural gas from the relatively shallow Devonian (Huron) shale in the Eastern United States. This partnership helped foster technologies that eventually became crucial to producing natural gas from shale rock, including horizontal wells, multi-stage fracturing, and slick-water fracturing.1 Practical application of horizontal drilling to oil production began in the early 1980s, by which time the advent of improved down hole drilling motors and the invention of other necessary supporting equipment, materials, and technologies, particularly down hole telemetry equipment, had brought some applications within the realm of commercial viability.2 The advent of large-scale shale gas production did not occur until Mitchell Energy and Development Corporation experimented during the 1980s and 1990s to make deep shale gas production a commercial reality in the Barnett Shale in North-Central Texas. As the success of Mitchell Energy and Development became apparent, other companies aggressively entered this play so that by 2005, the Barnett Shale alone was producing almost half a trillion cubic feet per year of natural gas. As natural gas producers gained confidence in the ability to profitably produce natural gas in the Barnett Shale and confirmation of this ability was provided by the results from the Fayetteville Shale in North Arkansas, they began pursuing other shale formations, including the Haynesville, Marcellus, Woodford, Eagle Ford and other shales. The development of shale gas plays has become a “game changer” for the U.S. natural gas market. The proliferation of activity into new shale plays has increased dry shale gas production in the United States from 0.39 trillion cubic feet in 2000 to 4.80 trillion cubic feet in 2010, or 23 percent of U.S. dry gas production. Wet shale gas reserves have increased to about 60.64 trillion cubic feet by year-end 2009, when they comprised about 21 percent of overall U.S. natural gas reserves, now at the highest level since 1971.3 The growing importance of U.S. shale gas resources is also reflected in EIA’s *Annual Energy Outlook 2011* (*AEO2011*) energy projections, with technically recoverable U.S. shale gas resources now estimated at 862 trillion cubic feet. Given a total natural gas resource base of 2,543 trillion cubic feet in the *AEO2011 R*eference case, shale gas resources constitute 34 percent of the domestic natural gas resource base represented in the *AEO2011* projections and 44 percent of lower 48 onshore resources. As a result, shale gas is the largest contributor to the projected growth in production, and by 2035 shale gas production accounts for 46 percent of U.S. natural gas production.

Aims & Research Methods: The successful investment of capital and diffusion of shale gas technologies has continued into Canadian shales as well. In response, several other countries have expressed interest in developing their own nascent shale gas resource base, which has led to questions regarding the broader implications of shale gas for international natural gas markets. The U.S. Energy Information Administration (EIA) has received and responded to numerous requests over the past three years for information and analysis regarding domestic and international shale gas. EIA's previous work on the topic has begun to identify the importance of shale gas on the outlook for natural gas.4 It appears evident from the significant investments in preliminary leasing activity in many parts of the world that there is significant international potential for shale gas that could play an increasingly important role in global natural gas markets. To gain a better understanding of the potential of international shale gas resources, EIA commissioned an external consultant, Advanced Resources International, Inc. (ARI), to develop an initial set of shale gas resource assessments. This paper briefly describes key results, the report scope and methodology and discusses the key assumptions that underlie the results. The full consultant report prepared for EIA is in Attachment A. EIA anticipates using this work to inform other analysis and projections, and to provide a starting point for additional work on this and related topics.

Scope: In total, the report assessed 48 shale gas basins in 32 countries, containing almost 70 shale gas formations. These assessments cover the most prospective shale gas resources in a select group of countries that demonstrate some level of relatively near-term promise and for basins that have a sufficient amount of geologic data for resource analysis. Figure 1 shows the location of these basins and the regions analysed. The map legend indicates four different colours on the world map that correspond to the geographic scope of this initial assessment:

• Red collared areas represent the location of assessed shale gas basins for which estimates of the

'risked' gas-in-place and technically recoverable resources were provided.

• Yellow collared area represents the location of shale gas basins that were reviewed, but for which estimates were not provided, mainly due to the lack of data necessary to conduct the assessment.

• White collared countries are those for which at least one shale gas basin was considered for this report.

• Gray collared countries are those for which no shale gas basins were considered for this report.

Conclusions: The estimates of technically recoverable shale gas resources for the 32 countries outside of the United States represents a moderately conservative 'risked' resource for the basins reviewed. These estimates are uncertain given the relatively sparse data that currently exist and the approach the consultant has employed would likely result in a higher estimate once better information is available. The methodology is outlined below and described in more detail within the attached report, and is not directly comparable to more detailed resource assessments that result in a probabilistic range of the technically recoverable resource. At the current time, there are efforts underway to develop more detailed shale gas resource assessments by the countries themselves, with many of these assessments being assisted by a number of U.S. federal agencies under the auspices of the Global Shale Gas Initiative (GSGI) which was launched in April 2010.8 Delving deeper into the results at a country level, there are two country groupings that emerge where shale gas development may appear most attractive. The first group consists of countries that are currently highly dependent upon natural gas imports, have at least some gas production infrastructure, and their estimated shale gas resources are substantial relative to their current gas consumption. For these countries, shale gas development could significantly alter their future gas balance, which may motivate development. Examples of countries in this group include France, Poland, Turkey, Ukraine, South Africa, Morocco, and Chile. In addition, South Africa's shale gas resource endowment is interesting as it may be attractive for use of that natural gas as a feedstock to their existing gas-to liquids (GTL) and coal-to-liquids (CTL) plants. The second group consists of those countries where the shale gas resource estimate is large (e.g., above 200 trillion cubic feet) and there already exists a significant natural gas production infrastructure for internal use or for export. In addition to the United States, notable examples of this group include Canada, Mexico, China, Australia, Libya, Algeria, Argentina, and Brazil. Existing infrastructure would aide in the timely conversion of the resource into production, but could also lead to competition with other natural gas supply sources. For an individual country the situation could be more complex.

Citation: Creties D. Jenkins, SPE, DeGolyer and MacNaughton, and Charles M. Boyer II, SPE, Schlumberger, *Coalbed- and Shale-Gas Reservoirs* (2008)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: Annual natural-gas production from coal bed- and shale-gas reservoirs in the US is approximately 2.7 Tscf, which represents 15% of total natural-gas production. Approximately 1.7 Tscf of this gas comes from more than 40,000 coal bed gas wells completed in at least 20 different basins. The remaining 1.0 Tscf comes from more than 40,000 shale gas wells completed in five primary basins. While the pace of coal bed-gas drilling is starting to slow, shale gas continues to be one of the hottest plays in the US, and drilling is expanding rapidly, especially in the south-central US (the Barnett shale and its equivalents), the Appalachian basin, and numerous Rocky Mountain basins. Outside the US, more than 40 countries have investigated the potential of coal bed gas, resulting in commercial projects in Australia, Canada, China, and India. No commercial shale-gas projects currently exist outside of the US, but work continues to identify both new shale-gas reservoirs and to add incremental shale-gas production in existing reservoirs. Given that worldwide coal bed-gas resources are estimated to exceed 9,000 Tscf and shale-gas resources are estimated to exceed 16,000 Tscf, it is clear that tremendous potential exists for future growth (Kawata and Fujita 2001).

Conclusions: Compared to conventional-gas reservoirs, coal bed- and shale-gas reservoirs are characterized by greater heterogeneity, multiple gas-storage mechanisms, and unique attributes that control productivity. Advances in understanding these complexities over the past 20 years have been accompanied by substantial improvements in drilling, completion, and production technologies. The result is faster dewatering, earlier and higher peak gas rates, more-accurate resource and reserves estimates, and improved economics. These successes have encouraged many companies to pursue international opportunities. As a result, many small- to moderate-sized coal bed-gas reservoirs have been developed outside the US during the past decade, and a significant investment has been made to identify the world’s most prospective shale-gas basins. Assuming that the pace of technological innovation can be maintained and that gas prices remain favourable, there is every reason to believe that significantly more coal bed- and shale-gas reservoirs will be developed in the near future and that their gas-production stream will become an increasingly important component of the world’s energy supply.

Citation: Mining Associates, *Coal, CBM and Shale Gas* (2013)

Topic Area: Mining Consultancy Firm

Jurisdiction: Australia

Abstract: Mining Associates is a specialist minerals and energy consultancy based in Brisbane, Australia. Mining Associates has the capability for resource evaluations and mine planning services for coal and the related coal seam gas and shale bed gas with the addition of 3 experts in these areas: Graham Muggeridge, David Graham and Bruce Wright. Graham has some 25 years' experience with RTZ/CRA including a management role in the exploration and development of Kaltim Prima Coal in Indonesia. David has been at the forefront of CBM and shale gas exploration and evaluation in western Canada. Bruce has over 30 years' experience in surface and underground mining in Queensland, New South Wales and New Zealand. He has managed mining operations in QLD and NSW and has been a General Manager of Oakleigh Coal Mines and Company Director of Sumitomo Coal Mining Brisbane.

Citation: International Energy Agency, *Are we entering a Golden Age of Gas? World Energy Outlook* (2011)

Topic Area: Gas Development

Jurisdiction: Global

Introduction: The factors that drive natural gas demand and supply increasingly point to a future in which natural gas plays a greater role in the global energy mix. Global uncertainties afflicting the energy sector can be seen as opportunities for natural gas. When replacing other fossil-fuels, natural gas can lead to lower emissions of greenhouse gases and local pollutants. It can help diversify energy supply, and so improve energy security. It can provide the flexibility and back-up capacity needed as more variable capacity comes on-line in power generations. Gas is a particularly attractive fuel fir regions, which are urbanising and seeking to satisfy rapid growth in energy demand. These are the very regions that will largely determine the extent to which gas use expands over the next quarter of a century.

Aims & Research Methods: The Golden Age of Gas Scenario, departing from the WEO-2010 New Policies Scenario- our base case- incorporates a combination of new assumptions that underpin a more positive future outlook for gas.

Conclusions: Natural gas is a flexible fuel that is used extensively in power generation and competes increasingly in most end-use sectors. It offers environmental benefits when compared to other fossil fuels. Gas resources are abundant, well spread across all regions and recent technological advances have supported increased global trade. However, there will always be uncertainties: lower economic growth, greater cost or other obstacles to unconventional gas production, higher achievements in energy efficiency, changes that improve the relative competitiveness of other fuels, but uncertainty can also work the other way. Based on the assumptions of the GAS Scenario, from 2010 gas use will rise by more than 50% and account for over 25% of world energy demand in 2035- surely a prospect to designate the Golden Age of Gas.

Citation: Vello A. Juuskraa and Scott H. Stevens, *Worldwide Gas Shales and Unconventional Gas: A Status Report* (2009)

Topic Area: Gas Shales

Jurisdiction: EU

Summary: This presentation analyses World Unconventional Gas Resources. All currently published resource estimates for world gas shales start with Rogner's

1997 "top-down" study of world hydrocarbon resources:

 Gas Shale Resource Endowment: 16,110 Tcf (456 Tcm)

The International Energy Agency "World Energy Outlook (2009)" assumed that

about 40% of Rogner's resource endowment would become recoverable:

 Gas Shale Recoverable Resource: 6,350 Tcf (180 Tcm)

While undoubtedly large, only basin- and play-level ("bottom up") appraisals of the

diverse gas shale basins of the world will build confidence on the size, quality and

Reducibility of this natural gas resource.

European Gas Shale Resources. While gas shale exploration is underway in many of the European basins, three areas stand out - - the Alum Shale of Sweden, the Silurian Shales of Poland and the Mikulov Shale of Austria. Our preliminary gas shale resource assessment for these three gas shale basins is 1,000+ Tcf (~30 Tcm), with a potential recoverable resource of 140 Tcf (4 Tcm).

World Gas Shales Resources. A number of major and leading independent oil and gas companies are circling the globe looking for high quality gas shales. Based on the experience to date in North America and Europe, it is likely that Rogner's resource endowment estimate for gas shales of 16,110 Tcf (456 Tcm) will prove to be conservative.

 China and India. China and India have numerous gas shale basins that are only now starting to be evaluated. Recently, Shell and PetroChina announced plans to jointly evaluate and develop the gas shales in Sichuan Province.

 Other Countries. Gas shale exploration is underway in many other parts of the world, including Australia, New Zealand and Southern Africa where Statoil, Chesapeake and Sasol recently announced joint plans.

World Unconventional Gas Resources. In addition to gas shales, the other two unconventional gas sources deserve their place on the world resource stage:

 Our country-by-country assessment of coal bed methane is 3,540 to 7,630 Tcf (100 to 216 Tcm), with an estimated 830 Tcf (24 Tcm) recoverable.

 Much work remains for defining the tight gas sand resources of the world.

Conclusions: KEY CHALLENGES

Three challenges need to be addressed if natural gas (particularly unconventional gas) is to become one of the major pathways to a low-carbon economy.

Challenge #1. Building Confidence in Adequate and Robust Natural Gas Supplies. Considerable skepticism still exists on the abundance of world unconventional natural gas supplies. Pronouncements that we are “running out of natural gas supplies”, voiced by M. King Hubbert in the 1970s, can still be heard for North America. Detailed basin-level assessments of gas shales and unconventional gas are essential for building confidence that sufficient supplies of natural gas exist to serve as a major climate change mitigation option.

Challenge #2. Addressing the Environmental Barriers to Greater Natural Gas Development. As drilling increases and production grows in areas not used to hydrocarbon production, a harsher “spotlight” will fall on unconventional natural gas development. “Green natural gas development” - - capturing methane emissions, reducing surface impacts, pursuing environmentally acceptable hydraulic fracturing and re-using produced water - - will help make this activity more environmentally friendly.

Challenge #3. Building demand for natural gas in a carbon constrained world. The unconventional gas resource base of North America and the world is large. Our view is that with an aggressive pursuit of unconventional gas, the worldwide natural gas resource base will prove to be sufficiently large to provide a major, lower CO2 emissions option for power generation and possibly for transportation.

Citation: CSIRO, *Coal Seam Gas Developments- Predicting Impacts* (April 2012)

Topic Area: Coal Seam Gas Developments

Jurisdiction: Australia

Introduction: Natural gas extracted from coal seams can offer a number of benefits as an energy source:

- natural gas typically burns more anciently than coal or oil and can emit less greenhouse gas at the points of extraction and combustion
- natural gas has a role in supporting the journey towards lower or zero emission renewable energy sources
- natural gas has direct use for a range of purposes such as heating and for powering fast-response, electricity-generating turbines
- Australia has abundant resources of natural gas
- gas can be piped to a liquid natural gas (LNG) plant where it can be processed into LNG for export
- the CSG export trade provides jobs and revenue to Australia.

Aims & Research Methods: Coal seam gas (CSG) is a form of natural gas that is extracted from underground coal seams. This factsheet outlines reasons for using natural gas as an energy source, some of the potential impacts of CSG developments and challenges associated with predicting these impacts.

Citation: Paul Stevens, *The 'Shale Gas Revolution' Hype and Reality* (September 2010)

Topic Area: The Shale Gas Revolution

Jurisdiction: Global

Introduction: Up to the 1990s, outside the former Soviet Union, gas failed to increase its share in global primary energy consumption. Yet the 1990s saw many of the earlier constraints on its use begin to erode. Together with its natural advantages as an energy source, this opened the prospects of much greater use of gas in the future. At the same time, economic and technical developments in liquefied natural gas (LNG) suggested that the international gas trade was likely to expand. Many observers began to speculate that these developments could encourage gas to become more of an international market. Questions began to be asked about whether the increasing globalization of gas might carry significant consequences, as had been the case with oil in the 1970s and after. However, (largely) unexpected developments in unconventional gas in the US have confused the picture, in what has been dubbed the shale gas revolution.

The shale gas revolution since 2000, shale gas production has leapt from accounting for only 1% of US production to 20% in 2009. However, there are doubts as to whether this 'revolution' can spread beyond the United States, or even be maintained within it. The technologies that made this possible – horizontal drilling and hydraulic fracturing – are now coming under increasing scrutiny for their negative environmental impacts: drilling moratoria are being sought while environmental impact studies are completed. Also, although unconventional gas resources are estimated to be five times those of conventional gas, there is concern that their depletion rates are much faster. The US experience was triggered by many favourable factors connected with geology, tax breaks and the existence of a vibrant service industry. There are serious doubts about whether such favourable conditions can be replicated outside the United States, especially in Western Europe where there is much current interest. In Europe the geology is less favourable, there are no tax breaks and the service industry for onshore drilling is far behind that in the United States.

Finally, there is concern that disruptions caused by shale gas developments will not find public acceptance, especially in a context where the gas is the property of the state and thus the benefits accrue to governments and not local landowners.

Aims & Research Methods: The recent 'shale gas revolution' in the United States has created huge uncertainties for international gas markets that are likely to inhibit investment in gas – both conventional and unconventional – and in many renewables. If the revolution continues in the US and extends to the rest of the world, energy consumers can anticipate a future dominated by cheap gas. However, if it falters and the current hype about shale gas proves an illusion, the world will face serious gas shortages in the medium term.

Conclusions: From this uncertainty two major problems arise. First, as the world recovers from global recession and as constraints on gas use continue to erode, demand will grow and gas will probably gain ever greater shares in the global primary energy mix. However, given investor uncertainty, investment in future gas supplies will be lower than would have been required had the shale gas revolution not happened, or at least had it not been so hyped up. If the 'revolution' in the United States continues to flourish and is replicated elsewhere in the world, this inadequate investment matters less. Consumers can look forward to a future floating on unlimited clouds of cheap gas as unconventional gas fills the gaps. However, if it fails to deliver on current expectations – and we will not be sure of this for some time – then in ten years or so gas supplies will face serious constraints. Of course markets will eventually solve the problem as higher prices encourage a revival of investment in conventional gas supplies. Yet given the long lead times on most gas projects, consumers could face high prices for some considerable time.

The second problem concerns investment in renewables for power generation – a necessary consequence of the general agreement that the world must move to a low carbon economy if climate change is to be controlled. The failure of the Copenhagen talks has already injected considerable uncertainty into the investment climate for power generation, not least because of uncertainty over the future price of carbon. The uncertainties created by the shale gas revolution have significantly compounded this investor uncertainty. In a world where there is the serious possibility of cheap, relatively clean gas, who will commit large sums of money to expensive pieces of equipment to lower carbon emissions?

Citation: API, David L. Miller and Stephanie Meadows, *API Introduction and API HF Standards for the Oil and Natural Gas Industry* (July 2011)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Aims & Research Methods: This presentation analyses API Standards and Standard Development, API HF related standards and publications and Use of API Standards.

Conclusions:

- API standards represents industry's collective wisdom on operational practices, developed and refined over many years
- API standards are widely cited by both Federal and State Regulators
- All API HF standards available for free on-line

Citation: Dr Mariann Lloyd-Smith and Dr Rye Senjen, *Hydraulic Fracturing in Coal Seam Gas Mining: The Risks to Our Health, Communities, Environment and Climate* (2011)

Topic Area: Chemical Use and Disclosure

Jurisdiction: Australia

Introduction: With the realities of climate change/chaos upon us, the scramble for sustainable energy sources is rapidly expanding. One potential source of energy in the Australian context is the extraction of gas from coal seam gas (CSG), shale gas, basin-cantered gas and tight gas. Until recently this these types of gas were too expensive to extract and too difficult to produce, but technological 'innovations' such as 'fracking' have made this gas accessible and commercially viable. Some commentators have compared this 'unconventional' gas extraction to a new gold rush and a way to ensure our energy future. It's estimated that up to 80% of all natural gas wells in the next 10 years will use fracking.

Aims & Research Methods: The National Toxics Network (NTN) calls on federal and state governments to implement a moratorium on the use of hydraulic drilling and fracturing chemicals ('fracking chemicals') used in the hydraulic drilling and fracturing of coal gas seams and gas shale extraction, until the fracking chemicals have been fully assessed for their health and environmental hazards by the industrial chemicals regulator, the National Industrial Chemical Notification and Assessment Scheme (NICNAS). NTN's assessment has found that only 2 out of the 23 most commonly used fracking chemicals in Australia have been assessed by NICNAS. Neither of these 2 chemicals have been specifically assessed for their use in hydraulic drilling and fracking. NTN demands that a comprehensive hazard assessment is carried out for all fracking chemicals used in Australia, including their risks to human health, ecotoxicology and environmental fate assessments (air emissions; releases to groundwater and watercourses), as well as a full costing of the long term public burden of the clean-up and remediation of contaminated areas and the impact on the increased landfill capacity needed to deal with the waste products created by these mining methods.

Conclusions: To provide a complete inventory of chemicals, full toxicity data including mixture toxicity and a risk assessment. Relevant authorities acknowledge however that not all chemicals can be assessed because some are commercial secrets, and even those that are disclosed, have very little data available. Only 2 out of 23 of the known fracking chemicals have been assessed by the regulator of industrial chemicals NICNAS, and neither was assessed for its use in CSG fracturing. There have been no requirements imposed for monitoring to assess long term impacts of fracking chemicals. Risk assessments of fracking fluids have generally failed to include adequate assessment of:

• Air emissions (eg volatile organic compounds) produced by fracturing chemicals

• The impact of the release of BTEX from the coal seam

• The impact of potential break down products or intermediates from fracking chemicals

• The endocrine disrupting potential of contaminants (of concern as impacts occur at very low levels)

• The combined effect of the mixture of chemicals on human health and the environment, especially water contamination

• Lack of life cycle assessment of fracking fluids.

Citation: *The SEAB Shale Gas Production Subcommittee Ninety-Day Report* (August 11, 2011)

Topic Area: Water quality and hydraulic fracturing issues

Jurisdiction: USA

Introduction: Natural gas is a cornerstone of the U.S. economy, providing a quarter of the country's total energy. Owing to breakthroughs in technology, production from shale formations has gone from a negligible amount just a few years ago to being almost 30 percent of total U.S. natural gas production. This has brought lower prices, domestic jobs, and the prospect of enhanced national security due to the potential of substantial production growth.

But the growth has also brought questions about whether both current and future production can be done in an environmentally sound fashion that meets the needs of public trust.

Aims & Research Methods: The Shale Gas Subcommittee of the Secretary of Energy Advisory Board is charged with identifying measures that can be taken to reduce the environmental impact and improve the safety of shale gas production. This 90-day report presents recommendations that if implemented will reduce the environmental impacts from shale gas production. The Subcommittee stresses the importance of a process of continuous improvement in the various aspects of shale gas production that relies on best practices and is tied to measurement and disclosure. While many companies are following such a process, much-broader and more extensive adoption is warranted. The approach benefits all parties in shale gas production: regulators will have more complete and accurate information; industry will achieve more efficient operations; and the public will see continuous, measurable improvement in shale gas activities.

Conclusions: A list of the Subcommittee's findings and recommendations follows. Improve public information about shale gas operations: Create a portal for access to a wide range of public information on shale gas development, to include current data available from state and federal regulatory agencies. The portal should be open to the public for use to study and analyse shale gas operations and results.

Improve communication among state and federal regulators: Provide continuing annual support to STRONGER (the State Review of Oil and Natural Gas Environmental Regulation) and to the Ground Water Protection Council for expansion of the *Risk Based Data Management System* and similar projects that can be extended to all phases of shale gas development.

Improve air quality: Measures should be taken to reduce emissions of air pollutants, ozone precursors, and methane as quickly as practicable. The Subcommittee supports adoption of rigorous standards for new and existing sources of methane, air toxics, ozone precursors and other air pollutants from shale gas operations. The Subcommittee recommends:

(1) Enlisting a subset of producers in different basins to design and rapidly implement measurement systems to collect comprehensive methane and other air emissions data from shale gas operations and make these data publically available;

(2) Immediately launching a federal interagency planning effort to acquire data and analyse the overall greenhouse gas footprint of shale gas operations throughout the lifecycle of natural gas use in comparison to other fuels; and

(3) Encouraging shale-gas production companies and regulators to expand immediately efforts to reduce air emissions using proven technologies and practices.

Protection of water quality: The Subcommittee urges 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. The Subcommittee recommends the following actions by shale gas companies and regulators – to the extent that such actions have not already been undertaken by particular companies and regulatory agencies:

(1) Measure and publicly report the composition of water stocks and flow throughout the fracturing and clean-up process.

(2) Manifest all transfers of water among different locations.

(3) 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.

(4) Additional field studies on possible methane leakage from shale gas wells to water reservoirs.

(5) 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.

(6) Agencies should review field experience and modernize rules and enforcement practices to ensure protection of drinking and surface waters.

Disclosure of fracturing fluid composition: The Subcommittee shares the prevailing view that the risk of fracturing fluid leakage into drinking water sources through fractures made in deep shale reservoirs is remote. Nevertheless the Subcommittee believes there is no economic or technical reason to prevent public disclosure of all chemicals in fracturing fluids, with an exception for genuinely proprietary information. While companies and regulators are moving in this direction, progress needs to be accelerated in light of public concern.

Reduction in the use of diesel fuel: The Subcommittee believes there is no technical or economic reason to use diesel in shale gas production and recommends reducing the use of diesel engines for surface power in favour of natural gas engines or electricity where available.

Managing short-term and cumulative impacts on communities, land use, wildlife, and ecologies. Each relevant jurisdiction should pay greater attention to the combination of impacts from multiple drilling, production and delivery activities (e.g., impacts on air quality, traffic on roads, noise, visual pollution), and make efforts to plan for shale development impacts on a regional scale. Possible mechanisms include:

(1) Use of multi-well drilling pads to minimize transport traffic and need for new road construction.

(2) Evaluation of water use at the scale of affected watersheds.

(3) Formal notification by regulated entities of anticipated environmental and community impacts.

(4) Preservation of unique and/or sensitive areas as off-limits to drilling and support infrastructure as determined through an appropriate science-based process.

(5) Undertaking science-based characterization of important landscapes, habitats and corridors to inform planning, prevention, mitigation and reclamation of surface impacts.

(6) Establishment of effective field monitoring and enforcement to inform ongoing assessment of cumulative community and land use impacts. The process for addressing these

issues must afford opportunities for affected communities to participate and respect for the rights of surface and mineral rights owners. Organizing for best practice: The Subcommittee believes the creation of a shale gas industry production organization dedicated to continuous improvement of best practice, defined as improvements in techniques and methods that rely on measurement and field experience, is needed to improve operational and environmental outcomes. The Subcommittee favours a national approach including regional mechanisms that recognize differences in geology, land use, water resources, and regulation. The Subcommittee is aware that several different models for such efforts are under discussion and the Subcommittee will monitor progress during its next ninety days. The Subcommittee has identified several activities that deserve priority attention for developing best practices:

Air:

(a) Reduction of pollutants and methane emissions from all shale gas production/delivery activity.

(b) Establishment of an emission measurement and reporting system at various points in the production chain.

Water:

(a) Well completion – casing and cementing including use of cement bond and other completion logging tools.

b) Minimizing water use and limiting vertical fracture growth.

Research and Development needs. The public should expect significant technical advances associated with shale gas production that will significantly improve the efficiency of shale gas production and that will reduce environmental impact. The move from single well to multiple-well pad drilling is one clear example. Given the economic incentive for technical advances, much of the R&D will be performed by the oil and gas industry. Nevertheless the federal government has a role especially in basic R&D, environment protection, and safety. The current level of federal support for unconventional gas R&D is small, and the Subcommittee recommends that the Administration and the Congress set an appropriate mission for R&D and level funding.

The Subcommittee believes that these recommendations, combined with a continuing focus on and clear commitment to measurable progress in implementation of best practices based on technical innovation and field experience, represent important steps toward meeting public concerns and ensuring that the nation's resources are responsibly being responsibly developed.

Citation: Secretary of Energy Advisory Board, *Shale Gas Production Subcommittee Second Ninety Day Report* (November 18 2011)

Topic Area: Water quality and hydraulic fracturing issues

Jurisdiction: USA

Introduction: The Shale Gas Subcommittee of the Secretary of Energy Advisory Board is charged with identifying measures that can be taken to reduce the environmental impact and to help assure the safety of shale gas production. Shale gas has become an important part of the nation's energy mix. It has grown rapidly from almost nothing at the beginning of the century to near 30 percent of natural gas production. Americans deserve assurance that the full economic, environmental and energy security benefits of shale gas development will be realized without sacrificing public health, environmental protection and safety. On August 18, 2011 the Subcommittee presented its initial Ninety-Day Report1 including twenty recommendations that the Subcommittee believes, if implemented, would assure that the nation's considerable shale gas resources are being developed responsibly, in a way that protects human health and the environment and is most beneficial to the nation. The Secretary of Energy's charge to the Subcommittee is included in Annex A and members of the Subcommittee are given in Annex B.

Aims & Research Methods: The Subcommittee recommendations in its initial report were presented without indicating priority or how each recommendation might be implemented. Progress in achieving the Subcommittee's objective of continuous improvement in reducing the environmental impact of shale gas production depends upon implementation of the Subcommittee recommendation; hence this final report focuses on implementation. On October 31, 2011, the Subcommittee held a public meeting at DOE headquarters in Washington, D.C., to learn the views of the Department of Interior, the Environmental Protection Agency, and the Department of Energy about progress and barriers to implementation of the Subcommittee recommendations. The Subcommittee is mindful that state and federal regulators and companies are already deeply involved in environmental management. Implementing the twenty Subcommittee recommendations will require a great deal of effort, and regulators, public officials, and companies need to decide how to allocate scarce human and financial resources to each recommendation, potentially shifting effort from other valuable existing activities. All of the Subcommittee recommendations in its Ninety-Day report involve actions by one or more parties: federal officials, state officials, and public and private sector entities. Two criteria are important in deciding on the allocation: the importance and ease of implementation. Early success in implementing some recommendations may stimulate greater effort on other recommendations, which require greater time and effort for progress. Decisions about when, how and whether to proceed with our recommendations are the responsibility of the public and private participants in the process – not the Subcommittee. But, the Subcommittee can be helpful at identifying those recommendations that seem particularly important and particularly amendable to early action.

Conclusions: The Subcommittee was gratified with the generally favourable, but not universally favourable, response to its initial report. In particular there was overwhelming agreement on two points: (1) If the country is to enjoy the economic and other benefits of shale gas production over the coming years disciplined attention must be devoted to reducing the environmental impact that accompanies this development, and (2) a prudent balance between development and environmental protection is best struck by establishing a strong foundation of regulation and enforcement, and adopting a policy and practice that measures, discloses, and continuously improves shale gas operations. The Subcommittee believes that if action is not taken to reduce the environmental impact accompanying the very considerable expansion of shale gas production expected across the country – perhaps as many as 100,000 wells over the next several decades – there is a real risk of serious environmental consequences causing a loss of public confidence that could delay or stop this activity. Thus, the Subcommittee has an interest in assessing and reporting on, the progress that is being made on implementing its recommendations or some sensible variations of these recommendations. The Subcommittee has the impression that its initial report stimulated interest in taking action to reduce the environmental impact of shale gas production by the administration, state governments, industry, and public interest groups. However, the progress to date is less than the Subcommittee hoped and it is not clear how to catalyse action at a time when everyone's attention is focused on economic issues, the press of daily business, and an upcoming election. The Subcommittee cautions that whether its approach is followed or not, some concerted and sustained action is needed to avoid excessive environmental impacts of shale gas production and the consequent risk of public opposition to its continuation and expansion.

Citation: Nathaniel Warner, Robert Jackson, Thomas Darrah, Stephen Osborn, Adrian Down, Kaiguang Zho, Alissa White and Avner Vengosh, *Geochemical Evidence for Possible Natural Migration of Marcellus Formation Brine to Shallow Aquifers in Pennsylvania* (2012)

Topic Area: Aquifer Contamination

Jurisdiction: USA

Introduction: The debate surrounding the safety of shale gas development in the Appalachian Basin has generated increased awareness of drinking water quality in rural communities. Concerns include the potential for migration of stray gas, metal-rich formation brines, and hydraulic fracturing and/or flow back fluids to drinking water aquifers. A critical question common to these environmental risks the hydraulic connectivity between the shale gas formations and the overlying shallow drinking water aquifers.

Aims & Research Methods: We present geochemical evidence from north-eastern Pennsylvania showing that pathways, unrelated to recent drilling activities, exist in some locations between deep underlying formations and shallow drinking water aquifers. Integration of chemical data and isotopic ratios from this and previous studies in 426 shallow groundwater samples and 83 Appalachian brine samples suggests that mixing relationships between shallow ground water and a deep formation brine causes groundwater salinization in some locations.

Conclusions: The strong geochemical fingerprint in the salinized groundwater sampled from the Alluvium Catskill and Lock Haven aquifers suggests possible migration of Marcellus brine through naturally occurring pathways. The occurrences of saline water do not correlate with the location of shale gas wells and are consistent with reported data before rapid shale gas development in the region. However, the presence of these fluids suggests conductive pathways and specific geostructural and/or hydrodynamic regimes in north-eastern Pennsylvania that are at increased risk for contamination of shallow drinking water resources, particularly by fugitive gases, because of natural hydraulic connections to deeper formations.

Citation: James Hanion, *Natural Gas Drilling in the Marcellus Shale NPDES Program Frequently Asked Questions* (March 2011)

Topic Area: Natural Gas Drilling

Jurisdiction: USA

Introduction: The Marcellus Shale is an organic rich rock that has been estimated to contain from 50 to 500 trillion cubic feet of natural gas. It was deposited in the Appalachian Basin

350 million years ago as part of an ancient river delta and consists of the bottom layer of an Upper Devonian age sedimentary rock sequence. Like most shale, the Marcellus was deposited as extremely fine grained sediment, with small pore spaces and low permeability that prevents gas from easily migrating[1]. Often called the Marcellus Black Shale due to its colour, the formation exists under much of southern New York, Pennsylvania, West Virginia, eastern Ohio, and far western Maryland. Although the shale outcrops at its namesake, Marcellus, New York, it generally lies at depths of 5,000 to 9,000 feet throughout much of the area. The Marcellus Shale generally ranges in thickness from 50 to 200 feet.

Aims & Research Methods: These Q&As provide advice on how to issue National Pollutant Discharge Elimination System permits for discharges from natural gas drilling in the Marcellus Shale. These Q&As do not impose legally binding requirements on EPA, states, tribes, other regulatory authorities, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA, state, tribal and other decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from those provided in the Q&As where appropriate. EPA may update these Q&As in the future as better information becomes available.

Citation: Government of Western Australia, *Department of Mines and Petroleum, Minerals and Energy Research News World Class Testing Facility Operating in Kalgoorlie* (March 2011)

Topic Area: Hydraulic Fracturing

Jurisdiction: Australia (WA)

Introduction: Two MERIWA research projects funded to a total of $712,690 have helped ensure their safety and protect massive industry investments. Over eight years, these two sequential projects led by Professor Ernesto Villaescusa of the Western Australian School of Mines (WASM) have resulted in the development of a unique dynamic test facility able to simulate the performance of rock reinforcement and surface support systems in mine conditions. The WASM Dynamic Test Facility enables suppliers and users of a wide range of ground support technology such as shotcrete and steel mesh, to test products and evaluate their use in specific conditions. The key to the facility is the development by Professor Villaescusa of a loading concept, involving momentum transfer that simulates the stresses caused by mining activity and violent rock failures. MERIWA Project M349 (2002-2005) included the design, construction and operation of the WASM Dynamic Test facility and related instrumentation and monitoring systems, and developing software to analyse test data and develop a preliminary database of test results. Much of this work was carried out by Dr Alan Thompson and PhD student John Player. MERIWA Project M349A (2006-2010) included further modifications to the test facilities, software enhancement and 80 more tests.

Aims & Research Methods: The reports on these two projects have been published by MERIWA and are available on CD at a nominal cost. Refinement of the test facility and expansion of its applications have continued since the research projects were completed, but as a result of the MERIWA funding:

• Industry and researchers now have access to a world class testing facility and an extensive database of information to help in designing better systems.

• More effective and reliable surface support and ground reinforcement systems are of obvious benefit to mine workers and mine operators.

Citation: Stephen G. Osborn, Avner Vengosh, Nathaniel R. Warner, and Robert B. Jackson, *Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing* (2011)

Topic Area: Hydraulic Fracturing

Jurisdiction: USA

Aims & Research Methods: Directional drilling and hydraulic-fracturing technologies are dramatically increasing natural-gas extraction. In aquifers overlying the Marcellus and Utica shale formations of northeastern Pennsylvania and upstate New York, we document systematic evidence for methane contamination of drinking water associated with shale gas extraction. In active gas-extraction areas (one or more gas wells within 1 km), average and maximum methane concentrations in drinking-water wells increased with proximity to the nearest gas well and were 19.2 and 64 mg CH_4 L^{-1} (n ¼ 26), a potential explosion hazard; in contrast, dissolved methane samples in neighbouring no extraction sites (no gas wells within 1 km) within similar geologic formations and hydrogeological regimes averaged only 1.1 mgL^{-1} ($P < 0.05$; n ¼ 34). Average $\delta^{13}C$-CH_4 values of dissolved methane in shallow groundwater were significantly less negative for active than for no active sites (−37 _ 7‰ and −54 _ 11‰, respectively; $P < 0.0001$). These $\delta^{13}C$-CH_4 data, coupled with the ratios of methane-to-higher-chain hydrocarbons, and δ^2H-CH_4 values, are consistent with deeper thermogenic methane sources such as the Marcellus and Utica shales at the active sites and matched gas geochemistry from gas wells nearby. In contrast, lower-concentration samples from shallow groundwater at no active sites had isotopic signatures reflecting a more biogenic or mixed biogenic/ thermogenic methane source.

Conclusions: The researchers found no evidence for contamination of drinking-water samples with deep saline brines or fracturing fluids. The researchers conclude that greater stewardship, data, and— possibly—regulation are needed to ensure the sustainable future of shale-gas extraction and to improve public confidence in its use.

Citation: Chesapeake Energy, *Water Use in Deep Shale Gas Exploration* (2011)

Topic Area: Hydraulic Fracturing

Jurisdiction: USA

Introduction: Water is an essential component of Chesapeake Energy's (Chesapeake) deep shale gas development. Chesapeake uses water for drilling, where a mixture of clay and water is used to carry rock cuttings to the surface, as well as to cool and lubricate the drillbit. Drilling a typical Chesapeake deep shale gas well requires between 65,000 and 600,000 gallons of water. Water is also used in hydraulic fracturing, where a mixture of water and sand is injected into the deep shale at a high pressure to create small cracks in the rock and allows gas to freely flow to the surface. Hydraulically fracturing a typical Chesapeake horizontal deep shale gas well requires an average of 4.5 million gallons per well.

Aims & Research Methods: This report released by Chesapeake states the following key points:

• Water resources are protected through stringent federal, state and local permitting processes.

• Natural gas production uses significantly less water per BTU of energy produced than other fuel sources such as coal, oil or ethanol.

• Water is essential for deep shale gas development.

• Deep shale gas drilling and hydraulic fracturing uses a small amount of water compared to other uses, and does not represent a long-term commitment of the resource.

Citation: DOE Office of Petroleum Reserves – *Strategic Unconventional Fuels, Fact Sheet: U.S. Oil Shale Resources* (2012)

Topic Area: Oil Shale Information

Jurisdiction: USA

Aims & Research Methods: This fact sheet presents general information regarding oil shales in the USA, oil shale locations, oil shale recovery, and oil shale resources compared with other Canadian energy resources.

Citation: Dave Healy, *Hydraulic Fracturing or Fracking: A Short Summary of Current Knowledge and Potential Environmental Impacts* (July 2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: The extraction of shale gas on a commercial scale is an activity that is licensable by the Environmental Protection Agency (EPA) of Ireland. While such activity is not likely to occur in the near future, it is likely that permits for exploration in the Lough Allen basin may be sought from the Department of Communications, Energy & Natural Resources (DoCENR) in the next 2 years, which may seek to perform extraction on a small scale as part of the exploration. Such permit applications may seek approval to use hydraulic fracturing techniques, known as 'fracking'. This method of gas extraction has never previously been used on a commercial basis in Ireland. It is envisaged that the EPA will be a statutory consultee with respect to any Environmental Impact Assessment required for shale gas projects at the exploration stage, and will therefore be required to gain expert knowledge on the environmental impacts in order to fulfil this role. Such knowledge would also be required to assess any licence applications for commercial gas extraction in the future.

Aims & Research Methods: This preliminary report aims to constrain this knowledge base by documenting what is currently known and understood about fracking and the potential environmental impacts, and will help to form the basis for a larger and more detailed research study. The objectives of this preliminary report are to provide information:

 on the potential environmental impacts of fracking in particular, and shale gas extraction in general, e.g. methane and chemical migration into ground water;

 on the role of geology in successful fracking and shale gas extraction;

 on the regulatory approaches of other countries;

 on the establishment of Best Environmental Practice; the possibility of fracking without the use of chemicals is investigated in this context.

Scope: This report contains the following elements:

 Introduction & Context

 Geological Principles of Relevance in Fracking & Shale Gas Extraction

 Potential Environmental Impacts

 Regulatory Approaches in Other Countries

 Establishing Best Environmental Practice

Conclusions: Published peer-reviewed data suggest that there is a low and probably manageable risk to ground water from fracking, whereas the potential impacts on the atmosphere from associated methane emissions and the risks of increased seismicity are less well known. However, the total number of published, peer-reviewed scientific studies remains low, and it is therefore prudent to consider and research in detail the full range of possible risks from fracking operations, including their magnitudes and uncertainties, and the potential environmental impacts of these risks in the exploitation of shale gas. The published reports (MIT, 2011; University of Texas, 2012) and those due to be published by the US EPA, a new EU Working Group on Shale Gas Regulation, and the International Energy Agency, will together provide a richer and more robust foundation for informed decision making in Europe. Much of the coverage to date in the traditional media and on the World Wide Web is not peer-reviewed and is often misinformed. Critical evaluations of shale gas fracking and the potential impacts on the environment must be based on peer-reviewed, scientific analyses of quantitative data. Agencies responsible for regulating or monitoring the environmental impacts of shale gas development need to be at the forefront of this effort (SEAB, 2011a). The design of any national regulatory framework to protect the environment from hydraulic fracturing operations should start with the supranational European Union directives and recommendations from working groups in progress.

Citation: Christopher Green, Peter Styles and Brian Baptie, *Preese Hall Shale Gas Fracturing: Review and Recommendations for Induced Seismic Mitigation* (April 2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: UK

Introduction: On 1 April and 27 May 2011, two earthquakes with magnitudes 2.3 ML and 1.5 ML were detected in the Blackpool area. These earthquakes were immediately suspected to be linked to hydraulic fracture injections at the Preese Hall well 1 (PH1), operated by Cuadrilla Resources Ltd. This well was hydraulically fractured during exploration of a shale gas reservoir in the Bowland basin. As a result of the earthquakes, operations were suspended at PH1 and Cuadrilla Resources Ltd commissioned a number of studies (Eisner *et al.*, 2011; Harper, 2011; GMI, 2011; de Pater and Pellicer, 2011 and Baisch and Voros, 2011) into the relationship between the earthquakes and their operations. An overall summary or synthesis of the findings was also published (de Pater and Baisch 2011).

In total, six hydraulic fracture treatments were carried out at different depths (Table 1). Seismicity was observed both during and after stages 2, 4 and 5. The largest magnitude event was 2.3 ML and occurred approximately 10 hours after shut-in, following the stage 2 treatment. (The magnitude 1.5 ML event on 27 May was approximately the same period of time after stage 4.) These events were found to be located in close vicinity to the point of injection and the signature of the events suggests that they all had similar locations and mechanisms.

Well-bore deformation was also observed following the first event in April, after stage 2. A caliper log run on 4 April showed that the extent of the deformation was greater than 0.5 inches over a depth range between 8480-8640ft MD.

Laboratory measurements of core samples, including uniaxial and triaxial testing, along with down-hole measurements, were used to determine elastic rock properties, rock strength and bedding plane strength (Harper, 2011). The laboratory measurements of rock strength were also used, along with density and image logs and minifrac data, to determine the magnitude of the minimum, maximum and vertical stresses and pore-pressure as a function of depth in the Preese Hall well (GMI, 2011). These results were used to develop a detailed geomechanical model of the reservoir (Harper 2011; GMI, 2011), Surface pressure matching from the fracture treatments was also used to estimate fracture size and geometry using a hydraulic fracture simulator (de Pater and Pellicier, 2011).

A simplified model consisting of a single fault plane was used to numerically simulate the geomechanical processes in the reservoir during the fracture treatments using a 3-D finite element model (Baisch and Voros, 2011). Simulated seismicity was compared with the observations and this method was also used to estimate the maximum expected magnitude for a similar fracture treatment. A critical magnitude for damaging ground motions was estimated, using the German DIN4150 standard, and a simple relationship for ground motions as a function of magnitude and distance (Baisch and Voros, 2011).

These studies examine seismological and geomechanical aspects of the seismicity in relation to the hydraulic fracture treatments, along with detailed background material on the regional geology and rock physics. They also estimate future seismic hazard and provide some recommendations for future operations and mitigation of seismic risk.

The key findings of their studies are as follows:

1. The earthquake activity was caused by direct fluid injection into an adjacent fault zone during the treatments. The fluid injection reduced the normal stress on the fault, causing it to fail repeatedly in a series of small earthquakes. The fault location is yet to be identified.

2. The Bowland Shale is a heterogeneous, relatively impermeable, stiff and brittle rock.

3. Bedding is pronounced throughout the reservoir and the structural dip of the bedding is variable and high. The bedding planes have low shear strength and show signs of previous slip.

4. Stresses are anisotropic and the in-situ stress regime is strike-slip. The difference between the maximum and minimum horizontal stresses is high and the orientation of maximum horizontal stress agrees with the regional stress orientation.

5. The maximum likely magnitude resulting from a similar treatment is estimated as 3.0 ML. An event of this size is not expected to present a significant hazard.

6. There is a very low probability of other earthquakes during future treatments of other wells.

7. The injected volume and flow-back timing are an important controlling factor in the level of seismicity, as evidenced from the lack of seismicity during and after stage 3.

8. The potential for upward fluid migration is considered low. In the worst case, fluid could migrate along the fault plane, but this would be limited due to the presence of impermeable formations above the Bowland shale.

9. Though some casing collapse was found in the lower reservoir section, well integrity has not been compromised. For future operations, they recommend

a) A conservative estimate of the minimum size of earthquake that could cause damage is 2.6 ML, based on German standards. This should be the maximum allowable limit for seismic activity.

b) Seismicity can be mitigated by modifying job procedure, principally by reducing injected volume and rapid flow back.

c) Seismicity can be mitigated by deploying a real-time seismic monitoring “traffic light” system, to take action when observed seismicity reaches certain levels.

The authors of the present report were asked by DECC to provide advice on the reports commissioned by Cuadrilla (Eisner *et al.*, 2011; Harper, 2011; GMI, 2011; de Pater and Pellicer, 2011 and Baisch and Voros, 2011) and advise on what additional information was deemed necessary in order to allow this independent technical review of the final reports to be as comprehensive as possible. We were also asked to provide general recommendations for future operational good practices, to mitigate seismic risk, if future hydraulic fracture treatments are to be permitted in this area.

It has to be noted that given the sparse nature of the available seismic data for detailed analysis, the work commissioned by Cuadrilla can only address the major questions and provide some useful insights into the relationship between operations and seismic activity.

Overall, we generally agree with the main conclusions about the nature and mechanism of the seismic activity, although we have the following concerns:

The stated low probability of future earthquakes during future treatments. There is not enough data to justify from a simple statistical analysis of potential realizations of the geomechanical situation that there is a low probability of encountering a similarly unique scenario in any future wells.

The potential for upward fluid migration seems overstated, based on microseismic shale gas data from the main US plays. Further analysis in this report seems to indicate that fracture containment was good, with little vertical height growth. However, it is difficult to reach any concrete conclusions without confirmatory information from fracture diagnostics.

We conclude that an effective mitigation strategy is a necessary pre-requisite for commencing operations and offer in section 7 below our own recommendations for future operational best practice and monitoring.

Aims & Research Methods: A series of studies were commissioned by Cuadrilla Resources Ltd to examine the possible relationship between hydraulic fracture operations at the Preese Hall well, near Blackpool, and a number of earthquakes which occurred in April and May 2011, the largest of which had a magnitude of 2.3 ML. The reports from these studies conclude that the earthquake activity was caused by direct fluid injection into an adjacent fault zone during the treatments, but that the probability of further earthquake activity is low. The reports analyse the earthquake activity and use available geological and geophysical data, including background geology, well logs and core samples, along with fracture treatment data, to develop a conceptual geomechanical model. A numerical model consisting of a single fault plane in a rock matrix was used to simulate the induced seismicity, compare with observations, and estimate maximum magnitudes for induced earthquakes. A critical magnitude at which damaging ground motions might occur was estimated using the German DIN4150 standard, and a simple relationship suggested for ground motions as a function of magnitude and distance. Finally, a protocol for controlling operational activity is proposed. This builds on extensive Enhanced Geothermal System experience and uses a traffic light system based on real-time monitoring of seismic activity.

We have been asked by DECC to review these reports, and the further studies and information provided by Cuadrilla; and to make appropriate recommendations for the mitigation of seismic risks in the conduct of future hydraulic fracture operations for shale gas.

Conclusions: We agree with the conclusion that the observed seismicity was induced by the hydraulic fracture treatments at Preese Hall. However, we are not convinced by the projected low probability of other earthquakes during future treatments. We believe it is not possible to state categorically that no further earthquakes will be experienced during a similar treatment in a nearby well. The analyses failed to identify a causative fault, and detailed knowledge of faulting in the basin is poor. In the present state of knowledge it is entirely possible that there are critically stressed faults elsewhere in the basin. It is possible that a 3-D seismic reflection survey could help better characterize faulting within the basin.

We also consider that the use of the numerical simulations to estimate maximum likely magnitude of any further earthquake should be treated with some caution, mainly because the model is necessarily simplistic due to lack of data to constrain parameters. Additionally, the numerical simulations fail to model some of the features of the seismic activity such as the low B-value. (On B-values, see background note on seismicity.) However, we consider that the historical record of maximum observed magnitudes from coal-mining induced earthquakes in the UK can be used to provide a realistic upper limit. This leads to a maximum magnitude of ~ 3.0 ML. An event of this size at an expected depth of 2-3 km is unlikely to cause structural damage. There are examples of mining induced earthquakes of similar magnitudes in the UK that caused superficial damage, for example, minor cracks in plaster, but these occurred at shallower depths. Such an event would be strongly felt by people within a few kilometres from the epicenter and could cause some alarm. The critical magnitude suggested by Cuadrilla's consultants to prevent the occurrence of damage is a conservative estimate. An earthquake with a magnitude of 2.6 ML is also unlikely to cause structural damage, even at a shallow depth, though again it may be strongly felt by people close to the epicentre.

Nevertheless, we consider that the maximum magnitude threshold of 1.7 ML, initially proposed for the traffic light system, is undesirably high from the viewpoint of prudent conduct of future operations. Based on this limit, no action would have been taken before the magnitude 2.3 ML event on 1 April 2011. Instead, we recommend a lower limit of 0.5 ML.

We recommend the following specific measures to Department of Energy and Climate Change (DECC) to mitigate the risk of future earthquakes in the Bowland Basin.

1. Hydraulic fracturing procedure should invariably include a smaller pre-injection and monitoring stage before the main injection.

Initially, smaller volumes should be injected, with immediate flow back, and the results monitored for a reasonable length of time. Meanwhile, the fracture diagnostics (microseismic and prefrac injection data) should be analysed to identify any unusual behaviour post-treatment, prior to pumping the job proper.

2. Hydraulic fracture growth and direction should be monitored during future treatments.

This should be done with industry standard microseismic monitoring using either an array of surface or down-hole sensors. Tiltmeters should also be used, if possible. Monitoring of upward fracture growth and containment by complementary diagnostics such as temperature or tracer logs, should also be carried out.

3. Future HF operations in this area should be subject to an effective monitoring system that can provide automatic locations and magnitudes of any seismic events in near real-time.

The system should employ an appropriate number and type of sensors to ensure reliable detection, location and magnitude estimation of seismic events of magnitude -1 ML and above. The number of sensors should also provide an adequate level of redundancy.

4. Operations should be halted and remedial action instituted, if events of magnitude 0.5 ML *or above are detected.*

We consider that this would be a prudent threshold value, to reduce the likelihood of events perceptible to local residents, and to offer a higher margin of safety against any possibility of damage to property. This threshold value can be adjusted over time, if appropriate in the light of developing experience.

Based on the induced seismicity analysis done by Cuadrilla and ourselves, together with the agreement to use more sensitive fracture monitoring equipment and a DECC agreed induced seismic protocol for future operations, the authors of this report see no reason why Cuadrilla Resources Ltd. should not be allowed to proceed with their shale gas exploration activities and recommend cautious continuation of hydraulic fracture operations, at the Preese Hall site.

In respect of future shale gas operations elsewhere in the UK, we recommend that seismic hazards should be assessed prior to proceeding with these operations. This should include:

1. Appropriate baseline seismic monitoring to establish background seismicity in the area of interest.

2. Characterisation of any possible active faults in the region using all available geological and geophysical data.

3. Application of suitable ground motion prediction models to assess the potential impact of any induced earthquakes.

Citation: Department of Energy and Climate Change, *Shale Gas Background Note* (2012)

Topic Area: Induced seismicity during hydraulic fracturing

Jurisdiction: UK

Introduction: This factsheet has been prepared for DECC by Dr C. Green of G Frac Technologies Ltd to assist understanding by non-specialists of the independent experts' report about the induced seismicity during hydraulic fracturing at the Preese Hall site, Lancashire, NW England.

Aims & Research Methods: This background note asks and provides answers to the following questions:

- What is a shale?
- What is different about shales and why are they hydraulically fracture stimulated?
- What is shale gas? Are there other types of unconventional reservoirs?
- Why is interest only now happening in unconventional, and particularly shale?
- What is the history of shale?
- How is shale development technology applied?
- What is hydraulic fracturing? What materials are used for fracturing?
- What techniques are used to analyse the location of the fractures created?
- How are wells designed? How is the well then completed?
- How are hydraulic fracture treatments carried out?

Citation: Peter Styles and Brian Baptie, *Briefing Note Induced Seismicity in the UK and its Relevance to Hydraulic Stimulation for Exploration for Shale Gas* (2011)

Topic Area: Induced seismicity during hydraulic fracturing

Jurisdiction: UK

Introduction: The continental crust of the UK has had a long and complex tectonic history, with a more recent phase of loading and unloading superimposed upon it from the advance and retreat of ice sheets during the last 10,000 years or so. It is crisscrossed by networks of faults, some of which move on a reasonably frequent basis with observable and often felt seismicity, such as the bounding faults of the Welsh Marches and others which have not had recorded seismicity in historic times but may be in a quasi-critical state, in which the rocks store energy which can be released by changes in stress or hydrogeological conditions. The crust can respond by failing in an earthquake, a release of elastic stored energy which can be, and often is, natural seismicity; or can sometimes be due to human activities such as mining, deep quarrying, coal mining, hydrogeological extraction or fluid disposal and activities associated with non-conventional hydrocarbon extraction, which is described as induced seismicity.

Aims & Research Methods: This paper investigates the hydraulic fracturing activities carried out in Lancashire at Preese Hall in 2011 and the following seismic events.

Conclusions: We agree that the hydro fracture process carried out in Lancashire at Preese Hall was the trigger of the sequence of minor seismic events observed near Blackpool between April and June 2011, with the highest on April 1st 2011 with a magnitude of 2.4.However, the state of stress, which was released by these events, was pre-existing, and the hydraulic changes made in hydro fracturing were simply the perturbation which initiated the sequence of events. The sequence may have occurred anyway at some later time (which may be of geological extent!) triggered by some other stress perturbation. Such interactions between tectonic features and anthropogenic activities associated with stimulation procedures used in hydrocarbon exploration of oil and more recently shale gas appear to be relatively rare (Holland 2011 reports a similar sequence with magnitudes from 1.0 to 2.8 in Oklahoma), but are not unknown; and induced seismicity from hard-rock and soft rock (coal, salt, gypsum, anhydrite and other minerals) are much more frequent.

Citation: Toni Harvey, *Guidance Notes for Coalbed Methane and Mines Gas Field Development* (October 2009)

Topic Area: Requirements for coal bed methane and mines gas field development plans.

Jurisdiction: UK

Aims & Research Methods: These notes outline DECC’s requirements for coal bed methane (cbm) and mines gas field development plans.

These notes also explain the arrangements for dealing with fields that cross licence boundaries and where operations are undertaken by a contractor on behalf of Licensees. They also cover licensee residence requirements, field operatorship requirements, the preparation of Field Reports for onshore fields in production and for cessation of production. The notes are intended as a working guide and not as a definitive explanation of the requirements of the model clauses or of the Secretary of State’s powers under them.

Citation: Library of the House of Commons, Patsy Richards, *Shale Gas and Fracking* (17 December 2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: UK

Introduction: UK Continental Shelf (UKCS) production of natural gas in 2011 was well under half the level produced in 2000. The UK has been a net importer of gas since 2004, and imports of natural gas in 2011 were historically high, similar to 2010, a record year. In 2011, for the first time since large scale gas extraction began, UK imports exceeded production.1 The rapid development of shale gas in North America has transformed the gas-market outlook. As early as 2009, announcing the 2009 World Energy Report, the International Energy Agency (IEA) stated that the share of unconventional gas in total US gas output was expected to reach 60% in 2030; Unconventional gas is unquestionably a game-changer in North America with potentially significant implications for the rest of the world. In the US, "unprecedented levels of domestic natural gas production" reduced net imports of natural gas into the US by a quarter in 2011, and several applications have now been made to the US Department of Energy for authorisation to export domestic LNG.2

The IEA World Energy Outlook special report on gas in 20113 described a 'golden age of gas' scenario in which natural gas overtakes coal by 2030, increasing to 25% of the global energy mix by 2035. Unconventional gas resources are now considered to be as large as conventional resources, with conventional recoverable resources equivalent to over 120 years at current global consumption. Aims & Research Methods: The recent rapid development of unconventional gas resources (notably shale gas) in North America has transformed the World gas-market outlook. The company Cuadrilla has been conducting test drilling in Lancashire. On 13 December 2012 the Secretary of State for Energy and Climate Change announced that exploratory hydraulic fracturing (fracking) for shale gas could resume in the UK, after a temporary moratorium following small seismic tremors near Blackpool in April and May 2011. There are several other extant UK onshore petroleum exploration licences which could be looked at for shale gas potential. However, the industry is unlikely to be a 'game-changer' in the UK to the same extent as in the US partly because of restricted resources, notably land area. Also, not all shales are likely to be equally productive, and the British Geological Society has estimated that perhaps only 10-20% of the full UK reserve may be recoverable.

Concerns have been raised regarding resource (land and water) use by fracking, net effects on greenhouse gas emissions and the risk of groundwater contamination, as well as general amenity and planning concerns of local residents opposed to development of this sort. A Royal Society/Royal Academy of Engineering report has concluded that contamination of aquifers is unlikely, and that pollution is most likely to occur through faulty well casings. It called however for the UK's offshore well examination scheme to be adapted for onshore activities, and for further work on the net effects on climate change. This is against the backdrop of the current Energy Bill which seeks to introduce 'clean, secure and affordable' energy supplies. Gas has lower carbon emissions than unabated oil or coal, but not renewable energy sources. However, it has a cheaper up-front cost than renewables or nuclear, and recent Government policy announcements in the 2012 Autumn Statement and in the new Gas Generation Strategy indicate a continuing strong role for gas, and support for shale gas.

Conclusions: During a Westminster Hall debate on the Government's response to the ECC Committee's report on shale gas, the overall consensus was that the Committee, which was broadly supportive of the industry, had taken a balanced and cautious approach. The Committee Chair, Tim Yeo MP, said that maintaining public confidence was absolutely essential, and that shale gas could make a contribution towards energy security and keeping prices down. On 5 December 2012 the Secretary of State laid the Government's *Gas*

Generation Strategy before Parliament. Chapter 5 of this deals with shale gas and says, in summary:

 There are very large quantities of gas in the shales beneath the UK, but not enough is known to estimate what fraction of this could be produced.

 If economic and safe, shale gas could, however, offer new economic opportunities for the UK. DECC will set up an Office for Unconventional Gas and Oil, which, working with Defra and other Government Departments, will join up responsibilities across Government, provide a single point of contact for investors and ensure a simplified and streamlined regulatory process.

 HM Treasury has opened discussions with industry on the appropriate structure of a fair tax regime for future shale gas production, and DECC will consult on how its licensing regime could be modified to support the particular characteristics of shale gas developments. DECC will also consult on an updated Strategic Environmental Assessment with a view to further onshore oil and gas licensing.

 If testing proves positive, shale gas production might commence in the second part

of this decade, but production is likely to grow more slowly than has been seen in the United States.

On the same day, in his Autumn Statement, the Chancellor said: Today, we publish our gas strategy to ensure that we make the best use of lower-cost gas power, including new sources of gas under the land. We are consulting on new tax incentives for shale gas and announcing the creation of a single office so that regulation is safe but simple. We do not want British families and businesses to be left behind as gas prices tumble on the other side of the Atlantic.56 These seem to be sending clear signals of the Government’s support for the industry. The *Energy Bill 2012*, currently before Parliament, includes an Emissions Performance Standard (EPS) set at a level to allow new gas generating plant to be built.

The Committee on Climate Change (CCC) has expressed its concerns about this without a decarbonisation target on the face of the Bill, saying it risks a dash for gas-fired generation instead of low carbon investment. 57 The ECC Committee has also concluded that the EPS proposals could lead to a dash for gas and a ‘lock-in’ to a high carbon system.58 More details can be found in the Library Research Paper on the Energy Bill Even as exploratory drilling resumes in Lancashire, or starts elsewhere, this is some way away from full production drilling, as Charles Hendry noted in July 2012:

Charles Hendry: I think that it will be a while before we see commercial production. The situation here is very different from that in the United States, where, for example, landowners own the mineral rights beneath their homes. That is not the case in this country, so there is not the same economic driver. We are seeing some exciting assessments of the potential, but it will be some time before we see specific licences for development.

Citation: State Conservation Commission, *Best Management Practices Handbook* (1994)

Topic Area: Water Quality Management

Jurisdiction: USA (Nevada)

Introduction: This Handbook of Best Management Practices is intended as a general guidance and information resource to assist agencies, entities and individuals in water quality management activities aimed at reducing or preventing nonpoint source pollution. The handbook is intended to provide the framework for soil and water conservation programs for water quality improvement throughout the State, including areas where waters are not part of major basins or stream systems. The ring binder format is designed to allow for inserting updates and revisions as deemed appropriate by the Nevada Division of Environmental Protection, the Nevada Nonpoint Source Task Force co-operators and the public.

U.S. Environmental Protection Agency (EPA) guidelines define Best Management Practices (BMPs) as "methods, measures or practices to prevent or reduce water pollution, including but not limited to, structural and non-structural controls, operation and maintenance procedures and scheduling and distribution of activities. Usually BMPs are applied as a system of practices rather than a single practice. BMPs are selected on the basis of site-specific conditions that reflect natural background conditions and political, social, economic, and technical feasibility".

Aims & Research Methods: In 1978, through the leadership of the Nevada Division of Conservation Districts, the Conservation Commission, and the Nevada Division of Environmental Protection, the first Handbook of Best Management Practices was developed as part of the water quality management planning process for addressing nonpoint sources of pollution in the nondesignated area in Nevada. The nondesignated area includes the entire state with the exception of Washoe and Clark counties, the Lake Tahoe Basin and the Carson River Basin. This 1994 revision, which was developed through a coordinated effort between these same groups, is applicable for remediating and eliminating nonpoint sources of pollution throughout the entire state.

Nonpoint sources of pollution, which include agriculture, grazing, silviculture, construction, hydrologic and habitat modification, mining, urban runoff and waste disposal, are now recognized as the major causes of water quality degradation in the nation’s streams and rivers. It is also recognized that the most effective means of reducing nonpoint source pollution is through a grass root level, voluntary approach in implementing best management practices and through the cooperative efforts of all those affected by the water quality problems.

In Nevada, the Conservation Districts have provided leadership in soil and water conservation programs for many years and are now in a unique position to spearhead and coordinate programs aimed at reducing nonpoint pollution. By working in cooperation with the Nevada Division of Environmental Protection, National Association of Conservation Districts, U. S. Soil Conservation Service, Agriculture Stabilization Conservation Service and other federal land management agencies, Conservation Districts can develop and implement water quality management plans which incorporate best management practices.

As the state-wide population continues to increase in both urban and rural areas demands placed on our limited surface and ground water resources also increase. Through a cooperative effort to develop water quality management plans which include the implementation of best management practices, it is hoped that the quality of Nevada’s water resources can be improved and maintained. It is also hoped that this Handbook of Best Management Practices will serve as a useful guide toward meeting that goal.

Conclusions: Best Management Practices (BMPs) are utilized to minimize erosion and sedimentation before, during and after development, construction, mining or agricultural projects. Temporary BMPs are designed for relatively short periods of time, before and during a specific project or until permanent BMPs are installed. Permanent BMPs are designed, constructed and maintained to function the entire life of the project and may be retained after the life of the project.

Temporary BMPs are typically designed for periods of up to one year or one winter and spring runoff season and may require a significant amount of maintenance depending on the extent of the surface disturbances and the intensity of precipitation and storm events which occur during the life of the project.

The primary difference between temporary and permanent BMPs is the construction materials and the design life. While a straw bale sediment barrier will function well on a temporary basis, a more permanent barrier or sediment basin would be required for long term or permanent installation. Most large scale development, mining or construction projects install permanent BMPs initially because the life of the project, or the magnitude of the surface disturbance warrants such an approach. A single family dwelling under a construction schedule of nine months, for example, would probably not require permanent BMPs. The specific conditions of the site, the project schedule and the proposed amount of surface disturbance typically govern the number and type of BMPs necessary to prevent nonpoint source pollution.

While any permanent BMP can function as a temporary BMP, temporary BMPs will not function as permanent BMPs. The BMPs contained within this Handbook have not been categorized by "temporary" and "permanent"; rather those BMPs that are temporary are so noted. The reader is directed to specific BMPs for his or her need (i.e. Erosion & Sediment Controls, Soil Stabilization Practices, etc.).

Citation: State of Colorado Oil & Gas Conservation Commission, Bill Ritter, Jr. *Gasland Documentary*: Answers (2012)

Topic Area: Gasland Documentary

Jurisdiction: USA (Colorado)

Introduction: The documentary *Gasland* has attracted wide attention. Among other things, it alleges that the hydraulic fracturing of oil and gas wells has contaminated nearby water wells with methane in a number of states including Colorado. Because an informed public debate on hydraulic fracturing depends on accurate information, the Colorado Oil and Gas Conservation Commission (COGCC) would like to correct several errors in the film's portrayal of the Colorado incidents.

Aims & Research Methods: Based upon our review of hundreds of Colorado gas samples over many years, the COGCC is able to differentiate between biogenic and thermogenic methane using both stable isotope analysis of the methane and compositional analysis of the gas. In the Denver-Julesburg and Piceance Basins, the COGCC has consistently found that biogenic gas contains only methane and a very small amount of ethane, while thermogenic gas contains not just methane and ethane but also heavier hydrocarbons such as propane, butane, pentane, and hexanes.

As explained below, *Gasland* incorrectly attributes several cases of water well contamination in Colorado to oil and gas development when our investigations determined that the wells in question contained biogenic methane that is not attributable to such development.

Conclusions: In addition, a number of recent amendments to the COGCC regulations address concerns raised about hydraulic fracturing:

• Rule 205 requires operators to inventory chemicals, including fracturing fluids, and to provide this information upon request to the COGCC and certain health care professionals;

• Rule 317 requires cement bond logs to confirm that aquifers are protected;

• Rule 317B imposes mandatory setbacks and enhanced environmental precautions on oil and gas development occurring near public drinking water sources;

• Rule 341 requires well pressures to be monitored during hydraulic fracturing;

• Rule 608 mandates additional pressure testing and water well sampling for coal bed methane wells; and

• Rules 903, 904, and 906 impose enhanced requirements for pit permitting, lining, monitoring, and secondary containment to ensure that pit fluids, including hydraulic fracturing flow back, do not leak.

Finally, it should be understood that the COGCC Director, Dave Neslin, offered to speak with *Gasland's* producer, Josh Fox, on camera during the filming of the movie. Because the issues are technical and complex and arouse concerns in many people, Director Neslin asked that he be allowed to review any material from the interview that would be included in the final film. Unfortunately, Mr. Fox declined. Such a discussion might have prevented the inaccuracies noted above.

Citation: Penn State Extension, *Marcellus Shale Gas Well Drilling: Regulations to Protect Water Supplies in Pennsylvania* (2012)

Topic Area: Water Use and Distribution

Jurisdiction: USA (Pennsylvania)

Introduction: Regulatory decisions affecting shale gas exploration with implications for water resources have been made by policy makers at the federal, multi-state, state, and local level. In all cases, regulations originate with legislation, such as Pennsylvania's Oil and Gas Act or the Pennsylvania Clean Streams Law. However, government agency rule-making based on statutes and court decisions interpreting legislation and regulations also affects the impacts of gas drilling on water resources and the environment. As shale gas activities have expanded over the past several years in Pennsylvania, several important changes in agency rules have been made. The decision in 2005 by the U.S. Congress to exempt hydraulic fracturing from the Safe Drinking Water Act has meant that regulating modern shale gas drilling has largely fallen to the states. The primary way in which Pennsylvania regulates shale gas extraction activities is through the state's Oil and Gas Act and via subsequent rulemaking provided in Chapters 78 and 79 of the Department of Environmental Protection's regulations, although a number of state water protection laws also influence aspects of the gas extraction process. The Oil and Gas Act pre-empts local governments from addressing many concerns relating to oil and gas extraction. Accordingly, municipalities may be pre-empted from addressing water supply protection. Decisions by the two multi-state river basin commissions covering the eastern and central parts of Pennsylvania have played a key role in managing water resources as shale gas development has expanded in the state. In 2010 and 2011, DEP finalized regulations covering allowable total dissolved solids in all oil and gas wastewater and improved well casing standards (see below). Many experts now expect a more stable regulatory climate in Pennsylvania for at least several years.

Aims & Research Methods: This publication summarizes the relevant components of the Oil and Gas Act, and the newly implemented regulations affecting gas well drilling and water supplies under authority of various environmental laws.

Conclusions: The Marcellus shale resource is being developed rapidly. Government agencies at all levels are struggling to keep pace. New technologies are being tried in both the resource development process and in managing environmental and water quality/quantity impacts. The recent implementation of the TDS standards and the strengthened well casing regulations, and the current political climate, have many observers expecting a more stable regulatory environment for several years. However, some stakeholders believe that the new technologies (e.g., deeper wells and horizontal drilling) make major parts of the state's Oil and Gas Act out of date. They favour significantly revising and updating the act through legislative action. There has been much activity by the regional river basin commissions concerning Marcellus water-related issues, and this activity may continue. A bill (the "FRAC Act," S. 587) to amend the Safe Drinking Water Act to repeal the exemption of fracking was reintroduced in Congress in March 2011. The U.S. Environmental Protection Agency announced in March 2010 that it would study "potential human health and water quality threats" from fracking. A draft report should be available in 2012. Check back frequently to the sites listed in the Resources section below for updated information on this complex issue.

Citation: Lisa Sumi, Shale Gas: *Focus on the Marcellus Shale* (2008)

Topic Area: Shale Gas Exploration and Practices

Jurisdiction: USA

Introduction: Natural gas prices have steadily increased over the past few years. This has spurred interest in the development of "unconventional" gas resources, such as gas shales. The U.S. Energy Information Administration projects that by 2030, half of the natural gas produced in the U.S. will be from unconventional sources. In 2005, approximately 10 trillion cubic feet (TCF) of conventional gas was produced in the U.S., versus 8 TCF of unconventional gas. Natural gas from shale accounted for about 6% of the gas produced in the U.S. (1.1 TCF). The majority of U.S. gas shale production came from four basins:

San Juan Basin, New Mexico/Colorado - 55 million cubic feet per day (mmcf/d)

Antrim Shale, Michigan - 384 mmcf/d

Appalachian/Ohio shales – 438 mmcf/d

Barnett Shale, Fort Worth Basin, Texas - 1,233 mmcf/d

Exploratory gas-shale drilling is occurring across the country. Some of the areas include: the Devonian shale in the Appalachian Basin; the MO wry shale in the Powder River Basin; the Mancos shale in the Uinta Basin; the Woodford shale in the Ardmore Basin; a Floyd/Neal shale play in the Black Warrior Basin; the Barnett shale in the Permian Basin; the New Albany shale in the Illinois Basin; and others.

Aims & Research Methods: This report focuses on the *Marcellus shale*, located in the Appalachian region of the U.S. Interest and exploratory drilling in the Marcellus shale is on the rise. This report was created to highlight some of the potential issues that may be important to consider if full-scale development occurs in the Marcellus shale. The information is based on experiences in other gas shale regions where development is in more advanced stages. Readers should be cautioned, however, not to assume that what has occurred in any other gas shale basin will necessarily occur in the Marcellus shale. There can be significant differences from one gas shale basin to another; and even within the same gas shale formation.

Citation: US Department of Energy, *Shale Gas: Appling Technology to Solve America's Energy Challenges* (2012)

Topic Area: Hydraulic Fracturing Activities and Shale Gas Development

Jurisdiction: USA

Introduction: The presence of natural gas—primarily methane—in the shale layers of sedimentary rock formations that were deposited in ancient seas has been recognized for many years. The difficulty in extracting the gas from these rocks has meant that oil and gas companies have historically chosen to tap the more permeable sandstone or limestone layers which give up their gas more easily.

But American ingenuity and steady research have led to new ways to extract gas from shales, making hundreds of trillions of cubic feet of gas technically recoverable where they once were not.

New technologies are also being applied to make certain that the process of drilling for this valuable resource minimizes environmental impacts.

Aims & Research Methods: This report provides information relating to shale gas development, hydraulic fracturing and the DOE research.

Conclusions: Currently, NETL is actively involved in advancing technologies that can help producers develop shale gas resources in the most environmentally responsible manner. Research is under way to find improved ways to treat fracture flow back water so that it can be reused or easily disposed of and to reduce the "footprint" of shale gas operations so that there is less disruption of the surface during drilling and completion operations.

DOE is refocusing the work done under Section 999 (Subtitle J) of the Energy Policy Act of 2005 on safety, environmental sustainability, and quantifying the risks of exploration and production activity.

Citation: US Department of Energy, *Modern Shale Gas Development in the United States: A Primer* (April 2009)

Topic Area: Shale Gas Development

Jurisdiction: USA

Introduction: Water and energy are two of the most basic needs of society. Our use of each vital resource is reliant on and affects the availability of the other. Water is needed to produce energy and energy is necessary to make water available for use. As our population grows, the demands for both resources will only increase. Smart development of energy resources will identify, consider, and minimize potential impacts to water resources. Natural gas, particularly shale gas, is an abundant U.S. energy resource that will be vital to meeting future energy demand and to enabling the nation to transition to greater reliance on renewable energy sources. Shale gas development both requires significant amounts of water and is conducted in proximity to valuable surface and ground water. Hence, it is important to reconcile the concurrent and related demands for local and regional water resources, whether for drinking water, wildlife habitat, recreation, agriculture, industrial or other uses. Because shale gas development in the United States is occurring in areas that have not previously experienced oil and gas production, the GWPC has recognized a need for credible, factual information on shale gas resources, technologies for developing these resources, the regulatory framework under which development takes place, and the practices used to mitigate potential impacts on the environment and nearby communities. While the GWPC's mission primarily concerns water resources, this Primer also addresses no water issues that may be of interest to citizens, government officials, water supply and use professionals, and other interested parties.

Aims & Research Methods: This Primer on Modern Shale Gas Development in the United States was commissioned through the Ground Water Protection Council (GWPC). It is an effort to provide sound technical information on and additional insight into the relationship between today's fastest growing, and sometimes controversial, natural gas resource development activity, and environmental protection, especially water resource management. The GWPC is the national association of state ground water and underground injection agencies whose mission is to promote the protection and conservation of ground water resources for all beneficial uses. One goal of the GWPC is to provide a forum for stakeholder communication on important current issues to foster development of sound policy and regulation that is based on sound science. This Primer is presented in the spirit of furthering that goal. Each state has laws and regulations to ensure the wise use of its natural resources and to protect the environment. The GWPC has conducted a separate study to summarize state oil and gas program requirements that are designed to protect water resources. These two studies complement one other and together provide a body of information that can serve as a basis for fact-based dialogue on how shale gas development can proceed in an environmentally responsible manner under the auspices of state regulatory programs. This Shale Gas Primer was intended to be an accurate depiction of current factors and does not represent the view of any individual state. Knowledge about shale gas development will continue to evolve. The GWPC welcomes insights that readers may have about the Primer and the relationship of shale gas development to water resources.

Conclusions: The primary differences between modern shale gas development and conventional natural gas development are the extensive use of horizontal drilling and multi-stage hydraulic fracturing. Horizontal drilling allows an area to be developed with substantially fewer wells than would be needed if vertical wells were used. The overall process of horizontal drilling varies little from conventional drilling, with casing and cementing being used to protect fresh and treatable groundwater. The use of horizontal drilling has not introduced new environmental concerns. On the contrary, the reduced number of horizontal wells needed, coupled with multiple wells drilled from a single pad, has significantly reduced surface disturbances and the associated impacts to wildlife and impacts from dust , noise, and traffic. Where shale gas development has intersected with urban and industrial settings, regulators and industry have developed special practices to help reduce community impacts, impacts to sensitive environmental resources, and interference with existing businesses. Hydraulic fracturing has been a key technology in making shale gases an affordable addition to the Nation's energy supply, and the technology has proven to be a safe and effective stimulation technique. Ground water is protected during the shale gas fracturing process by a combination of the casing and cement that is installed when the well is drilled and the thousands of feet of rock between the fracture zone and any fresh or treatable aquifers. The multi-stage hydraulic fracture operations used in horizontal wells may require 3 to 4 million gallons of water. Since it is a relatively new use in these areas, withdrawals for hydraulic fracturing must be balanced with existing water demands. Once the fracture treatment is completed, most of the fracture water comes back to the surface and must be managed in a way that conserves and protects water resources. While challenges continue to exist with water availability and water management, innovative regional solutions are emerging that allow shale gas development to continue while ensuring that the water needs of other users can be met and that surface and ground water quality is protected. An additional consideration in shale gas development is the potential for low levels of naturally occurring radioactive material (NORM) to be brought to the surface. While NORM may be encountered in shale gas operations, there is negligible exposure risk for the general public and there are well established regulatory programs that ensure public and worker safety Although the use of natural gas offers a number of environmental benefits over other fossil energy sources, some air emissions commonly occur during exploration and production activities. EPA sets standards, monitors the ambient air quality across the U.S., and has an active enforcement program to control air emissions from all sources, including the shale gas industry. Gas field emissions are controlled and minimized through a combination of government regulation and voluntary avoidance, minimization, and mitigation strategies. Taken together, state and federal requirements, along with the technologies and practices developed by industry, serve to protect human health and to help reduce environmental impacts from shale gas operations.

Citation: Ground Water Protection Council, *State Oil and Gas Agency Groundwater Investigations And Their Role in Advancing Regulatory Reforms A Two-State Review: Ohio and Texas* (August 2011)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: State oil and gas regulatory agencies place great emphasis on protecting groundwater resources. Agencies typically have broad authority to promulgate regulations, establish field rules, issue orders or directives, inspect permitted activities, enforce regulatory standards, require reports, and order corrective action for all phases of oil and gas exploration and production (E&P) activities from site preparation through eventual plugging, and final site reclamation. Oil and gas statutes typically include broad performance-based standards that establish the necessary authority to protect human health, safety, and the environment, while prohibiting contamination of surface and groundwater. State regulatory agencies also issue permits that establish site- specific terms and conditions for site development, drilling, and well construction that may be tailored to address site or region-specific groundwater resource protection concerns. In addition to regulatory requirements, state agencies employ a variety of non-regulatory processes to supplement existing standards such as:

1.Developing standard operating procedures;
2.Creating industry guidance documents;
3.Training and certifying inspectors;
4.Establishing risk-based inspection priorities;
5.Managing inspection and compliance history records;
6.Utilizing enhanced data management systems; and
7.Sponsoring and conducting research.

These regulatory and non-regulatory processes are designed to collectively manage risk and provide the regulated industry with a framework for successful development of oil and gas resources while protecting public safety and the environment. A central objective of every state oil and gas agency is to prevent groundwater contamination. A report published in May 2009 by the Ground Water Protection Council (GWPC), State Oil and Gas Regulations Designed to Protect Water Resources, recognized a number of factors that have shaped the evolution of state oil and gas regulations that protect groundwater resources including: (1) the passage of federal environmental laws beginning in the 1970s; (2) peer reviews conducted by the GWPC for state-administered Class II Underground Injection Control (UIC) State Oil and Gas Agency Groundwater Investigations

Aims & Research Methods: This study categorizes state determinations regarding causes of groundwater contamination resulting from the oil and gas industry E&P activities based on a review of agency records and discussions with agency personnel in two selected states: Ohio and Texas. This study also evaluates how those findings have contributed to the evolution of state regulatory authority and improvement of standard industry practices. The GWPC provides a forum for state groundwater protection officials to meet and discuss groundwater resource issues and policies with the regulated community, Non-Governmental Organizations (NGOs), and the public. The GWPC advocates development of policies and regulations that are supported by “sound science”. To determine the cause of contamination, incident investigations must be supported by sufficient facts and data collected according to standard methods and protocols. The data must then be interpreted and analysed by qualified experts who apply accepted scientific principles within their specialized fields, including hydrogeology, petroleum engineering, aqueous chemistry, and geophysics. This report describes how these two state agencies have utilized the findings of groundwater investigations to prioritize and implement regulatory reforms.

Conclusions:

1. Investigation Findings are Drivers of Regulatory Reform:

All land use and energy development activities present some level of associated environmental and public safety risk. There are no risk-free energy development options. State agencies use groundwater investigation findings as an important tool for identifying risks and deficiencies in their regulatory schemes. The findings and determinations of state agency groundwater investigations are important drivers of regulatory reform and improved industry practice. By identifying activities and patterns of failure resulting in groundwater contamination, state agencies prioritize regulatory reforms and strategically apply resources to improve standards that reduce risk associated with state-specific compliance issues. Over time, both Ohio and Texas have strategically enhanced regulatory standards for state-specific oil and gas E&P activities that have been found to cause groundwater contamination incidents. Dissimilarities in the scope and scale of regulated activities, land usage, groundwater usage, population densities, climatic, and geologic factors have contributed to the unique evolution of their respective regulatory programs.

2. Investigations are Applied Science: Groundwater investigations are exercises in applied science. An agency determination regarding the cause of groundwater contamination is a testable hypothesis. Investigations are typically conducted by a team of specialists including inspectors and geo-scientists. Determinations must be supported by sufficient facts and data that are collected and analysed according to standard methods and protocols. Data and evidence must be interpreted and analysed by specialists that apply scientific principles that are generally accepted within fields including: geology, hydrogeology, aqueous chemistry, geophysics, and petroleum engineering. Investigation findings and determinations are subject to review and testing, informally or formally through contested legal proceedings. Agency specialists must be able to establish their credentials as experts in order to present evidence and professional opinions during these review processes. This testing process, that is foundational to science, serves to filter and discard conclusions that are based on speculation, conjecture, or insufficient evidence.

3. Sound Science is Foundational to Good Public Policy: Regulatory proposals and policy should reflect sound science. Speculative conclusions and opinions about possible groundwater contamination incidents that are based solely upon anecdotes, innuendo, and oversimplified chronologies are not a sufficient foundation to advance national or state regulatory reforms or policies. While state investigation findings should not be viewed as inerrant, they are typically conducted by experienced and qualified personnel who recognize that their evidence, findings, and conclusions may face scrutiny under appeal, or peer review. Accordingly, state agency investigation findings and determinations, associated rulings by commissions that hear appeals, and court decisions should be valued and taken seriously when amending regulatory schemes and establishing new policies.

4. Incidents are Caused by Diverse Activities: In addition to contamination caused by legacy practices and orphaned sites, Ohio and Texas investigators have identified groundwater contamination caused by a wide range of regulated industry practices. Appropriately, Ohio and Texas have focused regulatory attention on those activities that have caused the majority of groundwater contamination incidents. In recent years, the national debate on natural gas E&P has been focused nearly exclusively on a single, brief, yet essential activity, hydraulic fracturing. Neither state has identified hydraulic fracturing as the cause of a single documented groundwater contamination incident. However, it has become increasingly apparent that in much of the popular literature, the term “hydraulic fracturing” has become synonymous with any and every E&P activity that can impact groundwater. When developing public policy, it is critical to differentiate activities that can contribute to groundwater contamination in order to accurately target and prioritize reforms. As in the practice of medicine, the physician must accurately diagnose the specific cause of an ailment, in order to prescribe the appropriate remedy. Although many states, including Ohio and Texas, have implemented or are considering new regulations that significantly improve documentation of hydraulic fracturing operations, including public disclosure of chemical

additives in fracturing fluids, it is critical that states maintain an appropriate focus on activities and practices that are actually found to cause groundwater contamination.

5. Regulatory Evolution is a Continuing Process: Both Ohio and Texas have demonstrated a commitment to the protection of groundwater resources as evidenced by the scope of regulatory amendments that have been advanced since the early 1980s. While these regulatory efforts are commendable, both states should continue to evaluate, update, and amend regulations in response to new technologies, evolving effective management practices, peer review recommendations such as those provided through the STRONGER process, and groundwater investigation findings and determinations. The goal should be to prevent contamination to the extent reasonably possible.

http://www.halliburton.com/public/solutions/contents/shale/related_docs/H063771.pdf

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Citation: Halliburton, *US Shale Gas An Unconventional Resources. Unconventional Challenges (White Paper)* (2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Introduction: Across the U.S., from theWest Coast to the Northeast, some 19 geographic basins are recognized sources of shale gas, where an estimated 35,000 wells were drilled in 2006. Presently, significant commercial gas shale production occurs in the Barnett Shale in the FortWorth Basin, Lewis Shale in the San Juan Basin, Antrim Shale in the Michigan Basin, Marcellus Shale and others in the Appalachian Basin, and New Albany Shale in the Illinois Basin. But it wasn't always so. Lacking an efficient means of production, U.S. shale gas reserves were largely ignored so long as market conditions made reserves more costly to produce than conventional sources. In fact, one of the first recognized major shale gas plays, the Barnett Shale of Texas, was under investigation as early as 1981, but not until 1995 was the hydraulic fracturing technology available that successfully brought in the gas at commercial rates. Then, five of the initial six wells each began producing more than two million cubic feet of gas per day and, soon after, introduction of horizontal drilling began to extend the basin where today two percent of all the gas consumed daily in the U.S. is produced.

Aims & Research Methods: Current increasing demand and lagging supply mean high prices for both oil and gas, making exploitation of North American unconventional gas plays suddenly far more lucrative for producers. One of the most important such plays to emerge has been U.S. shale gas, with current recoverable reserves conservatively estimated at 500 to 1,000 trillion cubic feet. Hydraulic fracturing and horizontal drilling are the key enabling technologies that first made recovery of shale gas economically viable with their introduction in the Barnett Shale of Texas during the 1990s. However, a comparison of the currently hottest shale plays makes it clear that, after two decades of development and several iterations of the learning curve, best practices are application-dependent and must evolve locally. That said, a review of current trends in these hot plays indicates that, in many cases, the impact of high-drilling density required to develop continuous gas accumulations can be minimized through early and better identification of the accumulation type and size, well-designed access and transportation networks, and cooperative planning and construction efforts, when possible.

Conclusions: As a source of abundant, high-quality natural gas, the potential of U.S. shale gas has only begun to be realized. While the challenges to producers may be significant—and significantly different from play to play—they are not insurmountable, providing the right technology and experience are on hand. While conventional horizontal directional drilling technologies have been used to drill shale gas wells, in almost every case, the rock around the wellbore must be hydraulically fractured before the well can produce significant amounts of gas, and the cost of fracturing horizontal wells can be as much as 25 percent of the total cost of the well. To keep development costs under control, there will be a need for improved exploration, production efficiencies and best practices that combine current knowledge and new approaches.

In most cases, multiwall drilling can afford improved efficiencies in hydraulic frac stimulation operations, enhancing the percentage of recoverable gas to boost production rates over the economic threshold, while pad drilling of several multilateral wells from a single pad will further improve the economies-of-scale and help reduce location costs while generating a minimal environmental footprint. The unconventional challenges of shale gas drilling demand higher levels of service intensity. Halliburton is uniquely positioned to respond with integrated solutions for more productive and cost effective shale exploitation.

Citation: USGS, Prepared in cooperation with (in alphabetical order) the Arkansas Natural Resources Commission, Arkansas Oil and Gas Commission, Duke University, Faulkner County, Shirley Community Development Corporation, and the University of Arkansas at Fayetteville, and the U.S. Geological Survey Groundwater Resources Program, *Shallow Groundwater Quality and Geochemistry in the Fayetteville Shale Gas-Production Area,* North-Central Arkansas, 2011 (2011)

Topic Area: Groundwater Quality

Jurisdiction: USA

Introduction: The study area is located in north-central Arkansas in Van Buren and Faulkner Counties; four of the sampling locations were slightly outside of these two counties but near to the county lines. The Fayetteville Shale gas-production area is approximately 2,500 square miles, and wells sampled for this study were distributed across an approximate area of 850 square miles or about one-third of the total gas-production area.

Aims & Research Methods: The purpose of this report is to describe general water quality and geochemistry of shallow groundwater in the Fayetteville Shale gas-production area in north-central Arkansas and evaluate the potential effects, if any, from activities related to shale-gas drilling and production. Groundwater wells were sampled during 2011 in two counties of north-central Arkansas: Van Buren County and Faulkner County. This report presents and assesses field and inorganic water-quality data, including major ions, trace metals, methane gas, and selected isotopes. Any constituents, notably organic compounds, that might have been added to fracturing fluids for gas drilling were not analysed for this study.

Conclusions: Although preproduction water-quality data were lacking for the wells sampled for this study, geochemical data presented a well-defined pattern of geochemical evolution based on natural rock-water and microbial mediated processes, strongly suggesting that the resulting water quality is derived from these natural processes with no effects from gas-production activities. Results from the groundwater quality monitoring activities for this study provide a baselines range and variation of geochemistry for the shallow groundwater in the study area, which can be used to assess future potential changes to groundwater quality in the area of gas production from the Fayetteville Shale

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Citation: Accenture, *Water and Shale Gas Development Leveraging the US experience in new shale developments* (2012)

Topic Area: Water Use and Distribution

Jurisdiction: USA

Introduction: Natural gas production in the United States has grown significantly in recent years as improvements in horizontal drilling and hydraulic fracturing technologies have made it commercially viable to recover gas trapped in tight formations, such as shale and coal. The United States is now the number one natural gas producer in the world and, together with Canada, accounts for more than 25 percent of global natural gas production.1 Shale gas will play an ever-increasing role in this resource base and is projected to increase to 49 percent of total US gas production by 2035, up from 23 percent in 2010, highlighting the significance of shale gas in the US energy mix in the future. Lower and less volatile prices for natural gas in the past two years reflect these new realities, with benefits for American consumers and the nation's competitive and strategic interests, including the revitalization of several domestic industries.

Aims & Research Methods: Global development of shale gas resources has the potential to expand significantly outside the United States. However, there continue to be environmental concerns, particularly with respect to water use. As operators outside the United States explore shale gas, there are many lessons that can be taken from the United States' experience. This paper highlights areas that operators of new shale developments should consider. It also includes an analysis of considerations for Argentina, China, Poland and South Africa focusing on water regulation, water use and management, and water movements during shale gas development.

Conclusions: The trends toward disclosure, holistic impact assessments, resource intensity and water management described in this study will have significant implications for operators. Not only will changes be required to maintain compliance, but also the requirements will create opportunities for competitive advantage in operations, particularly for larger operators.

Citation: EPA, *Investigation of Ground Water Contamination near Pavillion, Wyoming* (Draft) (December 2011)

Topic Area: Ground Water Contamination

Jurisdiction: USA

Introduction: The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. The scientific arm of EPA, the Office of Research and Development (ORD), conducts leading-edge research that helps provide the solid underpinning of science and technology for the Agency. The work at ORD laboratories, research centres, and offices across the country helps improve the quality of air, water, soil, and the way we use resources. The research described in this report was designed and conducted by ORD's National Risk Management Research Laboratory in Ada, Oklahoma, working in close collaboration with scientists from EPA Region 8 in Denver, Colorado.

Aims & Research Methods: In response to complaints by domestic well owners regarding objectionable taste and odour problems in well water, the U.S. Environmental Protection Agency initiated a ground water investigation near the town of Pavillion, Wyoming under authority of the Comprehensive Environmental Response, Compensation, and Liability Act. The Wind River Formation is the principal source of domestic, municipal, and stock (ranch, agricultural) water in the area of Pavillion and meets the Agency's definition of an Underground Source of Drinking Water. Domestic wells in the area of investigation overlie the Pavillion gas field which consists of 169 production wells which extract gas from the lower Wind River Formation and underlying Fort Union Formation. Hydraulic fracturing in gas production wells occurred as shallow as 372 meters below ground surface with associated surface casing as shallow as 110 meters below ground surface. Domestic and stock wells in the area are screened as deep as 244 meters below ground surface. With the exception of two production wells, surface casing of gas production wells do not extend below the maximum depth of domestic wells in the area of investigation. At least 33 surface pits previously used for the storage/disposal of drilling wastes and produced and flow back waters are present in the area. The objective of the Agency's investigation was to determine the presence, not extent, of ground water contamination in the formation and if possible to differentiate shallow source terms (pits, septic systems, agricultural and domestic practices) from deeper source terms (gas production wells). The Agency conducted four sampling events (Phase I - IV) beginning in March 2009 and ending in April, 2011. Ground water samples were collected from domestic wells and two municipal wells in the town of Pavillion in Phase I. Detection of methane and dissolved hydrocarbons in several domestic wells prompted collection of a second round of samples in January, 2010 (Phase II). During this phase, EPA collected additional ground water samples from domestic and stock wells and ground water samples from 3 shallow monitoring wells and soil samples near the perimeter of three known pit locations. Detection of elevated levels of methane and diesel range organics (DRO) in deep domestic wells prompted the Agency to install 2 deep monitoring wells screened at 233 - 239 meters (MW01) and 293 - 299 meters (MW02) below ground surface, respectively, in June 2010 to better evaluate to deeper sources of contamination. The expense of drilling deep wells while utilizing blowout prevention was the primary limiting factor in the number of monitoring wells installed. In September 2010 (Phase III), EPA collected gas samples from well casing from MW01 and MW02. In October 2010, EPA collected ground water samples from MW01 and MW02 in addition to a number of domestic wells. In April 2011 (Phase IV), EPA resampled the 2 deep monitoring wells to compare previous findings and to expand the analyse list to include glycols, alcohols, and low molecular weight acids.

Conclusions: The objective of this investigation was to determine the presence of ground water contamination in the Wind River Formation above the Pavillion gas field and to the extent possible, identify the source of contamination. The combined use of shallow and deep monitoring wells allowed differentiation between shallow sources of contamination (pits) and deep sources of contamination (production wells). Additional investigation is necessary to determine the areal and vertical extent of shallow and deep ground water contamination.

Detection of high concentrations of benzene, xylenes, gasoline range organics, diesel range organics, and total purgeable hydrocarbons in ground water samples from shallow monitoring wells near pits indicates that pits are a source of shallow ground water contamination in the area of investigation. Pits were used for disposal of drilling cuttings, flow back, and produced water. There are at least 33 pits in the area of investigation. When considered separately, pits represent potential source terms for localized ground water plumes of unknown extent. When considered as whole they represent potential broader contamination of shallow ground water. A number of stock and domestic wells in the area of investigation are fairly shallow (e.g., < 30 m) representing potential receptor pathways. EPA is a member of a stakeholder group working with the operator to determine the areal and vertical extent of shallow ground water contamination caused by these pits. The operator of the site is currently engaged in investigating and remediating several pit areas. Detection of contaminants in ground water from deep sources of contamination (production wells, hydraulic fracturing) was considerably more complex than detection of contaminants from pits necessitating a multiple lines of reasoning approach common to complex scientific investigations. In this approach, individual data sets and observations are integrated to formulate an explanation consistent with each data set and observation. While each individual data set or observation represents an important line of reasoning, taken as a whole, consistent data sets and observations provide compelling evidence to support an explanation of data. Using this approach, the explanation best fitting the data for the deep monitoring wells is that constituents associated with hydraulic fracturing have been released into the Wind River drinking water aquifer at depths above the current production zone.

Citation: Australia China Environment Development Plan Water Entitlements and Trading Project, *Water Entitlements and Trading in Queensland* (2012)

Topic Area: Water Use and Distribution

Jurisdiction: Australia (QLD)

Aims & Research Methods: This paper has been prepared to provide an overview of the water entitlements and trading framework in place in Queensland. It has been prepared specifically for input to the Australia/China Water Entitlements and Trading project. In some instances, processes or requirements have been slightly simplified or generalisations have been made for ease of explanation. This paper focuses on water management arrangements in Queensland. It can be viewed though as representative of arrangements in Australia generally. Water reform in Australia over the past decade has been predominantly driven by a series of agreements between the Australian and State governments. Under these agreements the States have agreed to introduce a range of reforms related to water management. Consequently, while the detail in respect of how water reform has been introduced in different States varies, the principles applied in each have been the same.

Conclusions: Look out for unintended consequences: Establishing water rights and allowing for trading can result in many unexpected and unintended consequences. In Queensland, the introduction of WET has impacted on areas as diverse as local government rates (which were set based on unimproved land values, and thus affected by the separation of land and water rights), estate law (because of how wills typically define the rights a person passes to another person on their death) and capital gains tax (because water rights are now regarded as a separate asset for tax purposes). While none of these Water Entitlements and Trading in Queensland particular issues may be of relevance in China, what is important to note is the range of different areas that can be affected by changes to the way water rights are defined. Ensure the community understands the importance of a WET system: Obtaining community acceptance of the water reform (particularly amongst water users) has been a long and challenging process. Developing compliance and support amongst water users has been dependent on demonstrating both the benefits of the new system (in terms of the increased certainty and flexibility granted to water users) as well as ensuring adequate sanctions for those who don't comply. Certainly there is evidence of major shifts in community attitudes over the past decade to water management. For example, in some areas where there was originally great opposition to moves to regulate the take of overland flow, many water users now realise that such regulation is essential to protect their existing water rights, and are more supportive of this type of approach. Ensure a universal approach to water management: Increasing regulation on one type of water (e.g. surface water) inevitably leads to increased pressure on other sources. Any management arrangements should there for address all sources at the same time. In Queensland, like elsewhere in the world, management of groundwater is generally more difficult and t times there has been a reluctance to address groundwater management issues (because of this difficulty) and efforts have focussed on surface water. This has been to the clear detriment of all concerned. Address problems sooner rather than later: While this is an obvious lesson, it is still worth stating. Where there have been emerging issues – such as problems associated with the unregulated taking of overland flow water – delays in addressing these issues have only compounded the problem and made a solution more difficult to find. Where it is evident that regulatory intervention will be necessary, decision makers should be encouraged to intervene as soon as possible. Recognise the value of water rights: Where water rights have now been separated from the title to land, the new water rights are in some cases worth more money than the residual land title. A WET framework needs to recognise the high economic value of water rights. This is particular important in setting appropriate penalties for breaching laws relating to the taking of water. Where the value of water is high, a small fine for taking water illegally will not act as an adequate disincentive. Be aware of the time and cost involved: The process of implementing a WET system is a long and costly one. In Queensland – a State with a small population, relatively few water-related environmental problems, and relatively few over-allocated catchments – the water reform process has taken more than 10 years and hundreds of millions of dollars and is still not completed. Consequently it is important to prioritise the various aspects of implementing a WET system, to identify the areas where the biggest threats exist and where greatest benefits from the introduction of WET can be obtained and to concentrate efforts in those areas.

Citation: IEA, *Golden Rules for a Golden Age of Gas World Energy Outlook*

Special Report on Unconventional Gas (November 2012)

Topic Area: World Energy Outlook

Jurisdiction: Global

Introduction: Natural gas is poised to enter a golden age, but will do so only if a significant proportion of the world's vast resources of unconventional gas – shale gas, tight gas and coal bed methane – can be developed profitably and in an environmentally acceptable manner. Advances in upstream technology have led to a surge in the production of unconventional gas in North America in recent years, holding out the prospect of further increases in production there and the emergence of a large-scale unconventional gas industry in other parts of the world, where sizeable resources are known to exist. The boost that this would give to gas supply would bring a number of benefits in the form of greater energy diversity and more secure supply in those countries that rely on imports to meet their gas needs, as well as global benefits in the form of reduced energy costs.

Yet a bright future for unconventional gas is far from assured: numerous hurdles need to be overcome, not least the social and environmental concerns associated with its extraction. Producing unconventional gas is an intensive industrial process, generally imposing a larger environmental footprint than conventional gas development. More wells are often needed and techniques such as hydraulic fracturing are usually required to boost the flow of gas from the well. The scale of development can have major implications for local communities, land use and water resources. Serious hazards, including the potential for air pollution and for contamination of surface and groundwater, must be successfully addressed. Greenhouse-gas emissions must be minimised both at the point of production and throughout the entire natural gas supply chain. Improperly addressed, these concerns threaten to curb, if not halt, the development of unconventional resources. The technologies and know-how exist for unconventional gas to be produced in a way that satisfactorily meets these challenges, but a continuous drive from governments and industry to improve performance is required if public confidence is to be maintained or earned. The industry needs to commit to apply the highest practicable environmental and social standards at all stages of the development process. Governments need to devise appropriate regulatory regimes, based on sound science and high-quality data, with sufficient compliance staff and guaranteed public access to information. Although there is a range of other factors that will affect the development of unconventional gas resources, varying between different countries, our judgement is that there is a critical link between the way that governments and industry respond to these social and environmental challenges and the prospects for unconventional gas production.

Aims & Research Methods: This report, in the *World Energy Outlook* series, treats these aspirations and anxieties with equal seriousness. It features two new cases: a Golden Rules Case, in which the highest practicable standards are adopted, gaining industry a "social licence to operate"; and its counterpart, in which the tide turns against unconventional gas as constraints prove too difficult to overcome.

The report:

„. Describes the unconventional gas resource and what is involved in exploiting it.

„. Identifies the key environmental and social risks and how they can be addressed.

„. Suggests the Golden Rules necessary to realise the economic and energy security benefits while meeting public concerns.

„. Spells out the implications of compliance with these rules for governments and industry, including on development costs.

„. Assesses the impact of the two cases on global gas trade patterns and pricing, energy security and climate change.

We have developed a set of "Golden Rules", suggesting principles that can allow policymakers, regulators, operators and others to address these environmental and social impacts. We have called them Golden Rules because their application can bring a level of environmental performance and public acceptance that can maintain or earn the industry a "social licence to operate" within a given jurisdiction, paving the way for the widespread development of unconventional gas resources on a large scale, boosting overall gas supply and making the golden age of gas a reality.

The Golden Rules underline that full transparency, measuring and monitoring of environmental impacts and engagement with local communities are critical to addressing public concerns. Careful choice of drilling sites can reduce the above-ground impacts and most effectively target the productive areas, while minimising any risk of earthquakes or of fluids passing between geological strata. Leaks from wells into aquifers can be prevented by high standards of well design, construction and integrity testing. Rigorous assessment and monitoring of water requirements (for shale and tight gas), of the quality of produced water (for coal bed methane) and of waste water for all types of unconventional gas can ensure informed and stringent decisions about water handling and disposal. Production related emissions of local pollutants and greenhouse-gas emissions can be reduced by investments to eliminate venting and flaring during the well-completion phase. We estimate that applying the Golden Rules could increase the overall financial cost of development a typical shale-gas well by an estimated 7%. However, for a larger development project with multiple wells, additional investment in measures to mitigate environmental impacts may be offset by lower operating costs.

In our Golden Rules Case, we assume that the conditions are in place, including approaches to unconventional gas development consistent with the Golden Rules, to allow for a continued global expansion of gas supply from unconventional resources, with far-reaching consequences for global energy markets. Greater availability of gas has a strong moderating impact on gas prices and, as a result, global gas demand rises by more than 50% between 2010 and 2035. The increase in demand for gas is equal to the growth coming from coal, oil and nuclear combined, and ahead of the growth in renewables. The share of gas in the global energy mix reaches 25% in 2035, overtaking coal to become the second-largest primary energy source after oil.

Conclusions: The prospects for unconventional gas production in Australia hinge to a large degree on whether policy-makers and the industry itself can sustainably manage the associated environmental risks on a basis that retains public confidence in the outcomes. In the Golden Rules Case, this is achieved, with unconventional gas output continuing to expand rapidly, reaching about 60 bcm by 2020 and 110 bcm in 2035. Coalbed methane contributes almost all of this increase, with shale gas production growing more slowly. As a result, total gas production more than triples, with unconventional gas accounting for more than half of gas output after 2020 (Figure 3.11). The projected level of coal bed methane production for 2020 assumes that the four LNG-export projects in Queensland proceed as planned and enter the market before the large increase in unconventional production in other countries, notably China, gains momentum.

Gas production is driven primarily by exports, based on both conventional and unconventional sources, which rise by 100 bcm in the Golden Rules Case. Exports reach 80 bcm in 2020, based on developments under construction, and continue to grow throughout the projection period. The value of those exports increases seven-fold to just over $55 billion in 2035 (in year-2010 dollars). In both the Golden Rules and Low Unconventional Cases, east coast Australian domestic prices rise towards the export netback price (the delivered export price less liquefaction and transport costs) from their current very low levels. The high capital costs of Australian LNG plants meaning that these netback levels are likely to be at least $5 to $6/MBtu below the price of LNG delivered to Asian markets. In the Golden Rules Case, Australia’s gas consumption nonetheless continues to expand on the back of government policies to encourage switching to gas for environmental reasons (including the recently agreed carbon trading scheme). In the Low Unconventional Case, coal bed methane production expands at a much slower pace on the assumption of bigger hurdles to development of these resources, while there is no shale gas production at all. In 2035, unconventional gas production falls to around 35 bcm – this is 75 bcm lower than in the Golden Rules Case. The higher international price environment in the Low Unconventional Case means that the upward pull on Australian domestic prices is stronger.

Gas exports still reach more than 110 bcm in the Low Unconventional Case, as investment is shifted to LNG projects based on conventional gas. In this case, the needs of importing countries are much increased and so any gas exporter with the capacity to export has an incentive to do so; this is certainly the case for Australia, with its conventional resources and existing export infrastructure, even if these conventional resources are more costly to develop. Export earnings are even higher in this case, as international gas prices are higher. Unsurprisingly, Australia would stand to benefit from restrictions on unconventional gas developments in other parts of the world, especially in Asia-Pacific, as it is able to expand its own production of conventional and unconventional gas.

Citation: Research Reports International, *Unconventional Oil and Gas Resources* (September 2006)

Topic Area: Unconventional Oil and Gas Resources

Jurisdiction: Global

Introduction: There are many different theories as to the origins of fossil fuels such as oil and natural gas. The most widely accepted theory says that fossil fuels are formed when organic matter, such as the remains of a plant or animal, is compressed under the earth, at very high pressure for a very long time. This is referred to as thermogenic formation where organic particles that are covered in mud and other sediment. Over time, more and more sediment and mud and other debris are piled on top of the organic matter. This sediment and debris puts a great deal of pressure on the organic matter, which compresses it.

This compression, combined with high subsurface temperatures break down the carbon bonds in the organic matter. At low temperatures (shallower deposits), more oil is produced relative to natural gas. At higher temperatures, however, more natural gas is created, as opposed to oil. That is why natural gas is usually associated with oil in deposits that are 1 to 2 miles below the earth's crust. Deeper deposits, very far underground, usually contain primarily natural gas, and in many cases, pure methane. Another theory of fossil fuel production is through abiogenic processes. Extremely deep under the earth's crust, there exist hydrogen-rich gases and carbon molecules. As these gases and molecules gradually rise towards the surface of the earth, they may interact with minerals that also exist underground, in the absence of oxygen. This interaction may result in a reaction, forming elements and compounds that are found in the atmosphere (including nitrogen, oxygen, carbon dioxide, argon, and water). If these gases and molecules are under very high pressure as they move towards the surface of the earth, they are likely to form methane or oil deposits. Natural gas can also be formed through the transformation of organic matter by tiny microorganisms. This type of methane is referred to as biogenic methane. Methanogens, tiny methane producing microorganisms, chemically break down organic matter to produce methane.

These microorganisms are commonly found in areas near the surface of the earth that are void of oxygen and in the intestines of most animals. Formation of methane in this manner usually takes place close to the surface of the earth, and the methane produced is usually lost into the atmosphere. In certain circumstances, however, this methane can be trapped underground, recoverable as natural gas. An example of biogenic methane is landfill gas.

Aims & Research Methods: This report analyses, sources of unconventional oil and gas, commercialization of unconventional resources, profiles of key producing regions and unconventional of land gas producers.

Citation: Chris Moran and Sue Vink, *Assessment of impacts of the proposed coal seam gas operations on surface and groundwater systems in the Murray-Darling Basin* (2010)

Topic Area: Surface and groundwater systems

Jurisdiction: Australia

Introduction: The preconditions for triggering the provisions of Section 255AA of the *Commonwealth Water Act (2007)* are that the activity must be:

 a subsidence mining operation;

 occur on a floodplain; and

 have potential to impact on Murray-Darling Basin (MDB) system inflows.

Based on advice in a report by Geoscience Australia (GA and Habermehl 2010), the location and nature of current proposed coal seam gas (CSG) developments in Queensland mean that the above preconditions may potentially be met and it is therefore prudent to commission an independent expert study in accordance with s255AA of the Water Act 2007 in order to inform government decision makers prior to approvals being granted. The independent expert sought advice from the Joint Liaison Committee for definition of the floodplain. A map of the extent of alluvial sediment in the Queensland Murray Darling Basin was supplied for this purpose.

Under the *Commonwealth Water ACT 2007* this study is restricted to analysis and evaluation of CSG activities that are physically occurring on the floodplain and therefore does not consider activities in CSG tenements that are not overlying alluvium. Figure 1 shows the extent of alluvium in the Murray Darling Basin and location of CSG tenements. The total area of alluvium shown in Figure 1 is 172,898 km2. Production schedules, proposed well locations during development of the fields, estimates of water production for individual wells and detailed hydrological modelling were not available for this report. Consequently the smallest spatial unit available for the assessment presented in this report is the tenement. Thus if a tenement intersected the alluvial extent shown in Figure 1, it was considered to be part of this assessment.

Within the study region, there are 13 companies undertaking CSG activities (including exploration, extraction and processing activities). The majority of tenements are to be developed by four proponents: Santos, BG/QGC, APLNG and Arrow Energy. Both Santos and QGC have had their developments approved with a significant number of conditions imposed by both State and Commonwealth Governments. The APLNG Environmental

Impact Statement is currently under review by the Queensland State Government. The number and area of tenements intersecting alluvium are summarised in Table 1. As of November 2010, there were 105 tenements in the MDB with a total area of 18,903 km2. The area of alluvial extent within these tenements is 4,130 km2. Arrow Energy and QGC have the highest proportion of alluvium in their tenements. There is 1,646 km2 of the Condamine Alluvium under CSG tenement.

Within the study region, there are currently 1,272 CSG wells. Figure 2 shows the current distribution of CSG production wells in the study area (QPED, October 2010). It can be clearly seen that current production is concentrated in well-defined areas. Each proponent is proposing that ~10,000 wells will be staged in operations over the lifetime of their projects (~ 40 years). Most CSG activity is occurring on the Northwestern – Western margin of the Condamine Alluvium (Figure 2).

The primary areas under consideration are: Santos tenements in the vicinity of Roma, the central and south-east development areas under development by QGC, all APLNG tenements and all Arrow Energy tenements. It should be noted that no information was available regarding Arrow Energy CSG developments.

In addition, only considering activities that occur on alluvium may represent a significant gap in this analysis. CSG activities located outside of the alluvium may indirectly impact on MDB alluvium and surface water flows by changing hydraulic conditions in surrounding aquifers which may change aquifer connectivity.

Aims & Research Methods: This report was commissioned by Department of Sustainability, Environment, Water, Population and Communities on advice in a report by Geoscience Australia and Habermehl (2010) that the location and nature of current and proposed CSG activities in Queensland may trigger Section 255AA - Mitigation of unintended diversions - of the *Commonwealth Water Act 2007.* The scope of this study was to undertake a desktop study to determine the impacts of the proposed CSG operations on the connectivity of groundwater systems, surface water and groundwater flows and water quality in the Murray-Darling Basin.

Underlying the MDB, the primary target of CSG development are the seams of the Walloon Coal Measures located in the Surat/Clarence Morton Basins. In order to extract gas, the hydrostatic pressure must be reduced by pumping water from cleats in the coal seams so that gas is desorbed from the coal pores. This dewatering has been predicted to result in drawdown of water levels in overlying and underlying aquifers in the region during CSG production.

Scope: The scope of this study included rivers, streams and associated alluvial aquifers in the MDB. The spatial coverage defined as alluvium was supplied by the government and covers an area of 172,898 km2. Assessment was restricted to CSG activities on this area. Although the Great Artesian Basin aquifers are not part of the MDB surface water management area, the impacts of dewatering of the Walloon Coal Measures on these aquifers may also impact alluvial aquifers, in particular the Condamine Alluvium. Given the spatial extent of CSG activities the primary focus of the report was the Condamine-Balonne River system and Central Condamine Alluvium. The Condamine River and the alluvium have been extensively used as water resource for agriculture. No data have been made available to examine the possible implications of hydrocarbons, eg, BTEX, in associated water. Engineering solutions for surface water storage, water treatment facilities and consequential brine management were not examined.

Conclusions: Many of the gaps identified in this work are similar to those identified by GA and Habermahl (2010). In particular, there appears to be little data that quantifies spatial variation in fundamental aquifer hydraulic properties. For impacts to be predicted and adequate management to be put in place then these data would need to be collected and be made available to the government, and the Queensland Water Commission.

To allow improvements in the assessment of aquifer drawdown and impact on other water users, the proponents would need to provide spatially explicit contour maps of the drawdown areas. The cumulative effect of all proponent activities is currently not able to be assessed.

All the proponents have postulated an adaptive management regime to development, with monitoring networks of water levels and water quality. The adaptive management loop will also need to include ongoing updating of the groundwater models used to predict drawdown with data on the hydraulic properties as well as ongoing review of the predicted with measured drawdown. Data required for this would need to include storativity, horizontal and vertical permeability for both aquifers and confining units. It will be critical to establish in advance what corrective measures will be enacted (risk mitigation strategies) when local effects occur. The proponents acknowledge uncertainty in their estimates of water production. The average annual production estimates of QGC for example are + 50% (GA and Habermehl, 2010). There are significant differences between different methods for estimating the amount of associated water depending on modelling approach, information available and assumptions regarding gas production quantities over time. Individual well water production should be monitored and data made available to the government along with water:gas profiles. These would be required to monitor predicted and actual water production allowing better forecasting predicted drawdown and aquifer impacts. Further, to improve modelling and forecasting assumptions and methods for estimating associated water would need to be explicitly stated with error estimates to ensure comparability of different estimation techniques and the volumes predicted.

A great deal of relevant data is currently held by the proponents. To enable this data to be included in models and assessments of cumulative impacts, data provided by proponents could be held as confidential for a period of time before becoming publically available. This would ensure the competitive and commercial interests of the companies while allowing the government to review model predictions and monitoring results thereby increasing the certainty of impact prediction and a timely and appropriate management response.

Vertical permeability and connectivity between aquifers has not been well quantified.

Full sensitivity analyses should be done using project and cumulative scenarios for the likely range of hydraulic variables. Results need to be spatially explicit and presented as contour plots.

The impact of such large scale dewatering and changes to capillary pull of the coal seams is completely unknown.

Existing faults and fractures must be accounted in the models, or at least signalled as areas of concern. To enable models to be kept up to date, ongoing monitoring of water levels and water production (including during exploration) in areas with known faults or fractures should be compared with modelled predictions and the models updated. In some areas analysis of the water:gas profile of different wells in relation to known locations of faults or fractures may be a useful first assessment of the importance of these fast flow paths.

Citation: Queensland Government, *CSG Water Management Policy* (February 2013)

Topic Area: Water Use and Management

Jurisdiction: Australia (QLD)

Introduction: The coal seams from which CSG is obtained contain both water and natural gas—consisting primarily of methane—which is bonded to the coal. For CSG to be released, the water must be pumped from the coal seams to reduce pressure—thereby releasing gas. A well is constructed to enable installation of a pump which is required to lower the water pressure. The released gas then travels to the surface via the well. The water that is pumped from the coal seams to the surface is referred to as CSG water. CSG water is also known as 'produced' or 'associated' water. The CSG Water Management Policy ('the policy') provides decision makers, proponents and the community with a clear understanding about the government's preferences for how CSG water will be managed. The government committed to revising the '2010' policy by December 2012 in its "Six month action plan: July – December 2012". In line with the government's commitment, the Department of Environment and Heritage Protection (EHP) developed a draft revised policy to reflect the government's priorities for the management of CSG water - emphasising a 'case by case' approach to beneficial reuse, injection and treatment.

Aims & Research Methods: The purpose of this report is to summarise the results of public consultation on the draft Coal Seam Gas (CSG) Water Management Policy 2012. The report outlines the key issues raised during consultation and the actions or responses to those issues.

Citation: EIA, *Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States* (June 2013)

Topic Area: Shale Formations

Jurisdiction: Global

Introduction: The report covers the most prospective shale formations in a group of 41 countries that demonstrate some level of relatively near-term promise and that have a sufficient amount of geologic data for a resource assessment. Figure 1 shows the location of these basins and the regions analysed. The map legend indicates two different colours on the world map that correspond to the geographic scope of this assessment:

• Red collared areas represent the location of basins with shale formations for which estimates of the risked oil and natural gas in-place and technically recoverable resources were provided. Prospective shale formations rarely cover an entire basin.

• Tan collared areas represent the location of basins that were reviewed, but for which shale resource estimates were not provided, mainly due to the lack of data necessary to conduct the assessment.

• White collared areas were not assessed in this report.

Aims & Research Methods: This report provides an initial assessment of shale oil resources and updates a prior assessment of shale gas resources issued in April 2011. It assesses 137 shale formations in 41 countries outside the United States, expanding on the 69 shale formations within 32 countries considered in the prior report. The earlier assessment, also prepared by Advanced Resources International (ARI), was released as part of a U.S. Energy Information Administration (EIA) report titled *World Shale Gas Resources: An Initial Assessment of 14 Regions outside the United States*.

There were two reasons for pursuing an updated assessment of shale resources so soon after the prior report. First, geologic research and well drilling results not available for use in the 2011 report allow for a more informed evaluation of the shale formations covered in that report as well as other shale formations that it did not assess. Second, while the 2011 report focused exclusively on natural gas, recent developments in the United States highlight the role of shale formations and other tight plays as sources of crude oil, lease condensates, and a variety of liquids processed from wet natural gas.

Citation: David Campin, *Environmental Regulation of Hydraulic Fracturing in Queensland* (2013)

Topic Area: Environmental Regulation of Hydraulic Fracturing

Jurisdiction: Australia (QLD)

Introduction: Since the late 1990s, coal bed methane (CBM) has grown to be a significant part of the Queensland economy, building alongside the world-scale coal export operations. Environmental regulation in Queensland, over the same period, has become highly integrated with petroleum activities following a unified mineral rights/land tenure and environmental permitting process. Development of environmental regulation of CBM evolved with the sector as industry-specific issues became evident. Following the announcement around 2008 of a number of multi-billion dollar LNG export projects with upwards of 40,000 wells, attention by interest groups and the public at large, gave rise to increased scrutiny by regulators of the scope of prevailing rules. Environmental regulation in Australia is largely state-based with nationally agreed guidelines adopted for various media (air quality, receiving water, drinking water etc.). In respect to the environmental aspects of CBM development, a National Framework has been recently agreed to, identifying performance principles including hydraulic fracturing, however the details will be developed and regulated by the states. In respect to the application of hydraulic fracturing, the CBM sector have indicated a likelihood of fracturing up to 40% of wells and the development of the extensive shale gas / tight gas resources (horizontal completions with 100% fracturing) is moving into exploratory stages. Thus the State can expect a very significant rise in application of the technology.

Aims & Research Methods: To date, because of the relatively few operators in the energy sector, permitting has been project based rather than rule based, resulting in older approvals having conditions inconsistent with modern expectations. The State Government has moved to amend this position by developing more performance focused codes that will have retrospective application in respect to new hydraulic fracturing programs. It has also moved toward greater emphasis on compliance activities. In respect to environmental regulation of hydraulic fracturing the State proposes a single comprehensive code encompassing the use of the technique across all energy sources and fluid systems: conventional oil and gas; unconventional oil and gas; and geothermal. The approach developed for environmental risk mitigation follows a series of pre-event disclosure requirements, engineering constraints, environmental protection measures, product accreditation, monitoring and post-event reporting. Fundamental to the approach is a comprehensive risk assessment considering a wide range of issues at local and regional scales. Environmental considerations include air, land and water impacts, ecological parameters, geological issues, noise, and waste. Performance matters include well integrity, water management and product specifications. Disclosure of products is required under Petroleum and Gas legislation but this code requires product accreditation under an international standard encompassing contaminant concentration limits, human toxicology and eco-toxicology. Evidence supporting code development includes both actual consideration of the environmental issues in Queensland and detailed review of hydraulic fracturing studies being undertaken or recently completed across the world. A detailed legislative review was completed considering rules from 54 jurisdictions (including Australia, United States, Canada, UK and Scotland, France and South Africa) across 58 identified regulatory matters.

Citation: API, *Freeing up Energy Hydraulic Fracturing: Unlocking America's Natural Gas Resources* (July 2010)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Aims & Research Methods: This report by the API provides information regarding hydraulic fracturing, well construction, groundwater protection, fracking fluids and correct regulations at the federal, state and local levels.

Citation: NWI, *The Coal Seam Gas and Water Challenge* (December 2010)

Topic Area: Water Use and Distribution

Jurisdiction: Australia

Aims & Research Methods: The Coal Seam Gas (CSG) industry offers substantial economic and other benefits to Australia. At the same time, if not adequately managed and regulated, it risks having significant, long-term and adverse impacts on adjacent surface and groundwater systems.

In light of the scale of potential benefits and associated risks, the National Water Commission is highlighting the need for appropriate management of CSG developments, consistent with the objectives of the National Water Initiative (NWI). To meet NWI objectives, the Commission recommends that industry, water and land-use planners, and governments adopt a precautionary approach to CSG developments, ensuring that risks to the water resource are carefully and effectively managed.

Current projections indicate the Australian CSG industry could extract in the order of 7,500 gigalitres of co-produced water from groundwater systems over the next 25 years, equivalent to ~300 gigalitres per year. In comparison, the current total extraction from the Great Artesian Basin is approximately 540 gigalitres per year.

Potential impacts of CSG developments, particularly the cumulative effects of multiple projects, are not well understood.

Conclusions: The Commission believes that wherever there is potential for significant water resource impacts, CSG activities should be incorporated into NWI consistent water planning and management regimes from their inception. Given the high level of uncertainty around water impacts, and the temporal nature of CSG developments, this will likely require a precautionary approach that demands innovation from water managers and planners, and significantly greater coordination with existing project approval processes.

Specifically, the Commission proposes the following principles be applied by state and territory jurisdictions to managing the cumulative impacts of CSG water:

- The interception of water by CSG extraction should be licensed to ensure it is integrated into water sharing processes from their inception.
- Project approvals should be transparent, including clear and public articulation of predicted environmental, social and economic risks along with conditions implemented to manage the risks.
- Adequate monitoring, including baseline assessment of surface and groundwater systems, should be undertaken to provide a benchmark for assessing cumulative impacts on other water users and water-dependent ecosystems.
- Jurisdictions should work to achieve consistent approaches to managing the cumulative impacts of CSG extraction. Such arrangements should consider and account for the water impacts of CSG activities in water budgets and manage those impacts under regulatory arrangements that are part of, or consistent with, statutory water plans and the National Water Initiative.
- Potential options to minimise the cumulative impacts of extraction on the water balance should be pursued as a first priority. These options include aquifer reinjection, where water quality impacts are acceptable, and groundwater trading or direct substitution for other water use.
- If discharges to surface waters are unavoidable, discharges should be conditioned so that environmental values and water quality objectives, including water quality to meet public health objectives, are protected. In such circumstances discharges to ephemeral streams should be pulsed to avoid flows in naturally dry periods.
- Jurisdictions should undertake water and land-use change planning and management processes in an integrated way to ensure that water planning implications of projects are addressed prior to final development approval.
- Clear accountabilities should be identified for any short- or long-term cumulative impacts from CSG processes, clarifying which organisations are responsible for managing and rectifying or compensating for any impacts.
- The full costs, including externalities, of any environmental, social and economic water impacts and their management should be borne by the CSG companies. This includes, if not already in place, mechanisms such as bonds and sureties that deal with uncertainty and the timeframes associated with potential impacts. Given that these

timeframes may extend for 100 or more years, current systems need to be re-evaluated.

- A precautionary and adaptive approach to managing and planning for CSG activities is essential to enable improved management in response to evolving understanding of current uncertainties. This includes impacts such as long-term reductions in adjacent aquifer pressures and levels, and impacts on environmental assets that are not adequately protected by current 'make good' mechanisms.

- Water produced as a by-product of CSG extraction, that is made fit for purpose for use by other industries or the environment, should be included in NWI-compliant water planning and management processes. This will enable CSG producers to manage this resource in accordance with the principles of the National Water Initiative.

The consequences of not managing the water risks and uncertainties associated with the economic benefits of CSG are substantial. Therefore, the Commission strongly argues for the careful, transparent and integrated consideration of water-related impacts in all approval processes.

The Commission's position is that NWI-consistent water access entitlements should be made available to coal seam gas activities wherever possible, as the use of Clause 34 of the NWI is only intended to operate in exceptional circumstances. Where Clause 34 is used, a clear and transparent explanation of why it was used, rather than complying with the normal water planning and management regime, should be provided.

Citation: IEA, *Annex of Regulation and Best Practice for Developing Unconventional Gas* (November 2012)

Topic Area: Regulation of Unconventional Gas

Jurisdiction: Global

Aims & Research Methods: This annex contains references to selected examples of current regulation and best practice, by relevant entity, for developing unconventional gas resources. These were chosen based on their close alignment with principles stated in the "Golden Rules"; consequently, many were influential in the development of the Golden Rules. The intention of this annex is to centralise selected examples, making these accessible to interested parties.

Citation: Santos, *CSG Water Monitoring and Management Plan* Santos GLNG Project Summary Plan – Stage 2 (2012)

Topic Area: Water Use and Management

Jurisdiction: Australia

Aims & Research Methods: Santos Gladstone Liquefied Natural Gas (GLNG) is a project that will convert coal seam gas (CSG) to liquefied natural gas (LNG) for export to global markets. In May 2010, the Queensland Coordinator-General approved the project under the

State Development and Public Works Organisation Act 1971. In October 2010, the Minister of Sustainability, Environment, Water, Population and Communities (SEWPaC) granted approval under the Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)

(EPBC), with various conditions, in particular:

• Condition 49 requires the submission and approval of a Stage 1 Coal Seam Gas Water Monitoring and Management Plan within 6 months of project approval; and

• Condition 52 requires the submission and approval of a Stage 2 Coal Seam Gas Water Monitoring and Management Plan within 18 months of project approval.

Santos GLNG has prepared both Stage 1 and Stage 2 CWMMPs (CWMMP) within the specified timeframes to meet the requirements of these conditions. This document provides a clear and succinct overview of Santos GLNG's response to these conditions and technical comments from the Expert Panel for major CSG projects on the Stage 1 CWMMP. It demonstrates that when the cumulative impacts of the GLNG Project and other approved CSG to LNG proposals are taken into account, the potential for impacts to Matters of National Environmental Significance is low. With appropriate mitigation measures in place, the GLNG Project can be developed and operated in a sustainable manner with no impacts to Matters of National Environmental Significance.

Conclusions: Santos GLNG is focused on maintaining continual improvement in environmental performance. Santos GLNG acknowledges that regular reporting is critically important to that process.

Santos GLNG will publish the following reports on the GLNG website (www.glng.com.au):

• Groundwater Impact Statement Updates.

• The Water Monitoring Portal: Quality checked data from all aspects of Santos GLNG's

monitoring network relating to protection of Environmental Values will be published quarterly on the portal. This includes: groundwater levels and quality; surface water, levels, flows and quality; water pressure; climate data; water reuse figures; and contoured data of water levels and water quality. The annual performance reports and impact statement updates will also be published on the Santos website (www.santos.com).

Finally, the Santos Water Portal will include links to the performance reports and impact assessments listed above.

Citation: SCER, *The Draft National Harmonised Regulatory Framework: Coal Seam Gas* (2012)

Topic Area: Coal Seam Gas Regulatory Framework

Jurisdiction: Australia

Aims & Research Methods: The National Harmonised Regulatory Framework (the Framework) is a guidance and reference tool for Australian federal, state and territory government regulators for the coal seam gas (CSG) industry. Its purpose is to provide a suite of national and global leading practices to consider and implement in the assessment and ongoing regulation of proposed projects for CSG exploration and production. The Framework is an important demonstration that governments are listening and responding to community concerns and are working together to strengthen regulation and ensure there is a balance between protecting social and environmental values and achieving economic outcomes. Consistent with this approach, the Framework also acts as a guide to industry on what leading practice regulation is, providing greater certainty and consistency for CSG operators. Other forms of unconventional gas fall outside the scope of this Framework. The issues and findings relating to CSG may not be equally applicable to other forms of unconventional gas such as shale gas and tight gas. Comparisons have frequently been drawn between shale gas developments in the United States and CSG developments in Australia. Although shale gas and CSG have some common exploration and development procedures, the geological and hydrological issues that apply to different forms of unconventional gas are also significant. Australian CSG production began in Queensland in 1996. In the five years to 2010–11, CSG production increased from 2 per cent to 11 per cent of Australia's total gas production. To date, growth has occurred predominantly in Queensland, with a small but growing contribution from New South Wales. Community concerns over the development of the CSG industry relate to its potential environmental, health and social impacts. For instance, the volume of water produced as a by-product of CSG extraction has raised concerns that the industry may damage or unsustainably deplete aquifers on which farmers, rural towns, and ecological communities depend. The failure of wells and the impact this could pose with respect to the contamination of potable aquifers is also pertinent.

Hydraulic fracturing has been a topic of public concern, specifically with respect to the use of chemicals and the risk of contamination to the environment. In addition, the treatment and management of waste water streams and salinity issues have raised questions over possible implications for human and animal health and food production. Another point of contention is industry access to CSG resources on privately held land, particularly that used by the agricultural sector. This has raised issues regarding the rights of individual land owners to limit access, rights of resource ownership, and the magnitude of compensation afforded to landowners for their costs, reduced amenity, and any reduction in agricultural production.

The concerns and issues raised by the community regarding CSG development in Australia to date have warranted the attention of governments and industry to acknowledge and address the calculated and perceived risks associated with CSG. As a result, in December 2011, governments – through the Standing Council on Energy and Resources (SCER) – have responded to community concern about the impacts of the CSG industry by agreeing to develop the Framework. The work program was selected to address the areas of community concern highlighted above through the following core areas:

•well integrity

•water management and monitoring

•hydraulic fracturing

•chemical use.

Scope: The methodology for preparing the Framework consisted of government, industry and community consultation, supported by research and analysis. The Commonwealth, all state governments and the Northern Territory Government participated in the development of the Framework as part of the Coal Seam Gas Steering Group. The steering group was supported by a stakeholder reference group comprising national peak bodies, and external advice and analysis through the following commissioned studies:

a.Multiple Land Use Framework Research Study (Sinclair Knight Merz)

b.A Leading Practice Framework for Coal Seam Gas Development in Australia (Sinclair Knight Merz)

c.Coal Seam Gas Legislative Review (Norton Rose Australia)

Conclusions: Since 2006–07, CSG production in Queensland and in New South Wales has grown from 99 petajoules (PJ) to 239 PJ, making up 11 per cent of total Australian gas production in 2010–11. In addition, there are three CSG-based LNG processing facilities under construction in Queensland to supply the export market. This surge of activity has placed pressure on land and water resources and, at times, outraged local communities. The sustainable development of the CSG sector in Australia requires a balanced consideration of economic, environmental and social aspects of CSG activities.

Australia cannot reap the benefits from CSG development if industry's social licence to operate and resulting community confidence have not been established. The successful development of the CSG industry depends on Australian governments, industry and the community working together. In particular, governments should aim to provide a policy and regulatory setting that encourages the growth of the industry, within a regime of relevant, enforced conditions and legislation to protect the environment and human health and facilitate social development and sustainability. The environment to best meet the needs of all participants should be underpinned by the principle of co-existence.

This is where a shared commitment exists among the resources industry, other land users and governments to multiple and sequential land use; better informed public discourse on resource development; merit-based land access that provides certainty for industry and improved community confidence in land use decision-making; and finally, the delivery of best possible outcomes for affected communities. Sustainable development of the CSG industry will be underpinned by the guiding principles of the Multiple Land Use Framework. These principles, when applied by industry, other land users, the community and governments, demonstrate a commitment to maximising the social, economic and environmental value of land and marine environments. Governments play a crucial role as the regulators of the CSG industry to deliver regulation that is effective in managing CSG activities and efficient in terms of maximising the benefits to the community. Importantly, governments are also educators by providing key messages and information to assist the general public, the CSG sector and the media. Current legislative arrangements of the Commonwealth and state and territory governments provide a sound mechanism for managing CSG exploration and development activities. Common elements for these regulatory systems include legislation for the protection of human health, conservation of the environment, protection of property rights and multiple land use.

The National Harmonised Regulatory Framework for CSG responds to community concerns about the potential environmental, health and social impacts of CSG development. It provides guidance on what constitutes leading practice in the core areas of well integrity, water management and monitoring, hydraulic fracturing and chemical use. Applied in conjunction with existing regulatory mechanisms, the Framework provides a consistent approach to managing CSG development from a regulatory perspective. While its primary purpose is to be a guidance document for governments, the Framework will benefit the community and industry by providing increased levels of consistency, certainty and transparency in the management of CSG development in Australia.

Citation: The Senate, The Parliament of the Commonwealth of Australia, *Environment Protection and Biodiversity Conservation Amendment (Protecting Australia's Water Resources) Bill 2011* (2011) Explanatory Memorandum

Topic Area: Environmental Protection

Jurisdiction: Australia

Aims & Research Methods: The Environment Protection and Biodiversity Conservation Amendment (Protecting Australia's Water Resources) Bill 2011 will require Commonwealth assessment and approval of mining operations likely to have a significant impact on water resources. The amendments set out in the Schedule of the Bill are to commence on the day the Bill is introduced into the Senate. Under normal circumstances commencement on Royal Assent would apply, however this retrospective commencement is required to ensure approvals for mining operations are not fast-tracked following introduction of this Bill. The intention is to ensure all mining operations commencing after the day this Bill is introduced are subject to Commonwealth assessment and approval where these operations are likely to have a significant impact on Australia's water resources.

Citation: Australian Energy Resource Assessment, *Chapter 4 Gas* (2012)

Topic Area: Gas Resources

Jurisdiction: Australia

Aims & Research Methods:

- Australia has significant gas resources, gas is Australia's third largest energy resource after coal and uranium.
- Most of the conventional gas resources are located off the north-west coast of Australia and are being progressively developed for LNO export and domestic use.
- Significant coal seam gas resources exist in the major coal basins of eastern Australia and are being developed for domestic use and potential export.
- Australia's gas resources are large enough to support projected domestic and export market growth beyond 2030 and are expected to grow further.
- Gas is a relatively flexible and clean energy source and is projected to be the fastest growing fossil fuel over the period to 2030.
- Gas is expected to significantly increase its share of Australia's energy production and exports, and make a substantially greater contribution to electricity generation.

Citation: The Senate, Rural Affairs and Transport References Committee, *Management of the Murray Darling Basin Interim report: the impact of mining coal seam gas on the management of the Murray Darling Basin* (November 2011)

Topic Area: Coal Seam Gas Management

Jurisdiction: Australia

Aims & Research Methods: This committee's inquiry into the Coal Seam Gas (CSG) industry is a subset of its broader inquiry into the Murray-Darling Basin and its capacity to maintain its position as a significant food producer in the context of reduced availability of water for agriculture, both as a result of water management decisions and, potentially, as a consequence of changing weather patterns resulting from climate change.

1.2 The Committee, as part of that general inquiry has been examining:

- The economic, social and environmental impacts of mining coal seam gas on:
    - the sustainability of water aquifers and future water licensing arrangements;
    - the property rights and values of landholders;
    - the sustainability of prime agricultural land and Australia’s food task;
    - the social and economic benefits or otherwise for regional towns and the effective management of relationships between mining and other interests; and
    - other related matters including health impacts.

1.3 The committee is required to report on the inquiry into the management of the Murray-Darling Basin by 30 November 2011. This report constitutes a first report on that matter. A final report will be tabled in the Senate on 29 June 2012. The committee will continue to monitor developments in the CSG industry.

1.4 This report concentrates on CSG developments within the Basin, which are the focus of the industry and of public concern. The main regions of concern to this committee, where the industry is expanding very rapidly, are in south-west Queensland and north-west New South Wales. The committee held hearings and inspections in Roma, Dalby and Narrabri and further hearings in Brisbane and Canberra. Details of these and of the submissions that the committee has received can be found in Appendices 1 and 2.

1.5 The committee has received 370 submissions to the general inquiry into the Murray-Darling Basin. Submissions specifically relating to the coal seam gas issue start at approximately number 200.

1.6 The committee has received submissions and some evidence from groups in areas outside the Basin, the Myall Lakes area and the Southern Highlands of New South Wales for example. Many of the issues and concerns dealt with in this report are of immediate relevance to those communities as well.

Conclusions:

Recommendation 1

1.72 The committee recommends that federal and state governments conduct a thorough review of the appropriateness of 'adaptive management' in the context of regulating the industry, given the significant gaps in information regarding cumulative and long term impacts of the industry.

Recommendation 2

1.85 The committee recommends that the Commonwealth Government, through the Council of Australian Governments, or Standing Council on Energy and Resources (SCER), take the initiative in promoting a consistent national regulatory framework for all aspects of the coal seam gas industry.

Recommendation 3
2.58 The committee recommends that, given the degree of uncertainty about the long-term consequences of the CSG industry on the water resources of the Great Artesian Basin, that the Commonwealth not give any further approvals for production of CSG in that part of the Murray-Darling Basin overlying the Great Artesian Basin pending the completion of the Queensland Government's regional groundwater model and the CSIRO & Geoscience Australia basin scale investigation of water resources.

Recommendation 4
2.59 The committee recommends that the Commonwealth await the completion of the Namoi Catchment study before considering any applications under the Water Act or the *Environment Protection and Biodiversity Conservation Act 1999* for approvals to undertake coal seam gas production.

Recommendation 5
2.60 The committee recommends that all future CSG development approvals should be preceded by the development of "... a regional-scale, multi-state and multi-layer model of the cumulative effects of multiple developments" of ground and surface water as recommended by Geoscience Australia.

Recommendation 6
2.70 The committee recommends that the Commonwealth take the necessary steps to amend the *Water Act 2007* to include that part of the Great Artesian Basin that underlies the Murray-Darling Basin within the definition of Basin water resources.

Recommendation 7
2.75 The committee recommends that the Commonwealth take the necessary steps to amend the *Environmental Protection and Biodiversity Conservation Act 1999* to include the sustainable use of the Great Artesian Basin as a 'matter of national environmental significance'.

Recommendation 8
2.81 The committee recommends that all future approvals require independent comprehensive monitoring of regional earth surface movements to assess whether any measurable subsidence is occurring. Where subsidence occurs and has an adverse effect on land management or the natural environment, for example by altering drainage, the responsible gas companies would be liable for any necessary remediation. Further all gas exploration and/or production in an area subject to subsidence or impacts from subsidence not foreseen in the EIS should cease until action is taken to ensure that no further damage will occur. Where subsidence occurs in a gas producing region the onus lies with the gas companies to demonstrate that the subsidence is not a result of gas production activities.

Recommendation 9

2.85 The committee recommends that it be a requirement of all exploration or production approvals that the fluids extracted from wells after fraccing are kept isolated in secure separate storages and prior to disposal are treated to the highest standards.

Recommendation 10
2.96 The committee recommends that the Commonwealth provide funds to NICNAS to enable that organisation to undertake a comprehensive review of the chemicals used in fraccing, having particular regard to the quantities, combinations of chemicals and the way in which these chemicals are used and to confirm safe levels for their use. This study should be completed within the next two years. The Commonwealth and state governments should act promptly to ensure all fraccing activities comply with any NICNAS recommendations.

Recommendation 11
3.64 The committee recommends that all CSG water should be included in the calculation of the total withdrawal from the ground and surface water systems. Seepage into depressurised coal seams, reinjection into regulated formations and virtual reinjection or surface disposal must be monitored and recorded if a complete picture of the state of artesian and sub-artesian water is to be maintained.

Recommendation 12
3.65 The committee recommends that where any aquifer used for the supply of stock or domestic water is depleted as a result of coal seam gas activities, the relevant company or companies should be required to pay for that water at the prevailing rate or make good the loss of water by virtual reinjection or reinjection where water to be reinjected is of an environmentally appropriate standard. The onus should rest with the gas companies to prove that, where an aquifer is depleted, it is not the result of coal seam gas extraction.

Recommendation 13
3.69 The committee recommends that as a general principle it should be established that where a gas company supplies treated CSG water for beneficial use to an existing water user in agriculture, industry or for domestic use that supply must be as a substitute for an existing allocation.
3.70 Where treated water is supplied to landholders (including on a company's own land) to develop a new crop or enhance existing production, that supply should be clearly understood to create no entitlement, above a pre-existing water licence, to water from any other source once the supply of CSG water ceases.

Recommendation 14
3.72 The committee recommends that comprehensive water management plans, *and the capacity to implement those plans*, particularly with regard to the disposal of salt and brine, be a requirement before any further production approval for coal seam gas be granted.

Recommendation 15
3.74 The committee recommends that all salt and brine residues that cannot be disposed of within the short term, either as part of an industrial process or by safe injection into a suitable aquifer, should be required to be removed from agricultural areas and water catchments. No controlled landfills for the disposal of salt should be permitted in the Murray-Darling Basin.

Recommendation 16

4.70 The committee recommends that the Commonwealth, in cooperation with the states, establish an independently managed trust funded by the gas companies to make financial provision for long-term rectification of problems such as leaks in sealed wells or subsidence and erosion caused by collapsing pipelines.

Recommendation 17
4.91 The committee supports the concept of strategic agricultural land and recommends that, when identified, exploration for, or production of, coal seam gas be banned from land identified under defined criteria.

Recommendation 18
4.99 The committee recommends that the Commonwealth, through the Council of Australian Governments, or other appropriate forum, request the States to insert in the relevant legislation a requirement that arbitration bodies charged with resolving disputes between landholders and the holders of exploration or production titles – the Land Court in Queensland; the Land and Environment Court in NSW – must give priority to the maintenance of agricultural production with minimal disruption in deciding any dispute.
4.100 Similarly, where a ministerial discretion such as that exercised under s.71 of the NSW Petroleum (Onshore) Act exists, the exercise of that discretion should be required to give priority to maintaining agricultural production with minimum disruption to the existing land-use.

Recommendation 19
4.107 The committee recommends that draft access agreements between landholders and gas companies include a requirement that company employees must have a landholder's approval whenever they wish to enter a property and that companies must maintain logs of staff entering private property.

Recommendation 20
4.108 The committee recommends that draft access agreements clarify the gas companies responsibility with regard to fire safety and require the gas company to advise landholders of all chemicals that are brought on to the land.

Recommendation 21
4.112 The committee recommends that legislation governing compensation to landholders include provisions that recognise as compensable effects the involuntary nature of landholders' dealings with coal seam gas companies and the social impact of coal seam gas exploration and production.

Recommendation 22
4.117 The committee recommends that States' include in the relevant legislation as a compensable effect the costs incurred by a landholder in seeking independent arbitration of a dispute over an access and compensation agreement, except where it can be demonstrated that the landholder had not negotiated reasonably and in good faith.

Recommendation 23
4.122 The committee recommends the Queensland and New South Wales governments establish mechanisms that provide where a landholder, having an access and compensation agreement with a coal seam gas exploration or production company, believes that that

agreement was entered into without proper advice or understanding of its implications, then the landholder be entitled to seek a review of the agreement

Recommendation 24
4.124 The committee recommends that the position of residents of small regional communities and on small blocks of land also be clarified and that enforceable conditions, including a buffer zone around houses, are included in exploration or production permits to ensure that, despite having no development on their land, they are not subject to excessive interference from coal seam gas developments.

Citation: Earth Resources, *National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development* (2013)

Topic Area: National Framework for CSG Development

Jurisdiction: Australia

Introduction: The National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development will improve decision making through access to Commonwealth funded expert advice regarding the potential impacts of coal seam gas and coal mining on water resources. On Tuesday 5 June 2012, Victoria signed the National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development. Signing the agreement will ensure that Victorian regulatory agencies have access to the most up to date scientific research on the impacts of coal seam gas on Victoria's water resources. Victoria will receive significant funding to carry out water resource modelling across the Gippsland Basin that will give a clearer picture of water resources in the area and any potential future impacts of coal seam gas developments. Victoria will also benefit from the input of the new Independent Expert Scientific Committee, a national statutory body that can provide advice to support decision making on project applications for coal seam gas development or a new coal mine.

Aims & Research Methods: The signing of the agreement reflects Victoria's commitment to meeting community expectations that decisions on development projects are based on a solid scientific understanding of the water resources and risks associated with the proposed development. Victoria already has a strong regulatory regime in place covering coal seam gas that ensures protection of the environment and the rights of landholders and those affected by proposed development. Nonetheless, it makes sense for Victoria to learn lessons from other jurisdictions where coal seam gas is produced.

The Independent Expert Scientific Committee will be an extra resource that Victorian regulators can draw on in making decisions about any future applications to begin producing coal seam gas or developing a large new coal mine. Victoria will refer coal seam gas and large coal mining development projects for assessment and advice to the Independent Expert Scientific Committee where they require an Environment Effects Statement. The focus of the committee is on providing scientific advice on the potential impact of coal seam gas and large coal mining projects on water resources. This will include advice on the quality, composition and quantity of water, environmental values of the water resources and the current and future economic, social and environmental uses of water. The National Partnership Agreement has now been signed by Victoria, Queensland, New South Wales and South Australia.

Citation: Council of Australian Governments, *National Partnership Agreement on Coal Seam Gas and Large Coal Mining Development* (2012)

Topic Area: National Framework for CSG Development

Jurisdiction: Australia

Aims & Research Methods:

1. This National Partnership Agreement is created subject to the provisions of the Intergovernmental Agreement on Federal Financial Relations and should be read in conjunction with that Agreement and its Schedules, which provide information in relation to performance reporting and payment arrangements under the Intergovernmental Agreement.
2. In entering this agreement, the Commonwealth of Australia and New South Wales, Victoria, Queensland, South Australia and the Northern Territory recognise that they have a mutual interest in:
   a. The long term health, quality and viability of Australia’s water resources; and
   b. The sustainable development of coal seam gas and coal mining industries, given their potential contribution to Australia’s energy security and balance of international trade.
3. Signatories to this Agreement acknowledge public concerns about the actual and potential impacts of CSG and coal mining activities on water resources and agree there is a critical need to strengthen the science that underpins the regulation of these industries.
4. Decision making about CSG and coal mining developments that are likely to have significant impact on water resources will be strengthened by:
   a. More closely identifying potential and actual impacts on water resources, and supporting parties to avoid or minimise significant impacts through a transparent process that builds public confidence;
   b. Substantially improving their collective scientific understanding of the actual and potential impacts of CSG and coal mining developments on water resources;
   c. Ensuring that the best scientific information and expertise underpins all relevant regulatory processes and decisions.
5. The implementation of this agreement will be consistent with the objectives and outcomes of all National Agreement and National Partnerships agreed by the parties.
6. Parties to this agreement are also committed by providing certainty for application timeframes and ensuring that assessment processes are clear to all parties.

Citation: Department of Natural Resources, Mines and Energy, *Coal Seam Gas Water Management Study Final Report* (2004)

Topic Area: Water Use and Distribution

Jurisdiction: Australia

Introduction: CSG development is an emerging challenge for resource professionals seeking to conserve natural values while meeting energy demands. CSG production involves extracting methane from coal seams by reducing groundwater pressure that keeps the methane trapped in the coal. A primary by-product of this process is water, which is often rich in salts and other constituents that render it unsuitable for many direct beneficial uses.
The predicted large volume and variable quality of this water make water management a key issue associated with CSG production. The amount of water that must be pumped off appears to vary not only from basin to basin, but also during the life of individual production wells. Strategies for management and beneficial use of the water are dictated by water quality and quantity at each CSG development site.

Aims & Research Methods: This "Coal Seam Gas Water Management Study" was commissioned by the Queensland Department of Natural Resources, Mines and Energy (NRM&E) and has been undertaken within the framework of the *Regional Minerals Program*, which is administered by the Australian Government Department of Industry, Tourism and Resources. The program's aim is to achieve both a cooperative and coordinated approach by industry and all levels of government to facilitate regional mineral and petroleum resource development and thereby generate regional employment opportunities. The key objectives of this study are as follows:

- identify the likely hydrogeological effects of water extraction on Surat Basin aquifers (coal and other)
- that are currently being accessed;
- identify, evaluate and cost technical options to manage water co-produced by coal seam gas (CSG)
- operations in the Surat Basin; and
- enable regulators to disseminate information to the community to increase awareness of the
- potential impacts (if any) of water extraction by the CSG industry.
- This report has been undertaken with the support and cooperation of both industry and government
- representatives. This study has been funded by:
- Australian Government, Department of Industry Tourism and Resources;
- Queensland Government, Department of Natural Resources, Mines and Energy; and
- Arrow Energy N.L., Origin Energy CSG Limited and Queensland Gas Company.

This study has been approached from an overview perspective, to identify key issues and concerns relating to potential groundwater impacts and water management options for the CSG industry. A detailed hydrogeological assessment has not been undertaken, due to the complexity of site-specific issues.

Key deliverables for the project are:
- an understanding of requirements and issues of both regulators and industry in relation to options for
- using groundwater extracted by the CSG industry;
- identification of research requirements to ensure confident understanding of any potential impacts on
- the groundwater environment as a result of CSG industry development; and

- enabling of regulators to disseminate information to the community to increase awareness of the
- potential impacts (if any) of water extraction by the CSG industry.

The key issues identified in relation to CSG water management, and considered as part of this study, are:

- sustainability of water extraction with respect to the groundwater resource;
- acceptance by regulatory authorities;
- identification of beneficial uses and water quality objectives, demand for end use, and water
- treatment options;
- cost-efficiency for the developer; and
- reliability of supply for the end user.

Conclusions: Water use and water quality are key elements of understanding the relation of CSG development and production to water resources. The type and magnitude of potential impacts due to the CSG development vary greatly throughout the CSG development area. Within the Surat Basin, the Walloon Coal Measures form the main target units for CSG development. Limited groundwater information is available on the coal seams that directly correlates hydrogeological response to CSG development. However, based on existing geological information and information from the NRM&E groundwater database, it was assumed that:

- no exploration is undertaken in the vicinity (i.e. 20 to 50 km distance) of outcrop zones of the WCM, predominantly due to the shallow seams being unprospective for CSG development;
- the nature of the Surat Basin coal seam units that contain the methane gas (i.e., layers of coal interbedded with confining layers having low vertical hydraulic conductivity) should minimise impacts to aquifers above these seams. Confining layers above the coal seam units should provide a degree of protection from drawdown associated with CSG production from the coal seams;
- the coal cleats do not provide a continuous porous medium that has been simulated by low hydraulic conductivity (approximately 0.12 to 0.0113 m/day) (PB, 2002); and
- leakage from overlying or underlying aquifers is also considered negligible due to the presence of fine-grained sediments (siltstone, mudstones and shale) below the coal measures and over or underlying formations.

Existing groundwater bores with in the WCM predominantly use the water supply for stock only due to the typically poor quality of groundwater. Of the 13,000 registered groundwater users with the study area, only approximately 300 are registered from the WCM. The majority of existing WCM registered users also access only the shallower seams (i.e. less than 300 m below ground level) within the full unit, whereas CSG industry development typically targets the coal seams at depths from 500 m to 700 m below ground surface level.

For this overview study a significant range of water management options has been presented. For each option, the applicability, constraints and data requirements have been briefly assessed where possible. For all options of use of CSG product water, two key factors must be known, the quality and quantity of supply. While some of the options presented may not be applicable in the short term, the aim is to present as many water use options as possible. The key water management options available for management of produced water include (but not limited to):

- surface discharge;
- underground injection;
- impoundment with no re-use (evaporation, recharge); and
- beneficial uses.

It is likely that a production area will require a combination of management options for produced water. It may be that a portion of the produced water is used on site, a portion is used for a beneficial use and part is disposed. Water management options will be site specific and will be influenced by some or all of the following factors:

- location of production area and proximity to communities, industries, agricultural lands;
- confidence of water extraction rates that can be guaranteed for beneficial use; water quality of produced waters;
- environmental sensitivity of surrounds;
- responsibility of capital costs for beneficial use scheme; and
- philosophy of the CSG producing company in accordance with Government policy/
- legislative framework.

Due to the water quality characteristic of the coal seam water within the Surat Basin, it is assumed that all or some of the management options chosen by industry may require treatment of the produced water to meet the required water quality. If a treatment option it should be recognised that it is likely that the waste stream from the treatment will require disposal.

It should also be noted that while surface water discharge has been included in the discussion as a potential water management option, the complexity of regulatory approvals and the poor water quality of CSG product water against the water quality of the receiving environment, does not allow for this option to the directly viable, from both an environmental and social acceptance perspective. Potential uses of water
If produced water was to be used for a beneficial use it may include but not be limited to:

- agriculture;
- aquaculture; niche/cottage industries — algae farming;
- industrial — coal mining, cooling water;
- municipal potable water supply;
- community water supply and recreational activities; and
- environmental — recharging streams/aquifers, minimum environmental flows, wildlife
- water supply and habitat creation.

Again the quality and quantity of CSG product water must be known in order to determine suitability of end use, reliability of supply to end use and level of treatment required.

Citation: SEAB, *Draft Comparison of Recommendations from the US Secretary of Energy Advisory Board (SEAB) Shale Gas Production Subcommittee Report and Initiatives Undertaken in Australia by Government and Industry* (2012)

Topic Area: Shale Gas Regulation

Jurisdiction: Australia

Aims & Research Methods: This table produced SEAB recommendations that are being used by WA regulators and independent experts as an indicative guide of issues being faced in Australian Shale Gas development. The table has the following column headings:

- SEAB Report (Recommendation and Comments)
- Relevant WA & National Initiatives (APPEA Code of Practice, WA Government and Commonwealth/ standing Council on Energy and Resources)

Citation: Morgan Stanley, *Australia Oil & Gas Shale Gas: Grab a Surfboard…* (June 2011)

Topic Area: Shale Gas and Investment in Australia

Jurisdiction: Australia

Introduction: The North American shale gas industry is a modern success story and the search for prospective shale gas acreage is now a global one. Commercial production from shale hasn't been seriously attempted in Australia yet, but that is about to change. A number of domestic and overseas companies are undertaking shale gas drilling and testing programs. Collectively the industry will spend about A$500mn this year on shale gas exploration, up from negligible levels a year ago. Australia has large sedimentary basins with enormous shale gas potential too. The 'gas-in-place' resource is independently assessed 1 by ARI to be in the range of 1380–2300 trillion cubic feet (Tcf) of which over 400 Tcf could technically be recovered. Current technology as applied in the US, and existing knowledge of specific Australian shale gas sequences, give rise to a view that production is feasible.

If there is lots of gas why has no-one one chased it before? Lack of market opportunities and infrastructure constraints have historically inhibited gas exploration. Even the Queensland CSG industry only really 'took-off' after resource owners cracked open the LNG export market – and that was as recent as 2008. Will it work? It should. The upcoming exploration wave aims to 'prove the concept' that production is feasible in the first instance. Some of the shale rocks in conventional production basins such as the Cooper and Perth basins, are reasonably well understood and appear to rank favourably against successful shale rock developments in the US. Fraccing of a handful of vertical wells has provided encouraging results but horizontal wells technology, a key success factor in the US, has yet to be deployed in Australia.

Will it be profitable? Commercial considerations are yet to be addressed and these are not insignificant in Australia. Shale gas is more expensive than conventional gas production, and can only succeed financially in markets where cheaper conventional production is depleting and gas prices are on the ascendancy. In Australia, low domestic gas prices are an existing barrier, but by the time this industry is ready to deliver, we anticipate domestic gas shortages and higher prices. LNG projects also provide access to higher prices.

Where should investors look first? Current understanding is that the most prospective shale gas basins are the Cooper and Perth basins; both will see drilling activity this year and both have under-utilized production infrastructure to enable commercial production. Activity is underway in new/frontier areas too, by foreign operators, e.g. in the Georgina, Beetaloo and Officer basins, as well as by Australian companies in the Canning Basin. These latter regions are more remote and so, face a higher initial economic hurdle, in our view.

What about other unconventional hydrocarbon plays? The scope of this report is limited to shale gas, which is just one sub-set of 'unconventional' oil and gas, which also includes coal seam gas and 'tight' gas production. We have chosen to limit the scope to shale gas operations, which is in its infancy, compared to coal seam gas, which in Queensland is well developed and we feel well known and understood by investors. However, the one caveat on this exclusion is that we note a number of companies are indicating the potential for shale and coal seam gas targets to co-exist in particular wells or basins, and those are referenced in this report as applicable. Where is the 'thundering herd?' Apart from Santos, whose land position is a result of incumbency, and small investments by Hess and CNOOC, participation levels by global E&P companies are small.

By contrast, asset deals for US shale gas in the past three years exceed US$70bn, with super-majors typically buying smaller independent producers. The shale gas industry in Australia today is analogous to the coal seam gas industry a few years ago. Then CSG was a 'cottage' industry populated by many small companies experimenting with production and techniques. Once technical success became apparent, a consolidation phase followed very rapidly, and within two years, US$24bn changed hands for undeveloped gas resources and today super-majors dominate Australian CSG. This could occur with shale gas too, but only after technical success is demonstrated, in our view. Investment strategy AWE and Beach Energy offer the best leverage to near term exploration events, while Santos has the greatest absolute upside in terms of exposure to prospective acreage plus it has production infrastructure. We recommend investors increase exposure to these stocks. Importantly, there appears to be very little of this shale gas potential currently priced into the stock prices.

Aims & Research Methods: This article provides valuations, recommendations, lessons learned from the US, technical information, risks of shale gas, basin overviews, company overviews and economic considerations of Australia's shale gas production and exploration.

Conclusions: News flow will drive any price increases for stocks active in the shale gas industry in Australia. Our fundamental stock valuations are unlikely to be affected for some time, until exploration activity results in reserve bookings which can be tangibly valued. Our key methodology for all E&P in Australia is DCF sum-of-parts. The issue that arises is that exploration acreage without proven or producing reserves has no cash flow profile, thus we resort to industry accepted yardsticks. One way to value acreage is to assess the investment that a company would be prepared to invest in an ongoing exploration program. The fact that two dozen companies are collectively intending to spend >US$500mn this year evidences that shale gas acreage has *some* value, but we do not have enough 'data points' yet to arrive at a 'number' that could be meaningfully applied, with any confidence. Another accepted rule of thumb would be to use precedent transactions, either in terms of asset deals or M&A.

It would be obvious to plumb the US industry for a methodology, and we are frequently presented with transaction multiples for prospective acreage. Our data set for 86 acreage transactions in the US since 2009 shows an average price per acre of US$5,500 (with a very wide range though with prices as high as US$$30,000). However, we observe the bulk of transactions are in regions where the prospectively is confirmed by nearby commercial production and where the production techniques to be applied and development costs reasonably well known. These parameters are not known in Australia, and moreover, the vast acreage positions that are typically held, in the order of thousands of square kilometres, renders applying an 'acreage value' meaningless. Consider the numbers that would result from applying $5,500/acre to Buru Energy's nine million acres or New Standard's eleven million acres. We could continue to embellish the point but suffice it to say that we reject US-type benchmarks *at this time*, and leave them in reserve for a future time once the exploration plays become de-risked. Rather than value what we don't know, let's assess what we do know. Here are three considerations:

1. Understand where 'core value' is in case exploration fails In our experience, Investors in exploration companies don't seek to value the unknown, but more importantly prefer to understand 'core' value for production and cash, then figure what the 'blue sky' is in the stock price, which is effectively the cost of the exploration option. At worst, if exploration fails, then the core value puts a floor under the stock price.

3. Invest ahead of the activity Market releases detailing planned activity drive share prices in anticipation of future success and recent recovery in, or outperformance in, stocks such as BPT or AWE characterize this. BPT has arguably been the most visible promoter of its shale gas program this year and in addition to positive conventional oil well results, the stock has outperformed domestic peers YTD. In this regard, AWE remains a laggard and expectation of a catch-up is implicit in our upgraded recommendation as well as what appears to be a discount to core value.

3. Assess the drilling and testing results when they become available. In general, we would be looking for evidence this year that the shales respond to fraccing. Given that most of the wells to be fracced are vertical wells, we would not expect commercial type flow rates, but we would anticipate operators to report the successful displacement of frac fluids into the shales, followed by the return of such and free gas flow. Failure to flow may evidence failure to frac and that may render the play worthless. Many wells are planned to be cored. Cores are sent to labs for analysis and often the results are not known for months and even then, rarely reported on. Increasingly we would expect operators to make available such parameters as TOC, thermal maturity, shale mineralogy. The provision of such information may be valuable. Recommendations and price targets Santos. Our Overweight recommendation is unchanged as is our $16.50 price target. Our full value is $19.27 and this does MOT include any value for conventional and unconventional gas resources, or value for infra-structure. Included in this DCF is an unrisked estimate of the PNG and GLNG LNG projects which are under construction. We believe that investors are likely to apply some discount to these developmental assets given the construction risks, and the potential for projects to go overtime or cost more. Santos' shale gas activities, relative to their other activities, is small at this time and perhaps less well publicized, hence we reckon that the STO share price does not reflect anything for potential future upside.

AWE on our analysis, is trading below the value of core production and cash. We think this is because investors fear further value-destroying news. Over the past 1-2 years there have been a series of production downgrades, rising capex, and capital-eating exploration dry-holes. Thus, the company's position in shale gas is probably overlooked in our view, yet its upcoming activity this year is real and potentially very value additive. We have upgraded our recommendation to Overweight, with a price target of $1.80 (which is unchanged). Contributing to the upgrade is but an extended period of share price underperformance tilts the risk-reward equation to reward. Beach Energy is active now, and we think near term news flow will likely power the price. With that in mind Morgan Stanley issued a positive Research Tactical Idea on May 18, 2011. Comparing core valuations though, it appears to us that there is already some value in the share price for the shale gas activity. We attribute this to BPT's comprehensive market presentations which provide some excellent detail and insight into the technical aspects behind its drilling for shale gas to date. Investors are clearly already ascribing some value to the shale gas activity and data to support this, or not, is expected over the next 30-40 days.

Citation: RISC, *Unconventional Gas in Australia* 2010 (May 2010)

Topic Area: Unconventional Gas Issues

Jurisdiction: Australia

Aims & Research Methods: This report provides information and analysis of unconventional gas including:

• Global context

• Key differences, critical success factors, resource maturation

• Australian unconventional gas industry:

• coal seam gas - LNG Projects

• fractured shale gas

• tight gas

• Key players

• Prospective basins, existing and emerging plays

• Costs and economics of gas supply

• Regulatory and environmental issues

Citation: Market Line, *Australia Oil & Gas Report* (2013)

Topic Area: Oil & Gas Production

Jurisdiction: Australia

Introduction: Australia is on track to become the world's largest liquefied natural gas (LNG) exporter by the end of our forecast period in 2022, surpassing Qatar as a series of major projects come online. However, the spiralling costs of LNG project will most likely slow the momentum in further expansion of Australia's LNG export capacity. The country will also have to contend with a growing reliance on oil imports as domestic crude oil production declines while refining outlook appears increasingly bleak in face of regional competition.

Aims & Research Methods: This report provides the BMI industry report of Australia Oil & Gas in 2013-2022.

Conclusions: The main trends and developments we highlight for Australia's oil & gas sector are:

■ Our forecast for gas production is 132.4bcm by 2017 from an estimate of 48.9bcm in 2012. This growth will be brought about by the development of gas fields that will come online alongside the completion of LNG projects. We expect about 75% of this gas to be exported as LNG, largely to Asian customers. By 2022, gas production is forecast to hit 164.9bcm. with LNG exports surpassing 100bcm.

■ However, expansion of liquefaction capacity - and consequently exports - could be delayed. Spiralling developments costs, owing to a shortage of skilled labour and a strong Australian dollar, together with an expected loosening of the global LNG market as more supplies come online, could worsen the economics of LNG projects in Australia.

■ According to the country's energy ministry, Australia is using oil three times faster than it is finding it. We estimate that oil production and consumption was 526,000 barrels per day (b/d) and 1.03mn b/d, respectively, in 2012. Consumption is expected to continue its uptrend to hit 1.08mn b/d in 2017 and 1.12mn b/d in 2022. Oil production, however, is projected to trend downwards to 518,600b/d in 2017 and 506,700b/d in 2022 due to the lack of notable projects beyond 2013.

■ Nonetheless, further oil discoveries and possible development particularly in the Cooper Basin, and production from liquid-rich shale pending further exploration could pose upside risks to our oil production forecasts.

■ The refining environment remains weak in Australia. Shell's 79,000b/d Clyde refinery in Sydney will close in September 2012, while Caltex announced that it will shut down the Kurnell refinery - Australia's second largest with a capacity of 124,500b/d and also located in Sydney - in the second half of 2014. Shell's Geelong refinery could suffer the same fate. The age, small size and relatively low complexity of the country's refineries has rendered them uncompetitive against regional counterparts.

■ As of July 2012, the Petroleum Resource Rent Tax (PRRT) has been extended to cover onshore petroleum projects and the North West Shelf project. Existing royalties and production excise tax will continue to apply from these areas, but will be creditable against future PRRT liabilities from each individual project. However, the Joint Petroleum Development Area in the Timor Sea remains exempt.

■ Australia's carbon trading scheme - the world's second largest after the European Union - came into effect on July 1 2012. Under this scheme, businesses will pay AUD23 (US$24.18) per tonne of carbon produced. The price will rise by around 2.5% in real terms in 2014 and 2015, but will be determined by the market, subject to a price ceiling and floor, in 2015. This could push the country towards the greater use of gas for commercial and residential needs.

■ At the time of writing we assumed an OPEC basket oil price for 2013 of US$104.40 per barrel (bbl), falling to US$101/bbl in 2014. Global GDP in 2013 is forecast at 2.9%, up from an assumed 2.5% in 2012, reflecting some recovery in the US and China, though uncertainty with regard to the eurozone debt situation will continue to hamper growth. For 2014, growth is estimated at 3.4%.

Citation: IBIS World, *Global Oil & Gas Exploration & Production* (September 2013)

Topic Area: Global Oil & Gas Exploration & Production

Jurisdiction: Global

Aims & Research Methods: Also known as hydrocarbon exploration or petroleum geology, the Global Oil and Gas Exploration and Production industry seeks natural resources from beneath the Earth's surface. Market share is highly concentrated among a few large companies, which are vertically integrated, multinational conglomerates. After the initial drilling, extraction and transport stages are completed, these companies typically also perform refining and manufacturing activities, which are excluded from this mature industry. Movements in oil and natural gas prices relative to production volumes play key roles in determining the industry's performance. Key markets include the developing nations of Brazil, Russia, India and China, also known as the BRIC nations. The emerging industrial capacities of BRIC nations have been driving up the cost for raw energy commodities, as a wide range of manufacturing pursuits require oil and natural gas as key inputs or energy sources for factory equipment. As such, industry revenue is expected to increase at an annualized rate of 1.3% over the five years to 2013. In 2013 alone, revenue is expected to expand 3.0% to reach an estimated $4.5 trillion as production volume increases.

Conclusions: The Global Oil and Gas Exploration and Production industry is expected to generate revenue of $4.5 trillion in 2013. This is up from $4.2 trillion in 2008, yielding annualized growth rate of 1.3% in the five years to 2013. Revenue is expected to expand 3.0% in 2013 as oil and gas prices moderately contract, which represents a slowdown from extremely large gains during 2010 and 2011, when oil prices surged. Shortterm spikes in the price of oil and gas have largely driven the industry's expansion over the period. However, industry performance did experience significant pitfalls, with an almost 40.0% drop in revenue during the global recession in 2009. Industry profit has also fluctuated according to oil and gas prices. This is a highly regulated industry, with various tiers of government involved in all stages of production. Governments determine which geographical areas of a country are open to oil exploration and extraction, issue exploration and production leases, and enforce environmental legislation. Environmental concerns associated with deep-sea oil and gas drilling came to the forefront in 2010 after the explosion of BP's Deepwater Horizon facility in the Gulf of Mexico. The US government's inquiry into the incident laid blame at the feet of both the industry and regulators in the United States. Consequently, regulation in the United States has been tightened, and firms involved in oil exploration and drilling also face more scrutiny in other jurisdictions, which raises operating costs through compliance monitoring and longer lead times.

Trade has become an increasingly important aspect of the industry over the past five years. About 57.0% of the oil produced in 2013 will be traded internationally, compared with nearly 32.0% of natural-gas output. Combined, the value of internationally traded oil and natural gas in 2013 is forecast to be $1.9 trillion. Output is dominated by Africa, the Middle East, Europe and North America. Over the next five years, oil and gas consumption is expected to expand moderately as global economic growth continues. Although the Organization of the Petroleum Exporting Countries is expected to moderate production levels so that the world average oil price fluctuates around $100.0 per barrel, occasional shortfalls in output are expected to periodically cause prices to spike at higher levels. In this climate, the industry's revenue is forecast to grow at an annualized rate of 2.5% in the five years to 2018 to $5.1 trillion.

BOOKS AND BOOK CHAPTERS

Citation: John Wils and Ewan Neilson, 'The Technical and Legal Guide to Global Hydrocarbons' (2013) 31 *JERL* 91

Topic Area: Hydrocarbons from technical, legal and commercial perspectives.

Jurisdiction: Global

Introduction: *The Technical and Legal Guide to Global Hydrocarbons*, co-edited by John Wils and Ewan Neilson, includes submissions by 75 current international specialists in the hydrocarbons industry. Readers are provided with an overview as to what this subject is all about from technical, legal and commercial perspectives.

Conclusions: The legal summary on research and development sets out to explain the principal stages in the development of new technology (confidential information, R&D agreements, background/foreground intellectually property). The mechanics of funding is touched on with a summary of the necessary investment. There is a short synopsis of the key intellectual property issues, including licensing, patents, copyright, trademarks and unregistered/registered design, and there is a case study touching on intellectual property laws. Offshore accidents and regulatory frameworks are reviewed. The different international regulatory approaches and practice (prescriptive approach and performance/goal setting) and the standards and enforcement of regulations are highlighted. An explanation is given about significant incidents resulting in regulatory reforms (Piper Alpha, West Atlas Montara Field, Brent Spar and deep-water Horizon drilling in the Macondo oilfield). We learn how different jurisdictions have reacted to international catastrophes such as Piper Alpha and the Macondo well explosion.

Citation: James Speight, Shale Gas Production Processes (Elsevier Science, 2013)

Topic Area: Shale Gas Technology, Processes, Chemistry, Environmental Regulation

Jurisdiction: USA

Abstract: The extraction of natural gas from shale formations is no simple task and perhaps the most expensive when compared to over unconventional gases. Although, its popularity has grown over the years, there is much to be done to make their production and processing more cost-effective. Brief but comprehensive, *Shale Gas Production Processes* begins with an overview of the chemistry, engineering and technology of shale gas. This is quickly followed by self-contained chapters concerning new and evolving process technologies and their applications as well as environmental regulations. Written in an easy to read format, *Shale Gas Production Processes* will prove useful for those scientists and engineers already engaged in fossil fuel science and technology as well as scientists, non-scientists, engineers, and non-engineers who wish to gain a

general overview or update of the science and technology of shale gas. In addition, the book discusses methods used to reduce environmental footprint and improve well performance.

Citation: OECD Publishing International Energy Agency, *Resources to Reserves 2013: Oil, Gas and Coal Technologies for the Energy Markets of the Future* (2013, OECD Publishing)

Topic Area: Energy Development, Environmental Aspects and Technological Innovation

Jurisdiction: Global

Abstract: The availability of oil and gas for future generations continues to provoke international debate. In 2005, the first edition of Resources to Reserves found that the known hydrocarbon resources were sufficient to sustain likely growth for the foreseeable future. Yet the book also predicted that developing oil and gas resources - and bringing them to market - would become more technically demanding. Resources to Reserves 2013 - a comprehensive update to the 2005 edition - confirms these earlier findings and investigates whether oil and gas resources can be produced at a reasonable cost and in a timely manner, while also protecting environmentally sensitive areas. Released amid a boom in shale gas and oil development in North America that is transforming the global energy landscape, the book surveys the cutting-edge technologies needed to find, produce and bring these reserves to the market, and it reviews the challenges on greenhouse gas emissions associated with fossil fuel production. With renewed interest in coal as a potential source of liquid and gaseous fuels, it also looks at technology advances for this fossil fuel.

Citation: Susan Sakmar, *Energy for the 21st Century: Opportunities and Challenges for Liquefied Natural Gas* (Edward Elgar, 2013)

Topic Area: Business and Economics Natural Gas Industry

Jurisdiction: Global

Abstract: Professor Sakmar's book is a must read for anyone interested in gaining a better understanding of the most dynamic segment of the global energy industry. Ð Jay Copan, Executive Director, LNG 17 Professor Sakmar's book provides a well-rounded overview of the global role that natural gas is expected to play in the future and the important role of LNG as a means of transporting gas to where it is needed. Readers will find the book to be a very convenient compendium of relevant global information and an important educational, informational resource. Ð Ronald D. Ripple, Director, Centre for Research in Energy and Minerals Economics, Curtin University, Australia Understanding global energy markets Ð what forces shape them and what trends define them Ð is critical for any professional trying to evaluate new energy developments and technological directions. Susan Sakmar's impressive ability to provide this context in terms of LNG markets makes her book valuable. Warren R. True, Sr., Chief Technology Editor, Oil & Gas Journal With clear and direct text, supplemented with key maps, charts and graphics from government, industry and other sources, the book moves the reader smoothly through the early history of LNG up to current developments, including shale gas and North American LNG exports. The book is a valuable resource for anyone interested in understanding global gas markets and the energy policy challenges facing us in the 21st century. Jacqueline L. Weaver, A.A. White Professor of Law, University of Houston Law Centre, US Countries around the world are increasingly looking to liquefied natural gas (LNG) Ð natural gas that has been cooled until it forms a transportable liquid Ð to meet growing energy demand. Energy for the 21st Century provides critical insights into the opportunities and challenges LNG faces, including its potential role in a carbon-constrained world. This comprehensive study covers topics such as the LNG value chain, the historical background and evolution of global LNG markets, trading and contracts, and an analysis of the various legal, policy, safety and environmental issues pertaining to this important fuel. Additionally, the author discusses emerging issues and technologies that may impact global LNG markets, such as the development of shale gas, the potential role of the Gas Exporting Countries Forum and floating LNG. The author contextualizes the discussion about the importance of LNG with an analysis of why the 21st century will be the golden age of natural gas. Accessible and non-technical in nature, this timely book will serve as an essential reference for practitioners, scholars and anyone else interested in 21st century energy solutions.

Citation: David Waples, *The Natural Gas Industry in Appalachia: A history from the First Discovery to Tapping of the Marcellus Shale* (McFarland and Company, 2nd ed, 2012)

Topic Area: History of the Gas Industry

Jurisdiction: USA

Abstract: The large scale, practical uses of natural gas were initially introduced by innovators Joseph Pew and George Westinghouse for the steel and glass industries in Pittsburgh, and local gas companies evolved from individual wells to an interstate supply network acquired by Rockefeller's Standard Oil interests. Natural gas is now a prevalent part of American markets with the production from the Marcellus shale and is filling the critical void left by a lack of new coal, oil, and nuclear power facilities. This vital American enterprise began in the Appalachian states as an accidental and underestimated by product of the oil rush of 1859. This book explores the evolution and significance of the natural gas industry to the present day.

Citation: Tom Wilber, *Under the Surface, Fracking, Fortunes and the Fate of the Marcellus Shale* (Cornell University Press, 2013)

Topic Area: Fracking Activities

Jurisdiction: USA

Abstract: Running from southern West Virginia through eastern Ohio, across central and northeast Pennsylvania, and into New York through the Southern Tier and the Catskills, the Marcellus Shale formation underlies a sparsely populated region that features striking landscapes, critical watersheds, and a struggling economic base. It also contains one of the world's largest supplies of natural gas, a resource that has been dismissed as inaccessible—until recently. Technological developments that combine horizontal drilling with hydraulic fracturing ("fracking") have removed physical and economic barriers to extracting hundreds of trillions of cubic feet of gas from bedrock deep below the Appalachian basin. Beginning in 2006, the first successful Marcellus gas wells by Range Resources, combined with a spike in the value of natural gas, spurred a modern-day gold rush—a "gas rush"—with profound ramifications for environmental policy, energy markets, political dynamics, and the lives of the people living in the Marcellus region. *Under the Surface* is the first book-length journalistic overview of shale gas development and the controversies surrounding it.

Control over drilling rights is at stake in the heart of Marcellus country—northeast Pennsylvania and central New York. The decisions by landowners to work with or against the companies—and the resulting environmental and economic consequences—are scrutinized by neighbours faced with similar decisions, by residents of cities whose water supply originates in the exploration area, and by those living across state lines with differing attitudes and policies concerning extraction industries. Wilber's even-handed treatment gives a voice to all constituencies, including farmers and landowners tempted by the prospects of wealth but wary of the consequences, policymakers struggling with divisive issues, and activists coordinating campaigns based on their respective visions of economic salvation and environmental ruin. Wilber describes a landscape in which the battle over the Marcellus ranges from the very local—yard signs proclaiming landowners' allegiances for or against shale gas development—too often conflicting municipal, state, and federal legislation intended to accelerate, delay, or discourage exploration.

Citation: Gabriel Navarro, *Earth Sciences in the 21st Century: Marcellus Shale and Shale Gas: Facts and Considerations* (Nova Science Publishers, 2011)

Topic Area: Fracking Activities

Jurisdiction: USA

Abstract: The Marcellus Shale is a sedimentary rock formation deposited over 350 million years ago in a shallow inland sea located in the eastern United States where the present-day Appalachian Mountains now stand. This shale contains significant quantities of natural gas. New developments in drilling technology, along with higher wellhead prices, have made the Marcellus Shale an important natural gas resource. This book explores water resources and natural gas production from the Marcellus Shale; the impact of Marcellus Shale gas play on current and future Carbon Capture and Storage (CCS) activities; and, applying this technology to solve America's energy challenges.

Citation: Spencer Ferguson, *Hydraulic Fracturing and Shale Gas Production: Issues, Proposals and Recommendations* (Nova Science, 2013)

Topic Area: Fracking Activates and Other Social Issues

Jurisdiction: USA

Abstract: Hydraulic fracturing is a technique used to free oil and natural gas trapped underground in low-permeability rock formations by injecting a fluid under high pressure in order to crack the formations. The composition of a fracturing fluid varies with the nature of the formation, but typically contains mostly water; a proppant to keep the fractures open, such as sand; and a small percentage of chemical additives. Some of these additives may be hazardous to health and the environment. The Shale Gas Production Subcommittee of the Secretary of Energy Advisory Board (SEAB) has recommended public disclosure, on a well-by-well basis, of all of the chemical ingredients added to fracturing fluids, with some protection for trade secrets. Currently, no such law or regulation exists at the federal level. In

his 2012 State of the Union Address, President Barack Obama said he would obligate "all companies that drill for gas on public lands to disclose the chemicals they use," citing health and safety concerns. In May 2012, the Bureau of Land Management (BLM) published a proposed rule that would require companies employing hydraulic fracturing on lands managed by BLM to disclose the content of the fracturing fluid. In addition, there have been legislative efforts in the 112th Congress. H.R. 1084 and S. 587, the Fracturing Responsibility and Awareness of Chemicals Act (FRAC Act), would create more broadly applicable disclosure requirements for parties engaged in hydraulic fracturing. Chemical disclosure laws at the state level vary widely. Of the 15 laws examined in this report, fewer than half require direct public disclosure of chemical information by mandating that parties post the information on the FracFocus chemical disclosure website. The level of detail required to be disclosed often depends on how states protect trade secrets, as these protections may allow submitting parties to withhold information from disclosure at their discretion or to submit fewer details about proprietary chemicals, except, perhaps, in emergencies. Even if a disclosure law does not protect information from public disclosure, other state laws, such as an exemption in an open records law, may do so. States also have varying laws regarding the timing of these disclosure requirements. This report provides an overview of current and proposed laws and regulations at the state and federal levels that require the disclosure of the chemicals added to the fluid used in hydraulic fracturing.

Citation: Clark D Richardson, *The Marcellus Shale Gas Resource: Development and Water Issues (Energy Science, Engineering and Technology)* (Nova Science Pub Inc, 2013)

Topic Area: Water Use and Management Issues

Jurisdiction: USA

Abstract: Until relatively recently, natural gas-rich shale formations throughout the United States were not considered to have significant resource value because no technologies existed to economically recover the gas. Development and deployment of advanced drilling and reservoir stimulation methods have dramatically increased the gas production from these "unconventional gas shales". The Marcellus Shale formation potentially represents one of the largest unconventional natural gas resources in the United States, underlying much of West Virginia and Pennsylvania, southern New York, eastern Ohio, western Maryland, and Western Virginia. Directional drilling and "hydraulic fracturing" are essential to exploiting these low permeability shale gas resources. Although oil and gas developers have applied these technologies in conventional oil and natural gas fields for some time, recent improvements in both technologies have allowed them to be applied effectively to unconventional gas shales on an industrial scale. This book reviews the Marcellus Shale resource, development processes, and related surface water and groundwater issues.

Citation: US House of Representatives, *Chemicals Used in Hydraulic Fracturing: Cancer and Health Risks from Underground Injection Natural Gas Production, Marcellus Shale Gas Fracking and Hydrofrac - House Committee Report* (Progressive Management, 2011)

Topic Area: Fracking Activities, Chemical Use and Disclosure

Jurisdiction: USA

Abstract: Investigators with the House Committee on Energy and Commerce have discovered that oil and gas service companies conducting hydraulic fracturing for shale gas production used more than 2500 fracturing products containing 750 chemicals, some of which are toxic and carcinogenic. This report lists every chemical disclosed by the industry, and reveals that some of the chemicals remain proprietary and cannot be identified. According to the report: Hydraulic fracturing has helped to expand natural gas production in the United States, unlocking large natural gas supplies in shale and other unconventional formations across the country. As a result of hydraulic fracturing and advances in horizontal drilling technology, natural gas production in 2010 reached the highest level in decades. According to new estimates by the Energy Information Administration (EIA), the United States possesses natural gas resources sufficient to supply the United States for approximately 110 years. As the use of hydraulic fracturing has grown, so have concerns about its environmental and public health impacts. One concern is that hydraulic fracturing fluids used to fracture rock formations contain numerous chemicals that could harm human health and the environment, especially if they enter drinking water supplies. The opposition of many oil and gas companies to public disclosure of the chemicals they use has compounded this concern.

Last Congress, the Committee on Energy and Commerce launched an investigation to examine the practice of hydraulic fracturing in the United States. As part of that inquiry, the Committee asked the 14 leading oil and gas service companies to disclose the types and volumes of the hydraulic fracturing products they used in their fluids between 2005 and 2009 and the chemical contents of those products. This report summarizes the information provided to the Committee.

Between 2005 and 2009, the 14 oil and gas service companies used more than 2,500 hydraulic fracturing products containing 750 chemicals and other components. Overall, these companies used 780 million gallons of hydraulic fracturing products – not including water added at the well site – between 2005 and 2009. Some of the components used in the hydraulic fracturing products were common and generally harmless, such as salt and citric acid. Some were unexpected, such as instant coffee and walnut hulls. And some were extremely toxic, such as benzene and lead. Appendix A (included in this reproduction) lists each of the 750 chemicals and other components used in hydraulic fracturing products between 2005 and 2009.

Citation: US Department of Energy, *Shale Gas and the US Energy Outlook: Recent Developments* (BiblioGov, 2013)

Topic Area: USA Energy Outlook Policy Issues

Jurisdiction: USA

Abstract: This document is a speech presented by deputy Administrator, Howard Gruenspecht to the Energy Council, Global Energy and Environmental Issues Conference in Santa Fe, NM.

Citation: United States Senate, Subcommittee on Water and Power, Committee on Energy and Natural Resources, *Shale Gas and Water Impacts* (Create Space, 2012)

Topic Area: Fracking Activities, Water Use and Management

Jurisdiction: USA

Abstract: Like many in Congress, I believe that natural gas has an important role to play as we move to a clean energy economy. That the benefits of abundant, domestically produced shale gas are clear, particularly in States like my home State of New Hampshire where 45 percent of the electricity is generated from natural gas. Shale gas has the potential to provide significant amounts of affordable, clean electricity to both homeowners and businesses. However, serious concerns have been raised about the effects that shale gas production and hydraulic fracturing have on water resources, particularly here in the eastern United States.

Citation: Frank Spellman, *Environmental Impacts of Hydraulic Fracturing* (CRC Press, 2012)

Topic Area: Fracking Activities, Other Social Issues, Environmental Issues, Chemical Use and Disclosure

Jurisdiction: USA

Abstract: There is a strong need for innovation and the development of viable renewable energy sources. Recent technological advances now allow natural gas supplies—previously believed inaccessible or non-existent—to be discovered, mined, and processed for both industrial and consumer use. The technology, a controversial process that is alternatively called hydraulic fracturing, fracking, fracing, or hydrofracking, has greatly expanded natural gas production in the United States. Presenting a balanced discussion, Environmental Impacts of Hydraulic Fracturing is a comprehensive guide to all aspects of hydraulic fracturing used to extract natural gas, along with gas exploration and production in various shale fields.

As the use of hydraulic fracturing has grown, concerns about its environmental and public health impacts have also increased—one of the most significant concerns being the fluids that are injected into rock formations to cause the fracturing contain potentially hazardous chemical additives. The book covers all facets of the issue, including ongoing controversies about the environmental and operator safety issues arising from possible water pollution, drinking water contamination, on-the-job safety hazards, and harmful chemical exposure to workers and residents near well areas.

The author discusses both the pros and cons of hydraulic fracturing, explaining the process in great detail. He describes the benefits of hydraulic fracturing and its importance in making the United States energy independent by drilling for its own resources, as well as the potential impacts to the surrounding environment. The text also includes suggestions and recommendations on how to mitigate environmental damage. Arguably the first book of its kind, this is the go-to text on the use and impacts of hydraulic fracturing.

Citation: US Government EPA, *2011 Ultimate Toolkit on Shale Gas, Hydraulic Fracturing, Fracking, Hydrofrac, the Marcellus Shale Natural Gas Controversy, Environmental and Safety Risks, Water Pollution* (Progressive Management, 2010)

Topic Area: Fracking Activities, Other Social Issues

Jurisdiction: USA

Abstract: This ring bound book and electronic book on CD-ROM provides a comprehensive guide to every aspect of shale gas, including the process of hydraulic fracturing, also known as hydrofrac or fracking, to extract natural gas, along with gas exploration and production in the Marcellus shale field of New York, Pennsylvania, West Virginia, and Ohio. There is comprehensive coverage of all aspects of the issue, including the ongoing controversy about the environmental and safety risks arising from possible water pollution and drinking water contamination. Contents include material from the EPA, USGS, Department of Energy, U.S. Congress, and others.

There is a complete reproduction of EPA public meeting comments from events in Texas, Colorado, Pennsylvania, and New York, offering valuable insight into the controversy.. The CD-ROM reproduces over 10,000 pages of technical documents and regulations provide unique details and understanding. While limited production has occurred in the Marcellus Shale to date, drillers in the Barnett Shale of Texas have demonstrated that new technology in the form of horizontal drilling and hydraulic fracturing of the shale (fracturing through the use of high pressure liquids) has helped overcome the flow capacity problem of gas shales. Horizontal drilling is a technique used to expose long sections of the reservoir rock to the wellbore. While a conventional vertical well penetrates and exposes only the thickness of a pay zone (e.g., 50 to 300 feet in the Marcellus shale), horizontal drilling can expose over a mile of reservoir rock for production by steering a drill bit to follow the pay zone. Hydraulic fracture stimulation creates additional flow paths to the well. In this process, fluid is pumped into the formation at high enough pressures and rates to split the rock. Sized particles such as sand are also mixed with the fracturing fluid to hold the crack open once pumping stops. In addition, wells can be oriented to intersect natural fractures that occur in many formations. As the oil and gas industry applies this technology to more wells in more parts of the country, it is important to ensure that the process is safe and environmentally sound. Environmental organizations, public health groups, and local communities have expressed concerns about the potential impact of the injection of hydraulic fracturing fluids in wells located in or near underground sources of drinking water. Others have raised concerns about the quantity of water needed to hydraulically fracture oil and gas wells and the disposal of contaminated wastewater from fracturing operations. The CD-ROM is packed with over 10,000 pages reproduced using Adobe Acrobat PDF software - allowing direct viewing on Windows and Macintosh systems. The Acrobat cataloguing technology adds enormous value and uncommon functionality to this impressive collection of government documents and material.

Citation: Vivek Bakshi, *Shale Gas and Other Unconventional Resources: A Practitioners Guide* (Globe Law and Business, 2012)

Topic Area: Fracking Activities, Other Social Issues

Jurisdiction: USA

Abstract: With shale gas already heralded as a game changer in North American markets, what role will unconventional natural gas resources come to play in the global supply mix? Answering this question requires the examination of a unique set of challenges which the global petroleum industry finds itself facing today. Complex environmental, social and technical issues must be navigated for the development of safe and sustainable hydraulic

fracturing practices to unlock the full potential of this unconventional resource. This guide will examine the issues around hydraulic fracturing in a practical and user-friendly manner. The practical new handbook will feature contributions from leading authorities in the field, including Guy Dayvault of Energy Deal Solutions, Jessica Davies and Rebecca Perkins of Allen & Overy and Michael Darowski of Hogan Lovells. Chapters cover key issues such as the regulation of hydraulic fracturing, including water use and disposal, natural gas pricing trends and operator issues, and coal seam gas and coal bed methane. Together, the contributions afford crucial insight into one of the youngest and fastest-moving areas of the natural gas industry. This guide will be an essential reference tool for natural gas producers, lawyers in private practice and in-house, energy industry advisers and end users worldwide, providing a practical and timely overview of the shale gas industry.

Citation: EPA, *2013 Complete Guide to Hydraulic Fracturing (Fracking) for Shale Oil and Natural Gas: Encyclopaedic Coverage of Production Issues, Protection of Drinking Water, Underground Injection Control (UIC)* (Progressive Management, 2012)

Topic Area: Fracking Activities and Other Social Issues

Jurisdiction: USA

Abstract: This up-to-date encyclopaedia of official documents and publications on the risks and rewards of shale gas, with over a thousand pages of content, provides vital information on the ongoing controversy over hydraulic fracturing for shale gas production. Contents include:

Regulatory Updates and Reports * Section 1: Natural Gas Subcommittee of the Secretary of Energy Advisory Board - Safety of Shale Gas Development * Section 2: Blueprint for a Secure Energy Future * Section 3: Secretary of Energy Advisory Board - Shale Gas Production Subcommittee 90-Day Report * August 18, 2011 * Section 4: Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources * U.S. Environmental Protection Agency Office of Research and Development * June 28, 2011 * Section 5: Marcellus Shale-Gas Development and Water-Resource Issues * New York Water Science Centre * John Williams * USGS * Section 6: Shale Gas Presentation to the SEAB Natural Gas Subcommittee * Section 7: Natural Gas Hydraulic Fracturing * Issues USGS is Tracking * Section 8: EPA Briefing to the SEAB Natural Gas Subcommittee to Examine Fracking Issues * Section 9: Shale Gas: Applying Technology to Solve America's Energy Challenges * Section 10: DOE/NETL-2011/1478 * A Comparative Study of the Mississippian Barnett Shale, Fort Worth Basin, and Devonian Marcellus Shale, Appalachian Basin * Section 11: Energy in Brief — What everyone should know about energy * Section 12: Shale Gas and the Outlook for U.S. Natural Gas Markets and Global Gas Resources * Section 13: Multi-Agency Collaboration on Unconventional Oil and Gas Research * Section 14: Chemicals Used in Hydraulic Fracturing: Cancer and Health Risks from Underground Injection Natural Gas Production, Marcellus Shale Gas Fracking and Hydrofrac - House Committee Report * Section 15: Modern Shale Gas Development in the United States: A Primer - Geology, Regulations, Environmental Considerations, Hydraulic Fracturing, Protecting Groundwater, Pollution Threats, Impact to Land * Section 16: NPS and USGS Material * Section 17: Congressional Action * Section 18: EPA Material * Section 19: DOE Hydraulic Fracturing Description.

Citation: Cecile Musialski, Matthias Altmann, Stefan Lechtenbohmer and Wener Zittel, *Shale Gas in Europe: A multidisciplinary analysis with a focus on European specificities (European Energy Studies)* (Claeys & Casteels Publishing, 2013)

Topic Area: Fracking Activities, Regulatory Issues

Jurisdiction: EU

Abstract: Over recent years, large-scale extraction of shale gas in North America has led to a growing attention to the potential opportunities and risks of unconventional gas extraction elsewhere, including in Europe where available sources are known to exist. The US experience shows that industry-wide extraction of shale gas may positively change the game, leading notably to an increased security of supply. But, the US experience also demonstrates that intensive extraction of shale gas entails environmental risks, in particular due to the intensive use of horizontal drilling and hydraulic fracturing. From a multidisciplinary viewpoint - of engineers, economists, policymakers, lawyers, and sociologists - this book assesses the specificities of large-scale shale gas extraction in Europe. Each topic is discussed in the light of the US experience, with a particular focus that highlights Europe's differences. The book evaluates the potential of shale gas in the EU, including the potential risks. The institutional framework is explained as it defines the legal and regulatory conditions under which industry-wide shale gas extraction will develop. Taking this background into consideration, the book's contributors anticipate the challenges ahead for shale gas extraction for the EU. The book also gives an account of individual stories in some EU countries, ranging from the French ban on shale gas to wide governmental support in Poland.

Citation: Paddy Manning, *What the Frack? Everything you need to know about Coal Seam Gas* (NewSouth, 2012)

Topic Area: Fracking Activities and Other Social Issues

Jurisdiction: Australia

Abstract: Australia has a new $50 billion industry. It carries unprecedented environmental risks but could be the path to energy salvation: cleaner than coal, safer than nuclear, a complement to renewables. Big oil and gas companies tell us we could be the biggest liquid natural gas exporter in the world, but greenies and farmers are united in their opposition to coal seam gas extraction on some of our most fertile agricultural lands. Will fracking thousands of coal seam gas wells ‘poison our food bowl’? Will coal seam gas really help tackle climate change? Where will they be drilling next? Journalist Paddy Manning unpicks the coal seam gas extraction story, visiting drill sites, boardrooms, pipelines, parliamentary offices and angry farm gate protests. It seems that coal seam gas extraction may be one boom that’s happening too fast.

Citation: Anthony Andrews, Peter Folger, Marc Humphries, Claudia Copeland, Mary Tieman, Robert Meltz, Cynthia Brougher, Congressional Research Service, *Unconventional Gas Shales: Development, Technology, and Policy Issues* (CreateSpace, 2012)

Topic Area: Regulatory Issues

Jurisdiction: USA

Abstract: In the past, the oil and gas industry considered gas locked in tight, impermeable shale uneconomical to produce. However, advances in directional well drilling and reservoir stimulation have dramatically increased gas production from unconventional shales. The United States Geological Survey estimates that 200 trillion cubic feet of natural gas may be technically recoverable from these shales. Recent high natural gas prices have also stimulated interest in developing gas shales. Although natural gas prices fell dramatically in 2009, there is an expectation that the demand for natural gas will increase. Developing these shales comes with some controversy, though. The hydraulic fracturing treatments used to stimulate gas production from shale have stirred environmental concerns over excessive water consumption, drinking water well contamination, and surface water contamination from both drilling activities and fracturing fluid disposal. The saline "flow back" water pumped back to the surface after the fracturing process poses a significant environmental management challenge in the Marcellus region. The flow back's high content of total dissolved solids (TDS) and other contaminants must be disposed of or adequately treated before discharged to surface waters. The federal Clean Water Act and state laws regulate the discharge of this flow back water and other drilling wastewater to surface waters, while the Safe Drinking Water Act (SDWA) regulates deep well injection of such wastewater. Hydraulically fractured wells are also subject to various state regulations. Historically, the EPA has not regulated hydraulic fracturing, and the 2005 Energy Policy Act exempted hydraulic fracturing from SDWA regulation. Recently introduced bills would make hydraulic fracturing subject to regulation under SDWA, while another bill would affirm the current regulatory exemption. Gas shale development takes place on both private and state-owned lands. Royalty rates paid to state and private landowners for shale gas leases range from 12½% to 20%. The four states (New York, Pennsylvania, Texas, and West Virginia) discussed in this report have shown significant increases in the amounts paid as signing bonuses and increases in royalty rates. Although federal lands also overlie gas shale resources, the leasing restrictions and the low resource-potential may diminish development prospects on some federal lands. The practice of severing mineral rights from surface ownership is not unique to the gas shale development. Mineral owners retain the right to access surface property to develop their holdings. Some landowners, however, may not have realized the intrusion that could result from mineral development on their property. Although a gas-transmission pipeline-network is in place to supply the northeast United States, gas producers would need to construct an extensive network of gathering pipelines and supporting infrastructure to move the gas from the well fields to the transmission pipelines, as is the case for developing any new well field.

Citation: Greg Gordon, John Paterson and Emre Usenmez, *Oil and Gas Law: Current Practice and Emerging Trends* (Dundee University Press, 2011)

Topic Area: Regulatory Policy

Jurisdiction: UK

Abstract: This highly successful book brings together academic and practising lawyers to consider the key regulatory and contractual dimensions of the mature hydrocarbon province on the UK Continental Shelf. Now in its eagerly anticipated second edition, the text has been fully updated and there are new chapters on Energy Security, Law and Technology in the Oil Field, and Acquisitions and Disposals. Introduction and Context : Oil and Gas on the UK

Continental Shelf: Current Practice and Emerging Trends Evolving Economic Issues in the Maturing UKCS The UK's Energy Security Licencing and Regulation: Petroleum Licencing Mature Province Initiatives The UKCS Fiscal Regime Access to Infrastructure Health and Safety at Work Offshore Environmental Law and Regulation on the UKCS Decommissioning Offshore Oil and Gas Installations Competition Law and the Upstream Oil and Gas Business Contracting and Commercial Issues: Joint Operating Agreements Unitisation Risk Allocation in Oil and Gas Contracts Law and Technology in the Oilfield Acquisitions and Disposals of Upstream Oil and Gas Interests Aspects of Land Law Relative to the Transportation of Oil and Gas in Scotland Dispute Management and Resolution.

Citation: Filippos Proedrou, *EU Energy Security in the Gas Sector: Evolving Dynamics, Policy Dilemmas and Prospects* (Ashgate Publishing, 2012)

Topic Area: Fracking Activities, EU Policy

Jurisdiction: UK

Abstract: This book fills an important gap in the literature on energy security in the gas sector in the European Union. Whilst the emphasis is often on energy security in the oil sector, the gas sector has grown in importance in recent decades, with increasing liberalization raising critical questions for the security of gas supplies. The share of gas in Europe's energy mix is rising and the differences between the politics and economics of gas and oil supply are becoming more pronounced. The author sheds light on the state of EU energy security in the gas sector, its interdependence with external suppliers and the current gas strategy. He examines the role of energy companies, EU member-states and EU institutions, locates the main developments in the gas sector and focuses on the principal challenges posed by such fundamental changes. The author scrutinizes the EU's relations with its main gas supplier, Russia, as well as with alternative suppliers, elaborates on the key infrastructure projects on the table and their principal ramifications, and discusses the main policies that member-states pursue to achieve energy security as well as the EU's internal contradictions. The book concludes with policy recommendations, particularly in the light of tougher environmental regulation.

Citation: Andrew Bruton and Amir Kordvani, *Chapter 3- Exploration* (Lexis Nexis, 2011)

Topic Area: Gas Exploration

Jurisdiction: Australia

Abstract: This guide card deals with exploration rights for minerals in Australia. Section 2 of this guide card deals with exploration licences and exploration permits which permit exploration over large areas of land. Section 3 of this guide card deals with other forms of exploration titles which provide for prospecting and exploring for minerals on a lesser scale.

KEY STATUTORY MATERIALS

Commonwealth of Australia Constitution Act 1900

Environmental Protection and Biodiversity Conservation Act 1999

National Water Commission Act 2004

National Water Initiative Agreement 2004

Natural Resources and Other Legislation Amendment Act 2010

Natural Resources and Other Legislation Amendment (Part 2) Act 2010

Water and Other Legislation Amendment Act 2010

Environmental Protection and Other Acts Amendment Act 2011

Environmental Protection Act 1994

Environmental Protection Regulations 2008

Environmental Protection (Water) Policy 1997

Environmental Protection (Waste Management) Regulation 2000

Environmental Protection (Waste Management) Policy 2000

Petroleum Act 1923

Petroleum and Gas (Production and Safety) Act 2004

Petroleum and Gas (Production and Safety) Regulation 2004

Queensland Coal Seam Gas Water Management Policy 2008

Water Act 2000

Water Supply (Safety and Reliability) Act 2008

Water Regulation 2002

Water Supply (Safety And Reliability) Regulation 2011

Water Resource (Great Artesian Basin) Plan 2006

Great Artesian Basin Resource Operations Plan 2007

Environment Protection and Biodiversity Conservation Amendment (Protecting Australia's Water Resources) Bill 2011 No. , 2011

Toxic Substances Control Act (TSCA) 15 U.S.C.

Safe Drinking Water Act of 1974, 42 U.S.C.

Energy Policy Act of 2005 42 U.S.C.

Water Quality Act of 1987, Pub. L. No. 100-4,

Clean Water Act, 33 U.S.C.

Emergency Planning and Community Right-to-Know Act of 1986

Community Right-to-Know Reporting Requirements, 55 Fed. Reg. 30,632-37 (July 26, 1990)

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 42 U.S.C. § 9601(14).

Resource Conservation and Recovery Act 42 U.S.C. (2006)

KEY CASE LAW

Citation: *Legal Environmental Assistance Foundation v U.S. Environmental Protection Agency*, [1997] 118 F.3d 1467 (LEAF I).

Summary: The 11th Circuit found that the injection of frac fluids into coal bed methane formations was subject to regulation under Alabama's UIC program. While the holding applied only to Alabama's UIC program, the 11th Circuit's 1997 decision had implications for other state-run UIC programs and resulted in Congress commissioning an EPA study on hydraulic fracturing.

Citation: *Amoco Production Company v Southern Ute Indian Tribe*, (1999) U.S. Supreme Court, (98-830) 526 U.S. 865.

Summary: In *Amoco*, the United States Supreme Court reversed a Tenth Circuit Court of Appeals *en banc* decision on the issue of CBM ownership. The Tenth Circuit held that CBM had rightfully been reserved to the Southern Ute Indian Tribe in 1938 when the U.S. government returned to the Utes equitable title to coal underlying homestead lands historically annexed from tribal territory. The *en banc* or full court decision was reached through judicial interpretation of conveyance language found in the 1909 and 1910 Coal Lands Acts. The Coal Lands Acts initially reserved to the federal government the subsurface lands of early homesteaders for the benefit of federal coal reserves. The Circuit Court found ambiguity in the Acts' conveyance language, to be resolved in favour of the Ute Tribe. The Tenth Circuit's statutory construction analysis was subsequently rejected however, by the United States Supreme Court whose decision turned instead on the "ordinary and popular sense" of coal's 1909 mineral definition. Although a host of experts in *Amoco* failed to agree on the physical nature of coal bed methane's relationship to coal, the Supreme Court held [*121] that "reservation of 'coal' in [the 1909 and 1910 Coal Lands Acts] did not encompass CBM gas, since the common conception of coal at the time . . . was limited to solid rock substance." The Supreme Court held, therefore, that CBM had not been reserved to the Ute Indian Tribe when coal rights in homestead lands were returned to them by the U.S. government in 1938. Therefore, even though the Ute tribe had rightfully reacquired coal ownership in 1938, it did not own the CBM embedded within the coal reserves in 1999.

Citation: *Arnold & Ors v Minister Administering The Water Management Act 2000 & Ors* [2010] HCA 3

Summary: he appellants held bore licences in the Lower Murray in New South Wales under the *Water Act 1912* (NSW) that were superseded with aquifer access licences under the *Water Management Act 2000* (NSW). The appellants' entitlements were less under the new aquifer access licences. Under the *Water Act* the appellants' bore licences were subject to change from the time they were granted. The Water Management Act provided for the Minister to determine water management policies and allowed the Minister to convert previous water licences to new licences under new terms as provided for under the Act.

In 2004 the Commonwealth and the each of the States and Territories (except Western Australia) entered the Intergovernmental Agreement on a National Water Initiative which providing for the creation of a National Water Commission. The agreement included objectives relating to water management in the Murray-Darling Basin. As a result of this and corresponding agreements, the NSW Government accepted Commonwealth funding ($55 million) to reduce the allocations of groundwater licences in the Lower Murray region using the powers of the *Water Management Act*. The Commonwealth funding was intended to help assist the NSW Government in offsetting the impact to licence holders. Commonwealth funding was administered through the National Water Commission under the *National Water Commission Act 2004* (Cth).

The appellants challenged the removal and replacement of their licences on the basis that:

- The replacement of their water licences by the Government of NSW as the result of funding by the Commonwealth, was an acquisition of property not on just terms in breach of s 51(xxxi) of the Constitution.
- The funding by the Commonwealth is a "regulation of trade or commerce" which is in breach of s 100 of the Constitution.

Arnold was heard immediately after *ICM Agriculture Pty Ltd v The Commonwealth* [2009] HCA 51. *ICM* revolved around an analogous factual situation to those in by Arnold. In *ICM* the High Court (6:1) ruled that the cancellation of bore licences and issuing of aquifer access licences with a reduced quota (under the same federal funding scheme), did not constitute an acquisition of property within the meaning of s 51 (xxxi).

The majority granted special leave but dismissed the appeal. The majority chose not to reassess the law in *Morgan v Commonwealth* [1947] HCA 6, namely that s 99 and s 100 of the Constitution applies only to laws being made under s 51(i). There was no need however for the Court to be pulled into an assessment of *Morgan*, given that the matter could be decided narrowly under the interpretation of 'waters of rivers' as per s 100. The majority determined that the Commonwealth law pertained to underground water only, rather than 'waters of rivers' and was therefore not within the scope of s 100: at [29] per French CJ; at [55] per Gummow and Crennan JJ; at [75] per Hayne, Kiefel and Bell JJ.

Citation: *Coastal Oil & Gas Corp. v. Garza Energy Trust*, 268 S.W.3d 1, 42 (Tex. 2008).

Summary: The Texas Supreme Court considered the hydraulic fracture subsurface trespass issue directly on point. The decision, with a single concurrence and three dissenting justices, was set to clarify a long-anticipated jurisprudential determination concerning hydraulic fracture subsurface trespass. Indeed, at the case's outset an affirmative modern pronouncement toward trespasser concerns arising from fracturing operations had not been given. Justice Hecht delivered the opinion of the Texas Supreme Court, addressing first Salinas's claim that the influx of "hydraulic fracturing fluid and proppants into another's land two miles below the surface constitutes a trespass for which the minerals owner can recover damages equal to the value of the royalty on the gas thereby drained from the land." Coastal argued that Salinas, as lessor, had no possessory right to the minerals, and therefore, no standing in trespass. The court disagreed, viewing Salinas's reversion interest as similar to the reversion interest of a landlord. Combined with the allegations of actual concrete harm, the standing requirement was fulfilled The court then turned to the hydraulic fracture subsurface trespass issue and ultimately concluded that the rule of capture precluded Salinas's claim. The majority gave four reasons for its holding. First, an aggrieved mineral owner seeking recovery for drainage is already provided full recourse under the law. An aggrieved property owner in such a situation may find recourse by drilling his own wells to offset the drainage, seeking drainage prevention regulation from the Texas Railroad Commission, suing the lessee for violating the implied covenant to prevent drainage, or seeking to pool .Second, allowing recovery for drainage induced by hydraulic fracturing "usurps to courts and juries the lawful and preferable authority of the Railroad Commission to regulate oil and gas production." Third, the court reasoned that the judicial system is ill equipped in making determinations of the value of the hydrocarbons drained. Finally, the court found persuasive the numerous industry participants that strongly opposed hydraulic fracture liability. Thus, the court decided—without deciding—that Salinas could not recover in trespass.

Citation: *Fiorentino v. Cabot Oil & Gas Corp.,* 750 F. Supp.2d 506, 510-11, 516 (Pa. M.D., 2010)

Summary: Sixty-three (63) property owners ("Plaintiffs") filed a complaint against Cabot Oil and Gas ("Cabot") to recover damages allegedly arising from Cabot's operation of natural gas wells in Dimock Township, Susquehanna County, Pennsylvania. Specifically, Plaintiffs alleged that Cabot improperly conducted hydraulic fracturing and other activities causing the release of methane, natural gas, and other toxins into Plaintiff's land and groundwater. After Plaintiffs filed a second amended complaint, Cabot moved to strike certain allegations contained in this complaint, and moved to dismiss the second amended complaint entirely.
The court addressed each claim Cabot sought to strike individually. Cabot argued that claims under the Hazardous Sites Cleanup Act must be dismissed due to Plaintiffs' failure to provide sixty-days (60) notice prior to commencing the lawsuit. With respect to the notice requirement, the court held that such notice is only required in suits for property damage and actual or potential bodily injury. In this case, the suit was for response costs, and thus no notice was required prior to filing the suit.

With respect to the strict liability claim, the issue was whether hydraulic fracturing constituted an abnormally dangerous activity. The court began its analysis by noting that this question has yet to be definitively answered in Pennsylvania. The court mentioned that some activities ancillary to drilling, such as the operation of a pipeline, have not been held abnormally dangerous, but it declined to rule on the issue as the record was insufficiently developed to make such a determination. Accordingly, the court denied Cabot's motion on this claim.

The next count Cabot sought to dismiss was the Medical Monitoring Trust Fund claim. This type of claim is appropriate where a plaintiff can prove exposure to a dangerous substance and that creates a heightened risk of medical problems warranting medical monitoring to be paid by the responsible defendant. Accepting all averments in the compliant as true, the court ruled that "fracking fluid" as well as the released methane could be the cause of the alleged injuries and that they may be reoccurring and ongoing. Accordingly, the court denied Cabot's motion to dismiss this claim. With regard to Plaintiffs' Gross Negligence claim, the court initially noted that Pennsylvania does not recognize claims based on gross negligence. Accordingly, the court granted Cabot's motion to dismiss this claim. However, the underlying allegations that support this claim were allowed to remain in the complaint to the extent that they support Plaintiffs' claim for punitive damages.

Finally, the court addressed Cabot's motion to strike from the second complaint all allegations regarding entitlement to relief under various damage theories.
The court ruled that future illness, emotional distress, punitive damages, and attorneys' fees are all plausibly recoverable, and the record was not sufficiently established to rule on the appropriateness of such relief. Accordingly, the court denied Cabot's motion to strike all allegations relating to the recovery of such damages.

Citation: *Berish v. Sw. Energy Prod. Co. & Sw. Energy Co.*, 763 F. Supp. 2d 702 (Pa. M.D. 2011);

Summary: In early 2008, Southwestern Energy Production Company ("SEPCO") was utilizing hydraulic fracturing and horizontal drilling techniques to extract natural gas from the Marcellus Shale rock formation in Susquehanna County,. Due to insufficient casing, the toxic and carcinogenic fracturing fluid discharged into the ground and contaminated the water supply surrounding the well. A group of landowners with properties near the well initiated a lawsuit against SEPCO alleging violations of the Hazardous Sites Cleanup Act, Negligence, Private Nuisance, Strict Liability, Trespass and seeking to set up a Medical Monitoring Trust. Additionally, Plaintiffs sought compensatory and punitive damages, as well as preliminary and permanent injunctions barring SEPCO from engaging in drilling activities. SEPCO moved to dismiss Plaintiffs' Strict Liability claim as well as the claim for Emotional Damages.

To recover under a theory of strict liability, the plaintiff generally must prove the defendant was conducting an abnormally dangerous activity and that such activities caused harm to the person, land, or chattels of another. The court will apply the Restatement (Second) of Torts six-factor test to determine if an activity is "abnormally dangerous."

The court later noted the merit of SEPCO's argument that no Pennsylvania court has held hydraulic fracturing or horizontal drilling activities as abnormally dangerous. However, the court determined this lack of precedent to not be dispositive with regard to the motion because such a determination is generally made after discovery. Due to the fact-intensive nature of determining whether an activity is abnormally dangerous, the court denied SEPCO's motion in order to allow the record to develop more fully.

Citation: *Parr v. Aruba Petroleum, Inc., No. 11-01650-E* (County Court at Law No. 5 of Dallas Cnty., Tex., filed Mar. 8, 2011).

Summary: Fifteen landowners in Chemung County, New York filed a lawsuit against several related companies alleging that they were negligent in drilling and operating their natural gas wells such that combustible gas was released into plaintiffs' wells and groundwater, and toxic sediments and industrial waste were discharged into the soil and water near plaintiffs' homes. The complaint alleges causes of action for negligence per se, common law negligence, nuisance, strict liability, trespass, and medical monitoring. The case was originally filed in state court

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Citation: *Baker v. Anschutz Exploration Corp.,No*. 11-CV-6119(W.D.N.Y.June 27, 2013)

Summary: The court denied defendants' motion to strike plaintiffs' expert reports for failure to comply with the court's Lone Pine order, which had required plaintiffs to present certain prima facie evidence to support their claims. Though conceding that the expert reports were "far from models of clarity," the court rejected defendants' contention that the reports failed to comply with the court's order to identify specific hazardous substances to which plaintiffs claimed exposure and to provide an explanation of causation. In the same decision and order, the court denied plaintiffs' motion to remand the proceeding to state court since, in light of the dismissal of Conrad Geoscience Corp. from the case, plaintiffs no longer had a basis for arguing that a lack of diversity compelled remand.

Citation: *Strudley v. Antero Resources Corp., No. 12CA1251* (Colo. Ct. App. July 3, 2013)

Summary: Plaintiffs sued several companies that operated several natural gas wells in Garfield County, Colorado within one mile of plaintiffs' property, alleging that the companies contaminated their well with several harmful chemicals, including hydrogen sulfide, hexane, n-heptane, toluene, propane, isobutene, and others. The complaint includes causes of action for negligence per se, common law negligence, nuisance, strict liability, trespass, and medical monitoring. On July 20, 2011, the court dismissed the negligence per se claim against one of the defendants, finding that it was not an operator or owner of the wells in question. The Colorado Court of Appeals reversed, holding that Lone Pine orders are not permitted as a matter of Colorado law. The court cited two Colorado Supreme Court decisions disfavouring requirements that plaintiffs provide prima facie evidence of their claims prior to discovery and found that recent amendments to the Colorado Rules of Civil Procedure (CRCP) were not "so substantial as to effectively overrule" these decisions. The court further held that even if the CRCP amendments did overrule the Supreme Court decisions, a Lone Pine order would not be called for in this particular case, which was neither a mass tort case nor as complex as cases in which Lone Pine orders were issued in other jurisdictions

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Citation: *Berry v. Southwestern Energy Co., 11-. CV-0045* (*E.D. Ark.*, filed May 2011)

Summary: Two class actions were filed on behalf of all residents living within three miles of any bore holes, wellheads, or other gas operations by defendant company. The cases were consolidated on July 22, 2011. Plaintiffs allege that their water wells and groundwater are contaminated with alpha methyl styrene or have emitted methane and hydrogen sulfide. The complaint alleges causes of action for strict liability, nuisance, trespass, and negligence. The court granted the defendants' motion for a more definite statement, holding that the plaintiffs must plead facts to give the companies adequate notice of what and how each driller supposedly harmed them. After the parties reached a settlement, the court issued a judgment dismissing claims against defendants Chesapeake Energy, BHP Billiton Petroleum (Fayetteville), and Southwestern Energy with prejudice. Claims against XTO Energy were dismissed without prejudice.

Citation: *Ginardi v. Frontier Gas Services, LLC, No. 11-CV-0420* (E.D. Ark. Apr. 19, 2012)

Summary: Plaintiffs filed a class action on behalf of all residents within one mile of any natural gas compressor or transmission station owned by defendants. The complaint alleges that defendants' operations pollute nearby groundwater and soil. The complaint alleges causes of action for strict liability, nuisance, trespass, and negligence. The court denied plaintiff's motion for class certification.

Citation: *Evenson v. Antero Resources Corp.*, (Denver Co. Dist. Ct. Aug. 17, 2012)

Summary: Several families residing in Garfield County, Colorado, filed a lawsuit alleging that drilling and exploration activities of defendant company exposed their properties to hazardous gases, chemicals, and industrial wastes. Plaintiffs are seeking class action status. The complaint includes causes of action for negligence and medical monitoring, among others. The state district court granted defendant's motion to dismiss, holding that it lacked jurisdiction over plaintiffs' claims. In particular, the court held that it could not enjoin the issuance of a drilling permit given that state law provided statutory mechanisms for seeking judicial review of such permits. In addition, the court held that the claims were not ripe because they were dependant on defendant seeking and being granted permits, which had not yet occurred.

Citation: *Dillon v. Antero Res., No. 2:11-cv-01038 (W.D. Pa. Aug. 11, 2011); Becka v. Antero Res., No. 2:11-cv-01040* (W.D. Pa. Aug. 12, 2011).

Summary: Related lawsuits were filed by two families against defendant company in July 2011. The cases were removed to federal court in August 2011. The complaints allege that in early 2010, the company began drilling on property within 400-600 feet of plaintiffs' well water supplies and that these activities contaminated their groundwater. The complaints include causes of action for negligence, strict liability, and trespass.

Citation: *United States v. Range Prod. Co., 11-CV-0116 (N.D. Tex. March 29, 2012)*

Summary: In December 2010, EPA issued an emergency administrative order pursuant to the Safe Drinking Water Act. The order identified contaminants that "may present an imminent and substantial endangerment to the health of persons" and determined that two wells were affected by the company's drilling activities in Fort Worth, Texas. The order required the company to take a number of steps to remediate impacted areas of the aquifer. The government filed a complaint for injunctive relief and civil penalties in January 2011. After the order was filed, the defendant argued that it was entitled to pre - enforcement review and that EPA was required to show facts supporting the underlying elements of the violation. On March 29, 2012, EPA withdrew the order following the U.S. Supreme Court's decision in Sackett v. EPA , which held that administrative orders are subject to pre - enforcement review.

Citation: *United States Steel Corporation v. Hoge* (1983)

Summary: The very first case to determine Coal Bed Methane ownership illustrates a very broad insight into the functional state of mineral law and its jurisprudential history in

America. *United States Steep Corp. v. Mary Jo Hoge (Hoge*) asserts legal arguments representative of mainstream practices and standard constructions of mineral law over the course of a hundred years of American coal mining. In *Hoge*, the Pennsylvania Supreme Court quieted title to a coal severance deed in favour of the appellant coal owner, United States Steel Corporation. The Court examined ownership rights against the backdrop of experimental hydro-fracturing of coal seams in the commercial development of coal bed gas. At the time, state justices labelled CBM as a mineral *ferae naturae*, or free moving mineral, and held that gas within the coal seam "*must necessarily belong to the owner of the coal*," so long as it remains within his property and subject to his exclusive control." The Court, however, qualified United States Steel's ownership of CBM interests as "less than perpetual." Qualification notwithstanding, *Hoge's* holding secured CBM extraction rights for the coal owner by denying them to surface owners, who themselves, wanted to lease drilling rights to CBM reserves in the coal. The Pennsylvania Court buttressed its decision by highlighting the far greater value of coal over CBM. n54 It determined that "the [energy] value of the coal bed gas is only one percent of the b.t.u. value of the coal." n55 Justices credited United States Steel with expending costly [*123] drilling operations to extract CBM reserves from the coal seam in questions. n56 In that light, the Court held that all means of drilling was rightful extraction even hydro-fracturing, since the "damage to coal inflicted by these processes is within [the company's] dominion to inflict." n57 The result was a holding, which not only decided the question of CBM ownership in Pennsylvania, but also determined the extent of the coal owner's *right to develop* CBM from reserves within the coal seam. In its conclusion, the Court noted that "it strains credulity to think that the grantor intended to reserve the right to extract a valueless waste product with the attendant potential responsibility for damages resulting from its dangerous nature."

Citation: *Centre for Biological Diversity v. BLM, No. 11-CV-6174* (N.D. Cal. Mar. 31, 2013)

Summary: Several environmental groups filed a lawsuit challenging the federal government’s leasing of nearly 2,700 acres of federal land in California to oil and gas developers for fracking. The complaint alleges violations of NEPA and the Mineral Leasing Act of 1920 (MLA) for failing to fully analyse the environmental impacts of fracking. According to the complaint, BLM issued a final environmental assessment finding no significant impact for the lease sale in June 2011. The court granted plaintiffs’ motion for summary judgment as to their NEPA claims, finding that the potential use of horizontal drilling and hydraulic fracturing techniques in future well development had “reasonably close causal relationship” to the action at issue even though single well development had been the norm in the past, and that BLMwas unreasonable in categorically refusing to consider projections of drilling that included fracking operations. Rather than determining a remedy, the court ordered the parties to meet and confer and submit an appropriate judgment. The court denied plaintiffs’ motion for summary judgment as to the MLA claims.

Citation: *Matter of Norse Energy Corp. USA v. Town of Dryden* (3d Dep’t May 2, 2013)

Summary: A company sued the Town for adopting a resolution (Resolution 126) that prohibited exploration or extraction of natural gas. The company argued that the zoning resolution was pre-empted by the Oil, Gas and Solution Mining Law (OGSML) (seeECL§23-0303(2)),which regulates the development and production of oil and gas in the state. The trial court upheld the ordinance, rejecting claims by the oil and gas company that it was pre-empted by the OGSML. The court held that the OGSML only pre-empts local regulations concerning the operations of oil and gas industries and does not expressly pre-empt local regulation of land use and zoning.

The Third Department affirmed, holding that the OGSML neither expressly nor impliedly pre-empted the Town's zoning ordinance. With respect to express pre-emption, the Third Department held that the statutory text, legislative history and decisional law supported a conclusion that the OGSML did not pre-empt local bans on activities relating to oil and gas drilling. With respect to implied pre-emption, the court concluded that the OGSML did not conflict with local laws, finding that the local laws dictated the districts in which drilling could occur, while the OGSML mandated technical and operational requirements for drilling activities within those districts.

Citation: *Butler v. Charles Powers Estate, No. 27 MAP 2012* (Pa. Apr. 24, 2013)

Summary: The owner of a 244-acre parcel of land filed an action to quiet title. The heirs of a previous owner of the parcel sought a declaratory judgment that Marcellus shale gas was included in the reservation of rights to the heirs in the previous owner's deed, which stated that "mineral" rights were reserved. The trial court dismissed the request for a declaratory judgment. On appeal, the appellate court reversed, holding that although natural gas was not specifically reserved in the deed, it was unclear whether Marcellus shale constitutes a type of mineral such that the gas in it falls within the deed's reservation. Thus, it remanded the case for further proceedings. The Pennsylvania Supreme Court reversed the appellate court's decision and reinstated the order of the trial court. Citing the Dunham Rule (derived from Dunham & Shorttv. Kirkpatrick, 101 Pa. 36 (Pa. 1882), and its progeny), the Supreme Court held that the trial court correctly concluded that Marcellus shale natural gas was not contemplated in the reservation of rights.

Citation: *Power River Basin Resource Council v. Wyoming Oil and Gas Conservation Commission*(Wyo. Dist. Ct. Mar. 21, 2013)

Summary: Four environmental groups filed a lawsuit alleging that the Wyoming Oil and Gas Conservation Commission unlawfully withheld the identities of hydraulic fracturing chemicals used by oil and gas producers. The complaint challenges Wyoming's application of the trade secret exception under Commission rules that otherwise require oil and gas companies to disclose the chemicals they use in the hydraulic fracturing process. The petition alleges that the Commission violated the state's Public Records Act by denying their request for documents submitted to the Commission by several oil and gas companies. The court affirmed the agency's determination that certain information constituted trade secrets and was therefore exempt from disclosure. Plaintiffs are appealing the ruling to the Wyoming Supreme Court.

Citation: *In re Lipsky, No. 02-12-00348-CV*(Tex. Ct. App. Fort Worth Apr. 22, 2013)

Summary: In the original proceeding for a writ of mandamus concerning whether the trial court abused its discretion in denying motions to dismiss Range's counterclaims against landowner plaintiffs and an environmental consultant (relators) as in violation of Texas's anti-SLAPP(Strategic Lawsuits Against Public Participation) statute, the court of appeals determined that relators had met their initial burden of establishing that Range's counterclaims were based on relators' exercise of their right to free speech and right to petition. The court of appeals further ruled that the trial court did not clearly abuse its discretion in determining that Range had presented clear and specific evidence to establish a prima facie case for its defamation and business disparagement claims against relator Steven Lipsky, but that it had abused its discretion in determining that prima facie cases for such claims had been made against the other relators. The court also ruled that the trial court abused its discretion in denying the motions to dismiss the civil conspiracy and "aiding and abetting" counterclaims against all relators. Finding that relators had no adequate remedy on appeal, the court conditionally granted writs of mandamus and ordered the trial court to dismiss the civil conspiracy and aiding and abetting claims against Steven Lipsky and all claims against the other relators.

Citation: *American Petroleum Institute v. EPA No. 12-1405* (D.C. Cir. Apr. 3, 2013)

Summary: Nine petitions were filed by environmental groups, industry associations, and the state of Texas challenging EPA's air pollution standards for certain oil and gas operations, including gas wells. EPA's final rule was released in April 2012 and published in August 2012. The final standards are expected to reduce emissions of volatile organic compounds, methane, and air toxics. However, the rule does not directly regulate methane, which the petitions by environmental groups challenge. In a clerk's order, the court granted the Texas petitioners' motion for voluntary dismissal. The Texas petitioners had informed the court that they believed that "the issues in this case more directly affect the industry petitioners and can be fully and adequately addressed by them." In a clerk's order, the court granted EPA's unopposed motion to sever the challenge to the new source performance standards (NSPSs) from the challenge to the national emissions standards for hazardous air pollutants (NESHAPs). The challenges were suspended pending EPA actions on petitions for reconsideration. The NSPS challenge (now assigned to docket number 13-1108) is to be held in abeyance until August 30, 2013. The NESHAP challenge is to be held in abeyance until May 30, 2014, with a progress report due to the court from EPA on October 1, 2013.

Citation: *Ctr. for Biological Diversity v. Jewell No. 13-CV-1749* (N.D. Cal., filed Apr. 18, 2013)

Summary: Plaintiffs asserted a NEPA challenge to the sale by the Bureau of Land Management (BLM) of oil and gas leases for almost 18,000 acres of federal land in California. Plaintiffs alleged that in asserting that only one well would be drilled on each acre, BLM failed to address the potential impacts of hydraulic fracturing on water and air quality and other resources.

Citation: *Bombardiere v. Schlumberger Tech. Corp.,No.11-cv-00050* (N.D. W. Va. Jan. 30, 2013)

Summary: In this action, plaintiff alleged that he had been injured by exposure to hydraulic fracturing chemicals in the course of his work at gas wells. He asserted the following counts:

negligence/willful, wanton and reckless misconduct; deliberate intent pursuant to West Virginia Code §23-4-2(c) (Workers' Compensation Act); alter ego; agency; strict liability/ultrahazardous activity; preparation and use of proprietary chemical fracking fluids; wrongful interference with employment/wrongful interference with protected property interests; and punitive damages. Defendants removed the action based on diversity jurisdiction. The court "so ordered" a stipulation and order dismissing Consol Energy, Inc. and CNX Gas Corp. from the case, and withdrawing plaintiff's alter ego claim against CNX Gas Co., LLC (CNXGas Co.) The court granted in part the motion for summary judgment of defendant SOS Staffing Services, Inc. (SOS), which had a Master Services Agreement with defendant Schlumberger Technology Corp. (Sclumberger) to provide temporary employees to Schlumberger and which had hired plaintiff to work at Schlumberger. The court granted SOS's motion as to the negligence, agency, wrongful interference with employment, and punitive damages counts. The court reserved ruling on the deliberate intent claim and denied summary judgment for the strict liability claim on the ground that it was moot since plaintiff had withdrawn it.

Citation: *Lenape Resources, Inc. v. Town of Avon Index No. 1060-2012* (Sup. Ct. Livingston Co. Mar. 15, 2013)

Summary: The Town of Avon enacted a one-year moratorium on natural gas drilling activities within the Town. Plaintiff challenged the moratorium on a number of grounds. Plaintiff's principal contention was that the moratorium was expressly pre-empted by New York's Oil, Gas and Solution Mining Law (OGSML). Citing the New York Court of Appeals precedent (but writing that "[i]n this Court's view, the Court of Appeals' decision in FrewRun is flawed"), the court concluded that the moratorium was not pre-empted because it did not relate to the regulation of the oil, gas and solution mining industries but was concerned instead with general land use planning. Plaintiff has filed a notice of appeal. The appeal will be heard by the New York State Appellate Division's Fourth Department.

Citation: *Scoggin v. Cudd Pumping Services, Inc.No. 11-CV-00678* (E.D.Ark.June 10, 2013)

Summary: This action was commenced by a grandmother on behalf of her minor grandchildren who resided with her and who were allegedly exposed to "noxious and poisonous carcinogenic matter and compounds" as a result of their home's proximity to hydraulic fracturing operations. Plaintiffs alleged strict liability, nuisance, trespass, and negligence claims and sought compensatory and punitive damages as well as establishment of a medical monitoring fund. Plaintiffs and defendants filed a stipulation to dismiss the action without prejudice.

Citation: *Hallowich v. Range Resources Corp.No. 2010-3954* (Pa. Ct. Com. Pl. Mar. 20, 2013)

Summary: Plaintiffs filed this lawsuit without a complaint in 2010. They asserted that defendant energy companies' drilling operations resulted in contamination to their property. Plaintiffs also asserted that the Pennsylvania Department of Environmental Protection failed to enforce the state's laws against defendants, thereby violating plaintiffs' right to be free of a

State-created danger. In July 2011, plaintiffs filed to discontinue the action because the parties had reached a settlement for which they sought court approval because the settlement affected the rights of minor children. The court held a hearing on August 23, 2011, and an order of the same date granted the defendant energy companies' motion to seal the record in the case. Two newspapers sought to intervene and unseal the record. The court denied the newspapers' requests to intervene as untimely, but on appeal the Pennsylvania Superior Court remanded the newspapers' petitions with instructions to rule on the merits of the requests. On March 20, 2013, the Court of Common Pleas granted the motions to unseal the record. The court concluded that the common law right of access to court records compelled opening the record and that defendants' claims of a right to privacy were meritless, finding that businesses do not have a right of privacy under the Pennsylvania constitution.

Citation: *Vodenichar v. Halcon Energy Properties, Inc.No. 13-cv-00360* (W.D.Pa. Apr. 4, 2013)

Summary: Plaintiff landowners initiated this class action lawsuit alleging breaches of contracts against energy companies. Plaintiffs had previously initiated a federal lawsuit against Halcon Energy Properties, Inc. (Halcon) under the court's diversity jurisdiction, which they voluntarily dismissed after Halcon indicated it would join two Pennsylvania companies. After plaintiffs reinitiated their lawsuit in Pennsylvania state court, Halcon removed the action, claiming that it fell within the scope of the Class Action Fairness Act. The federal court remanded the action, finding that the "home state exception" applied because plaintiffs had established that at least two-thirds of the plaintiffs and the "primary defendants" (which did not include Halcon) were Pennsylvania citizens.nc.No. 13-cv-00360 (W.D.Pa. Apr. 4, 2013)

Citation: *Auth v. Marco Drilling, Inc.1674 WDA2011* (Pa. Super. Ct. Mar. 28, 2013)

Summary: Property owners appealed the denial of their request for a preliminary injunction to prevent a drilling company from using a private road for access to a drilling site. The court hearing the appeal affirmed the denial, finding that the increased traffic, maintenance, and changes to the roadways caused by the drilling company's use did not pose an unreasonable burden on the property owners, and that maintenance agreements into which some of the property owners had entered could not serve as a basis for an injunction.

Citation: *State ex rel. Morrison v. Beck Energy Corp.2013 0465* (Ohio June19, 2013)

Summary: Beck Energy Corp. began drilling in the City of Munroe Falls, Ohio after obtaining a permit from the Ohio Department of Natural Resources. The City issued a stop work order and sought an injunction in court, alleging that the drilling was not in compliance with the City's permitting requirements for drilling, zoning, and construction of rights-of-way. The trial court granted a preliminary injunction on May 3, 2011 and subsequently issued an order granting a permanent injunction. On appeal, the Ohio Court of Appeals reversed, finding that the state's oil and gas drilling statute conflicted with and thus pre-empted the local drilling ordinances as well as the City's requirements for obtaining zoning certificates for drilling activities. The City's rights-of-way ordinances were not pre-empted but could not be enforced "in a way that discriminates against, unfairly impedes, or obstructs oil and gas activities and operations." The Ohio Supreme Court accepted an appeal for review.

Citation: *Mont. Envtl. Info. Ctr. v. BLMNo*. 4:11-cv00015 (D. Mont. June 14, 2013)

Summary: A coalition of environmental groups sued the Bureau of Land Management (BLM) for allegedly failing to consider the climate change impacts of oil and gas leasing on public lands in Montana and the Dakotas. The groups alleged that the Interior Department failed to control the release of methane from oil and gas development on nearly 60,000 acres of leases sold in 2008 and December 2010 in violation of NEPA. The environmental groups settled an earlier action under which BLM agreed to suspend the 2008 leases and conduct a supplement EIS of their climate change impacts. In August 2010, BLM said that emissions from developing these leases could not be tied to specific climate change impacts and decided to move forward with issuing the 2008 leases and a new round of 2010 leases. The court granted defendants' motion for summary judgment and dismissed the lawsuit on standing grounds, finding that plaintiffs had failed to establish injury-in-fact. Noting that plaintiffs' recreational and aesthetic interests were "uniformly local "and the effects of greenhouse gas emissions "diffuse and unpredictable," the court found that plaintiffs had presented "no scientific evidence or recorded scientific observations to support their assertions that BLM's leasing decisions will present a threat of climate change impacts on lands near the lease sites." The court further held that plaintiffs had made no effort to show that methane emissions from the lease sites would make a "meaningful contribution" to global warming and had thus failed to show that potential climate change impacts to the local environment were "fairly traceable" to greenhouse gas emissions associated with the challenged leases.

Citation: *In re West Bay Exploration Co.UICApp. Nos. 13-01 & 1302* (E.A.B.Apr. 16, 2013)

Summary: Petitioners challenged an underground injection control permit for a brine wastewater disposal well in Mississippi issued to West Bay Exploration Co. by EPA Region 5. Among other things, the petitions challenged EPA's findings that the permitted injection would not contaminate underground sources of water and that the well would not adversely affect endangered species, including the Indiana bat. The Environmental Appeals Board dismissed the petitions as moot after the Region 5 regional administrator unilaterally withdrew the permit.

Citation*: Stone v. Chesapeake Appalachia, LLCNo*. 5:12-cv-00102 (N.D. W. Va. Apr. 10,2013)

Summary: Plaintiffs, who were parties to a lease held by defendants for the oil and gas within and underlying their property, commenced this action alleging (1) breach of contract based on defendants' pooling and unitizing the Marcellus shale formation underlying plaintiffs' property in violation of their lease; (2) trespass by engaging in hydraulic fracturing on plaintiffs' property; and (3) that the defendants failed to protect plaintiffs' property from drainage. The case was removed to federal court. The court denied defendants' motion for summary judgment. The court found that hydraulic fracturing under the land of a neighbouring property without that party's consent is not protected by the "rule of capture," but rather constitutes an actionable trespass. In reaching this conclusion, the court determined that the West Virginia Supreme Court would not adopt the "rule of capture" principles ascribed to in the Texas Supreme Court's Coastal Oil & Gas Corp. v. Garza Energy Trust decision, which in the court's view "gives oil and gas operators a blank check to steal from the small landowner." The court also denied summary judgment on the breach of contract and drainage claims.

Citation: *Caldwell v. Kriebel Resources Co., LLC, No. 1305 WDA2012* (Pa. Super. Ct. June 21, 2013)

Summary: The Pennsylvania Superior Court affirmed the dismissal by the Court of Common Pleas of plaintiffs' amended complaint. Plaintiffs had entered into an oil and gas agreement in 2001 with defendant Kriebel Resources Co., LLC. The agreement provided for a two-year term that could be extended so long as oil or gas was being produced. Plaintiffs sought to terminate the lease, alleging that defendants had only engaged in shallow gas drilling and had not initiated development activities for the Marcellus shale. The Superior Court declined to read into the 2001 agreement an implied covenant to develop all strata of natural gas, and also rejected plaintiffs' claim that defendants' had breached an implied covenant to develop in "paying quantities." The court also was not persuaded that it should impose a "good faith" standard for all aspects of the industry that affect natural gas production and therefore give plaintiffs an opportunity to show that defendants had not acted in good faith as to the amount of gas being produced from plaintiffs' property.

Citation: *BHP Billiton Petroleum (Arkansas) Inc. BHP Billiton Petroleum (Fayetteville) LLC Chesapeake Operating Inc. and Clarita Operating,* (LLC Case 4:11-cv-00474-JLH Document 2 Filed 06/09/11)

Summary: On March 23, 2011, Jacob Sheatsley filed a class action lawsuit claiming that "Central Arkansas has seen an unprecedented increase in seismic activity, occurring in the vicinity of" wastewater disposal injection wells which are part of hydraulic fracturing operations. According to the Arkansas Geological Survey, there had been 599 seismic events in Guy, Arkansas between September 20, 2010 and the date of the lawsuit. The largest earthquake in 35 years occurred on February 28, 2011, and measured 4.7 in magnitude. On that same day, the U.S. Geological Survey recorded as many as 29 earthquakes around Greenbrier and Guy, Arkansas, that ranged in magnitude from 1.7 to 4.7.33 Mr. Sheatsley alleged causes of action for public nuisance, private nuisance, absolute liability, negligence, and trespass, all based on the interference with the use and enjoyment of property and on the risk of serious personal harm and property damage from the earthquakes.

Four additional class actions complaints quickly followed, with the same allegations. All were originally filed in state court and removed to federal court. In addition to the lawsuits alleging water contamination, plaintiffs in several Arkansas class-action lawsuits have claimed that hydraulic fracturing operations damaged their properties by causing earthquakes. *Frey v. BHP Billiton Petroleum (Arkansas) Inc., et al.*, No. 4:11-cv-475 (E.D. Ark. June 9, 2011); *Hearn v. BHP Billiton Petroleum (Arkansas) Inc., et al*, No. 4:11-cv-474 (E.D. Ark. June 9, 2011); *Lane v. BHP Billiton Petroleum (Arkansas) Inc., et al*, No. 4:11-cv-477 (E.D. Ark. June 9, 2011); *Palmer v. BHP Billiton Petroleum (Arkansas) Inc., et al*, No. 4:11-cv-476

(E.D. Ark. June 9, 2011). The class actions have been consolidated into one action currently pending in the Eastern District of Arkansas. *Hearn v. BHP Billiton Petroleum (Arkansas) Inc., et al.*, No. 4:11-cv-474 (E.D. Ark.). On August 31, 2011, all four lawsuits were consolidated under Case No. 4:11-cv-00474, *Hearn v. BHP Billiton Petroleum (Arkansas) Inc., et al.* With the filing of these additional class actions, on July 13, 2011, Mr. Sheatsley voluntarily dismissed his lawsuit, in "an effort to streamline these cases and further judicial economy." On June 25 2012, the court dismissed Deep Six as a party and therefore denied the summary judgement motion as moot. An amended complaint was filed on April 9, 2013 which is still pending.

Citation: *Frey v. BHP Billiton Petroleum (Arkansas) Inc., et al.* , Case No. 4:11-cv-0475-JLH (E.D. Ark., June 9, 2011)

Summary: In sum, the plaintiffs' Complaints allege that the operation of two wastewater injection disposal wells in Faulkner County by "the Defendants" are causing or contributing to earthquakes in Central Arkansas (9 of the Complaints). Under the heading "Factual Background" (19-22 of the Complaints), the plaintiffs describe the Fayetteville Shale. Thereafter, the plaintiffs allege "the Chesapeake Well" and "the Clarita Well" began operations in 2009 (23-24 of the Complaints). Plaintiffs allege separate defendant Chesapeake Operating, Inc. ("Chesapeake") owned and operated the Chesapeake Well, but that "the well is now owned and operated by BHP" (15 of the Complaints). (The "Clarita Well" is alleged to be owned and operated by separate defendant Clarita Operating, LLC (16 of the Complaints)).

The Frey Plaintiffs, as well as the Palmer Plaintiffs,1 the Lane Plaintiffs and Plaintiff Hearn are all residents of Faulkner County and have filed identical Complaints against identical defendants asserting identical allegations, identical legal theories and seeking identical relief. The only differences in the four Complaints are the names of the plaintiffs. All of the plaintiffs have filed a Motion to Consolidate their four cases (*see* Doc. No. 14). The allegations of the Complaints fail to state a claim upon which relief can be granted as to BHP Arkansas and BHP Fayetteville, and accordingly, the plaintiffs' Complaints should be dismissed as to them pursuant to Rule 12(b)(6), Fed. R. Civ. P. To survive a Rule 12(b)(6) motion, a plaintiff must plead facts to state a claim that is "plausible on its face." *Ashcroft v. Iqbal*, __U.S., 129 S.Ct. 1937, 1949 (2009). A complaint fails to state a claim for relief where the well-pleaded facts only permit an inference of "the mere possibility" of misconduct. *Id*. at 1950. To pass muster, the factual allegations must nudge the alleged claims "across the line of conceivable to plausible." The District Court of Arkansas held the Complaints of the plaintiffs fail to allege sufficient facts to support any plausible claim against BHP Arkansas and BHP Fayetteville under the causes of action alleged, and the Complaints of the plaintiffs against BHP Arkansas and BHP Fayetteville should be dismissed pursuant to Rule 12(b)(6), Fed. R. Civ. P.

CONFERENCE PROCEEDINGS

Citation: Walter Heinz, 'Socio Economic Challenges of Shale Gas Developments in Europe' (Paper Presented at SPE European HSE Conference and Exhibition - Health, Safety, Environment and Social Responsibility in the Oil &Gas Exploration, London, United Kingdom, Apr 16 - 18, 2013 2013)

Topic Area: Socio-Economic issues of Shale Gas Development

Jurisdiction: EU

Abstract: In Europe, the exploration of shale gas resources has just started, but with the exception of Poland most activities have been halted or delayed because of stakeholder concerns about environmental risks of hydraulic fracturing. With examples from Poland and Germany, the paper summarizes these socio-economic challenges, covers the sensitive dialogue of technical experts with non-technical stakeholders, discusses suggestions on how to address perceived versus real environmental risks, and concludes with an outlook on how these constraints may be overcome so that shale gas developments in Europe may proceed. According to published stakeholder concerns and media coverage in Europe, most of the concerns are linked to a perceived risk of groundwater contamination through the use of chemicals during hydraulic fracturing, or the release of methane or induced seismicity. Based on an analysis of perceived versus real environmental risks, and how they have been addressed in the media, suggestions for a re-focus of stakeholder communication and management are drawn. Operators might be well advised to develop a collaborative strategy to overcome stakeholder concerns in an industry with a poor reputation and biased media coverage.

Aims & Research Methods: The paper provides suggestions for such a strategy refocus with the objectives of creating stakeholder acceptance and gaining supporters. Elements of this are full disclosure of project information, stakeholder engagement and education

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Citation: John McFarland, 'The Future of Regulation in Hydraulic Fracturing' (2012) (Paper Presented at the State Bar of Texas' 34th Annual Advanced Real Estate Law Seminar)

Topic Area: Fracking Activities

Jurisdiction: USA

Introduction: The primary program regulating water quality effects of hydraulic fracturing is the Safe Drinking Water Act, which regulates the underground injection of fluids. The Clean Water Act would apply only to activities that affect ―waters of the United States.‖ Other substantive federal regulatory programs are unlikely to substantively affect hydraulic fracturing due to exclusions for oil and gas exploration activity. However, NEPA imposes procedural requirements that a federal agency must meet before taking a major federal action, which could affect hydraulic fracturing on federal land.

Aims & Research Methods: This paper provides an overview of Hydraulic Fracturing, preserving water quality at the Federal, State and Local Level. The paper also provides an analysis of protecting public health, the environment, water resources, air quality and property title in relation to hydraulic fracturing.

Scope: This paper addresses some of the recent controversies and some pending and proposed changes that will affect hydraulic fracturing.

Conclusions: In the face of growing public concern over oil and gas drilling practices, cities are passing stricter regulations on the industry. Some cities in the Marcellus Shale area have even gone so far as to ban certain drilling techniques all together. As cities become more active, their power to regulate oil and gas drilling activities has become an issue. In Texas, home rule cities generally have broad authority to adopt ordinances ―for the good government, peace or order of the municipality or for the trade and commerce of the municipality. An ordinance of a home rule city is presumed valid. However, a court will overturn an ordinance that is so unreasonable and arbitrary that it is a clear abuse of discretion. Further, general law cities – Types A, B, or C – must have explicit statutory authority to act. Finally, specific statutory provisions, or total pre-emption, can limit the authority of a Texas city to pass particular ordinances. A number of Texas cities and towns, including Arlington, Bartonville, Bedford, Clebourne, Decatur, Denton, DISH, Flower Mound, Fort Worth, Hurst, and Weatherford, have recently drafted ordinances that impose varying requirements, of varying stringencies, on oil and gas drilling in general, and fracturing in particular.

Citation: Joel Adams and Clem Rowe, 'Differentiating Applications of Hydraulic Fracturing' (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Abstract: Hydraulic fracturing has received abundant media attention in recent years due to a rapid increase in the use of the technique in combination with horizontal drilling technology to produce oil and gas resources from tight reservoirs. Hydraulic fracturing techniques are alsoused in a variety of other applications that are unrelated to oil and gas production, including tunnel and dam construction, enhanced geothermal energy, carbon sequestration, groundwater remediation, block cave mining, rock burst mitigation, and water well development. Environmental concerns associated with large-scale hydraulic fracturing in oil and gas reservoirs have resulted in political efforts to ban the technique with legislation now in place in certain states in the US and countries around the world. Concerns include soil and ground water contamination and induced seismicity.

Aims & Research Methods: A clear understanding of how hydraulic fracturing techniques are used in various applications is important to avoid unintended consequences of any regulations aimed at hydraulic fracturing in the oil and gas industry. The methodology for each application varies widely in terms of scale, pressures applied, additives, and fracture propagation. Mining rock stress measurements, for instance, focus primarily on the breaking strength of rock, and can be conducted with a small-volume high-pressure pump that produces only a few litres/minute. The total volume of water injected may be on the order of tens or hundreds of litres. A typical oil and gas well hydraulic fracture treatment, on the other hand, requires millions of litres of injected proprietary fluid and proppant in order to propagate and maintain the fracture effectively into the reservoir. Though both applications are termed hydraulic fracturing, they differ greatly in terms of potential impacts to the environment.

Citation: Ken Huggins and Amit Nakhwa, 'New Technologies in Fracturing for Shale Gas Wells are Addressing Environmental Issues' (Paper presented at 18th Middle East Oil & Gas Show and Conference (MEOS), Bahrain International Exhibition Centre, Manama, Bahrain, Mar 10 - 13, 2013 2013)

Topic Area: Hydraulic Fracturing Activities, Environmental Issues

Jurisdiction: Global

Abstract: To further address these environmental issues, members of Oil & Gas (O&G) industry associations, including the American Petroleum Institute (API), Society of Petroleum Engineers (SPE), International Association of Drilling Contractors (IADC) and the International Association of Oil & Gas Producers (OGP) based in London and Brussels, continue to develop sound science and field-proven best practices in the form of industry standards, such as those referenced in this paper.

Technical publications by O&G service companies have provided numerous case histories highlighting these applicable technologies. These presented technologies and practices have helped to demonstrate the positive impacts for shale gas development projects.

Aims & Research Methods: This paper discusses how applied science, historically safe operations, advancements in technology and standard processes are helping to address and reduce environmental issues (EI) for hydraulic fracturing in shale gas wells. The technologies presented include equipment footprints allowing for a reduced risk for environmental effects, 3D fracture mapping, microseismic fracture mapping, "green" fracturing fluids, bacteria control through UV light technology and an improved method of water recycling. This combination of scientifically-derived technologies and best practices (a.k.a standards) is assisting in lowering the risk for EI and addressing misconceptions about hydraulic fracturing.

Citation: R. Perfetto and L. Tealdi, SPE, Eni E&P, 'Hydraulic Fracturing as a Development Strategy - Successful Case Histories from the Congo Basin: A Matter of Technology and Risk Attitude' (Paper presented at Nigeria Annual International Conference and Exhibition, Lagos, Nigeria, 30 July - 1 August 2013)

Topic Area: Hydraulic Fracturing as a Development Strategy

Jurisdiction: Africa (Nigeria and The Congo)

Abstract: Testing novel technologies, developing abandoned reservoirs and rejuvenating mature fields require top-notch technical preparation and fit for purpose risk exposure attitude. Even in case of the commercial availability of the right technology at the right time, studying a technological pilot and actually executing it highly depends on the risk exposure attitude of the management which plays a crucial role. The history of Hydraulic Fracturing activity in

Congo goes up to 2007; with the background of producers with very low or nil performance and the high costs of fracking offshore for the first time in the country, the risk of investment and technological failure was elevated. At the time of the first pilot test in K-field offshore, the eni Congo management was not so interested in the immediate gains. The management was betting on eventual success of the technology, which would start a new era for the development of low permeability reservoirs in Congo and thus making a huge impact on the future of the company production and reserves.

Aims & Research Methods: This papers describes the lessons learnt in 5 years of frac operations in Congo with over 130 diverse frac operations (performed on different reservoir of diverse permeability ranges, green to brown fields, onshore to offshore, conventional single stage to multistage fracturing, acid and proppant frac with water base and oil base frac fluids). This paper would also serve as potential reference for all Operations Managers who are willing to optimize their assets value by means of Hydraulic Fracturing but face difficulties in winning mental barriers towards novel technologies inside or outside their companies.

Citation: Aaron Padilla, 'Social Responsibility & Management Systems: Elevating Performance for Shale Gas Development' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Social Responsibility and Management of Shale Gas Development

Jurisdiction: USA and EU

Abstract: The case studies illustrate several benefits driven by management systems: increased organizational focus and identification of resourcing needs through deliberate planning, performance innovations to meet stakeholder expectations and concerns, an ability to meet the challenge of community-level engagement with underlying confidence in processes. The company's experience in these case studies also illustrated a difference between the environment, health and safety (EHS) function and the external affairs function in the extent that the management system governed performance . Practioners also noted a seeming trade-off in employing a management systems approach: that better performance in the short- and long-term requires reconciliation with initially slower decision making and operational expansion. Finally, this paper presents several practical tips on social responsibility and shale gas across the key dimensions of a management system, with three concluding considerations around the importance of adequate resourcing, sharpening functional responsibility and accountability for social performance and the role of company-wide requirements.

Aims & Research Methods: This paper presents findings on the effectiveness of management systems to elevate social performance, illustrated by two case studies of shale gas development in the United States and Europe. This paper provides practical insights to the upstream oil and gas industry on (a) using management systems to drive a higher level of social performance for shale gas development and (b) generally integrating social performance even more effectively into management systems.

Citation: J. Daniel Arthur, H. William Hochheiser, and Bobbi Jo Coughlin/ALL Consulting, LLC, 'State and Federal Regulation of Hydraulic Fracturing: A Comparative Analysis' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 24-26 January 2011)

Topic Area: Regulation of Hydraulic Fracturing

Jurisdiction: USA

Abstract: While hydraulic fracturing is a well-developed technology that has been used for more than 40 years, its wide-spread use for coal-bed natural gas and shale gas development has raised questions about the appropriate regulatory approach to ensure that groundwater resources are protected. In response to recent public concerns about hydraulic fracturing, Congress introduced the Fracturing Responsibility and Awareness of Chemicals Act (FRAC Act). The FRAC Act would amend the Safe Drinking Water Act (SDWA) to regulate hydraulic fracturing under the same laws and regulations that are used for the Underground Injection Control (UIC) program. Proponents of the FRAC Act assert that federal regulation is necessary to ensure protection of groundwater resources. Opponents argue that federal regulation creates a one-size-fits-all approach that is inefficient and protects poorly. In addition, they argue that states are best suited to regulate hydraulic fracturing given their ability to tailor regulatory requirements to local conditions.

Aims & Research Methods: This paper will provide an overview of state regulation of hydraulic fracturing including some of the various approaches taken, different levels of regulatory detail, and recently adopted changes as well as changes that have been proposed, but not yet adopted. The paper will also examine how hydraulic fracturing would likely be regulated under the SDWA and discuss the pros and cons of federal regulation of hydraulic fracturing from the stand point of both regulatory burden to the industry and the potential for improved environmental protection.

Citation: B. Huls, SPE, BJ Services, 'Maximizing the Marcellus Gold Rush While Minimizing Negative Impacts' (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Environmental concerns associated with Marcellus Shale development

Jurisdiction: USA

Abstract: The Marcellus Shale, often referred to as "America's next super giant," has generated considerable interest in the Northeastern United States. Producers are leasing vast acreages, drillers are converging from across the nation, and service companies are mobilizing in force. Jobs are being created with local businesses benefitting from the increased activity associated with extracting shale gas. While technological advancements in horizontal drilling and hydraulic fracturing have allowed for a footprint significantly reduced from years gone by, and despite positive influxes of revenue, development of the Marcellus Shale in the Appalachian Basin is not without controversy. The speed at which the Marcellus is being developed, coupled with the lack of understanding by the public about a domestic fuel source long taken for granted, is creating a tension over how best to maximize the Marcellus Gold Rush while minimizing the negative impacts on the local environment.

The Marcellus Shale lies amidst some of the largest blocks of contiguous forests east of the Mississippi. More than 72 percent of the Susquehanna River Basin sits above the Marcellus. Consumptive water use to fracture a horizontal well can be in the millions of gallons. Unfamiliar chemicals are being transported and operations continue around the clock. There is no history of activity like this in the modern age in this region. Community groups have formed on both sides of the issues, while government agencies have ramped up their efforts to monitor extraction and consider the Marcellus as a new revenue stream for deficit-ridden state budgets.

Aims & Research Methods: This paper will address environmental concerns associated with Marcellus Shale development and explore positive solutions to mitigate local conflict and enhance cooperation. The exigency of addressing issues in the development of this new resource from an industry perspective as well as the local economic and environmental impacts will also be examined.

Citation: Amit D. Nakhwa, Boots & Coots, Ken Huggins, Halliburton, Ronald Sweatman, Consultant, 'Shale Gas Well Fracturing Technologies Help Address HSE Concerns' (Paper presented at Offshore Mediterranean Conference and Exhibition, Ravenna, Italy , March 20 - 22, 2013)

Topic Area: Health, safety, and environmental concerns for hydraulic fracturing

Jurisdiction: Global

Abstract: To further address these HSE concerns, members of Oil & Gas (O&G) industry associations, including the American Petroleum Institute (API), Society of Petroleum Engineers (SPE), International Association of Drilling Contractors (IADC) and the International Association of Oil & Gas Producers (OGP) based in London and Brussels, continue to develop sound science and field-proven best practices in the form of industry standards, such as those referenced in this paper. Technical publications by O&G service companies have provided numerous case histories highlighting these applicable technologies. These presented technologies and practices have helped to demonstrate the positive impacts for shale gas development projects.

Aims & Research Methods: This paper discusses how applied science, historically safe operations, advancements in technology and standard processes are helping to address and reduce health, safety, and environmental (HSE) concerns for hydraulic fracturing in shale gas wells. The technologies presented include an improved method of removing total suspended solids in order for water recycling, UV light equipment used for bacteria control in fracturing fluids, fracturing fluids comprised of ingredients sourced from the food industry, aquifer protection using 3D fracture mapping and microseismic fracture monitoring and equipment footprints allowing for smaller well locations. This combination of scientifically-derived technologies and standards (a.k.a. best practices) is assisting in lowering the risk for HSE incidents and addressing misconceptions about hydraulic fracturing.

Citation: Christian Fulda, Andreas Hartmann, Jeff Prilliman, Stefan Wessling, 'Wellbore Construction Improved by Real-Time Borehole Images' (Paper presented at 6th International Petroleum Technology Conference, Beijing, China, Mar 26 - 28, 2013 2013)

Topic Area: Borehole imaging

Jurisdiction: Global

Abstract: Imaging has been used in the industry for many years in a variety of applications such as structural and sedimentary analysis, as well as fracture system analysis. Especially noteworthy are resistivity images having the highest resolution which is a direct consequence of the physical nature of the measurement. With resistivity images even small features such as natural or induced fractures can be identified.

High-resolution borehole images are data sets where a physical quantity of the formation is measured with respect to time or depth and toolface azimuth. The toolface azimuth is defined by the angle through which the sensor has been rotated around the borehole axis in a plane perpendicular to the borehole axis from a reference direction such as magnetic north or borehole high-side. The measurement is color-coded and plotted as a two-dimensional map with the first axis of the map representing either time or depth, the second axis representing the toolface azimuth, and the colour corresponding to the measured resistivity. Since the penetration depth of the measurement is relatively small in the range of 1" – 2", the map corresponds in some respect to an unwrapped image of the borehole wall (Fig. 1). In this image, features in the borehole wall such as boundary layers or fractures can be identified. For example, if the borehole was drilled through a substantially planar bed boundary, this boundary will appear on the image as a sinusoid.

Historically, images were acquired with wire line-based acquisition systems which represent an enhancement of the so-called dipmeter tool where three or more substantially identical sensors are moved in close proximity to the borehole wall in a direction parallel to the borehole axis. Wireline tools often utilize a mechanism for pressing the sensors at different toolface azimuths against the borehole wall which causes them to slide along the formation while the tool is moved through the borehole. While drilling, the concept of sliding sensors is not preferred because in a drilling environment the sensors would be subject to excessive wear. Instead, the rotating drilling tool is used as a platform for a single sensor which rotates and moves along the borehole wall on a helix-shaped sensor path.

Aims & Research Methods: Borehole imaging is a useful and well-known formation evaluation technology. In recent years, two major developments have opened the door to several new application areas. First, the technology to acquire borehole images was conveyed from pure wire line systems to logging-while-drilling systems. Imaging-while-drilling technology benefits from acquiring borehole images from a nearly unaltered borehole in an almost virgin formation. Secondly, high-end mud pulse telemetry systems, in combination with advanced data-compression methods, enable the reception and use of high-resolution borehole images while drilling. This data is available for further real-time analysis at the surface during different stages of the wellbore construction process. Several examples going beyond the pure formation evaluation aspect, demonstrate how high-resolution borehole images are used to improve wellbore construction. In particular, methods with respect to wellbore integrity, geosteering, and completion stage identification are demonstrated. These applications use the high resolution borehole images to identify borehole events such as induced fractures or breakouts, as well as formation features such as bedding, faults, or natural fractures. Wellbore integrity methods mainly use the images to identify borehole breakouts and induced fractures. Geosteering is predominantly based on the evaluation of bedding at a dipping angle with respect to the borehole that can be determined from images.

The completion stage of operations benefits from the identification of natural fractures and fractures that were created during hydraulic stimulation of offset wells.

Citation: Mirko van der Baan, University of Alberta, David Eaton, University of Calgary, Maurice Dusseault, University of Waterloo, 'Microseismic Monitoring Developments in Hydraulic Fracture Stimulation' (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Microseismicity research

Jurisdiction: Global

Abstract: The last decade has seen a significantly increased interest in microseismic monitoring by the hydrocarbon industry due to the recent surge in unconventional resources such as shale-gas and heavy-oil plays. Both hydraulic fracturing and steam injection create changes in local pore pressures and in situ stresses and thereby brittle failure in intact rock plus additional slip/shearing in naturally fractured rock. Local rock failure or slip yields an acoustic emission, which is also known as a microseismic event. The microseismic cloud represents thus a volumetric map of the extent of induced fracture shearing, opening and closing. Microseismic monitoring can provide pertinent information on in situ reservoir deformation due to fluid stimulation, thus ultimately facilitating reservoir drainage.

Aims & Research Methods: This paper reviews some of the current key questions and research in microseismicity, ranging from acquisition, processing to interpretation.

Citation: G. Steyl, Golder Associates Pty Limited and University of the Free State, G. J. van Tonder, University of the Free State, 'Hydrochemical and Hydrogeological Impact of Hydraulic Fracturing in the Karoo, South Africa' (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Hydraulic fracturing Activities and Chemical Disclosure and Use

Jurisdiction: Africa

Abstract: Hydraulic fracturing has become a prevalent public and regulatory issue in most countries developing shale gas. South Africa has only recently been exposed to terrestrial gas resource development and this has created unique regulatory issues which are currently being resolved. One of the key issues under debate is the protection of groundwater resources in rural areas, since most of South Africa's rural and some inland cities are dependent on groundwater for potable water supply. A second concern is the infrastructure requirements to handle the material movement processes during the development of each well field and subsequent processing of waste generated on site. Regarding the waste material production, a phased approach is required which considers the initial well development activities, production and subsequent well abandonment. Each phase has a unique risk associated with it and thus would require different management options. At the current stage most of the focus is on the initial stages of well development but the long term view has been neglected to some extent. Due to the unique geological structure of the Karoo, the presence of dolerite structures, a number of risk mitigation methods might be required to successfully develop hydraulically fractured wells. In all aspects the chemical and hydrogeological impacts related to well field development cannot be ignored in the Karoo aquifer system, as it may directly influence human and environmental health.

Aims & Research Methods: This paper will present chemical perspective on the hydraulic fracturing perspective that will deal with the impact of hydraulic fracturing fluid and flow back water. Additionally, the interaction of wellfield development and hydrogeology of the Karoo area will be discussed and how it relates to future water quality issues.

Citation: Paul Krishna, ExxonMobil; Bertrand Janus, Total; Cynthia Ann Peterson, PETRONAS; Brett Doherty, RasGas; Robert Sherman, Halliburton; Helen Murphy, IPIECA; and Charlie Curlee, Independent, 'Sustainability reporting on the rise within the Petroleum Industry - A view of the industry and experiences from an NOC, IOC and Service Company' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Sustainable Development of Gas Resources

Jurisdiction: Global

Abstract: In 1987, the Brundtland Report, "Our Common Future", produced the widely accepted definition of sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". But what can sustainability mean for the oil and gas industry, which produces fossil fuel required to meet basic human needs today such as food, fuel and shelter? The oil and gas industry provides a fundamental energy resource while improving health, reducing poverty, and increasing productivity for the global population. Oil and gas are therefore integral to promoting economic growth and will continue to play a major role in meeting the world's energy needs for the foreseeable future. Global energy policies are promoting low-carbon energy technologies, and the use of modern renewables will almost triple by 2035 to about 14% of total supply. However, renewables cannot satisfy global demand growth, so consumption of both oil and gas will also continue to grow.

Aims & Research Methods: Oil and gas companies must therefore continue to discover, produce and supply these energy resources, and it is essential that they do so in a safe, environmentally sound and socially responsible manner. This requires safeguarding the environment; respecting the rights of others; protecting the health, safety and security of workers and the public; meeting increasingly stringent laws and regulations, and yet managing a range of operational, reputational and financial risks. An additional responsibility for companies is the need to communicate openly how they conduct their operations – the vision, decisions and strategies used to pursue resource developments. Sustainability reporting is therefore both a responsible and an expected method for companies to communicate publicly on environmental and social performance. The oil and gas industry has made significant progress on these objectives but challenges remain and individual companies need to tell their own sustainability stories in a clear, transparent, and honest manner.

Finally, sustainability reporting also helps to establish a basis for continuous improvement in business processes and risk management. In particular, reporting has value for reputational risk, access to capital, and strengthened customer and employee relationships. For oil and gas companies, reporting can provide a robust platform for describing how strategic issues are being addressed through long-term plans and current initiatives. Stakeholders can now find details of a company's high level vision and strategy for dealing with sustainability-related impacts, implementing action plans and assessing outcomes on company websites and in annual reports.

Citation: Sandeep Janwadkar, SPE; Mark Thomas; Steve Denney; Baker Hughes, 'Improving the Production Potential of Shale Gas Wells by Optimizing Multi-Stage Completions Cost Using High-Resolution LWD Images' (Paper presented at Abu Dhabi International Petroleum Conference and Exhibition, Abu Dhabi, UAE, 11-14 November 2012)

Topic Area: Drilling and Completions

Jurisdiction: UAE and USA

Abstract: Developing unconventional shale gas plays in the Middle East is starting to gain momentum in activity based on the success of unconventional shale gas in North America. A closer look at the statistics reveal that although initial well productivity in North America has increased with the adoption of new drilling and completion technologies, it is still difficult to forecast the success of a single well, as results may be quite inconsistent within the same section or across the play.

Aims & Research Methods: This paper reviews the factors affecting well productivity and focuses on optimized completions design based on a better understanding of the stress fields in the sub-surface as well as the fracture network. Based on experience from the Barnett Shale, one of the most mature and prolific natural gas fields in North America, the paper will highlight the importance of natural fractures, offset induced fractures, faults, and internal stresses, which are increasingly important to characterize and map as infield drilling increases. A high-resolution logging while drilling (LWD) electrical imaging tool was used to acquire images on a well drilled between two wells drilled between two offset wells 600ft apart within the same section. Fracture systems, faults, and stresses in the field were interpreted and mapped to further develop completions, fracture treatments and well placements. The paper shows how LWD images were used to determine which stages had previously been fractured and to explain how production from offset wells was reduced by as much as 40%. Operators have increased well productivity by up to 20% in more than 300 wells drilled to date. Lessons learned can be applied to most conventional and unconventional plays around the world.

Citation: Tayeb A. Tafti, SPE, U. of Southern California and Fred Aminzadeh, SPE, U. of Southern California, 'Characterizing Fracture Network in Shale Reservoir Using Microseismic Data' (Paper presented at SPE Western Regional Meeting, California, USA, 21-23 March 2012)

Topic Area: Faults and Fracture Characterization, Exploration, Development, Structural Geology

Jurisdiction: Global

Abstract: Microseismic monitoring currently is proven technology for characterizing fracture network created from fluid injection and hydraulic fracturing. In last decade, Many authors have published their research about microseismic methods in fracture detection. Among them, Albright (1982) used microseismic hypocentral location as an indicator for fracture location and pore pressure. Brady et al. (1994) demonstrated that comparing different monitoring wells to find the cloud of microseismicity can eliminate the errors in determining associated fracture network height and width. Rutledge et al. (1998) used relative mapping of microseismic events to obtain high precision fracture images. Phillips et al. (1998) applied Hodogram-inclination to locate microseismic events and consequently fracture zones to indicate their widths; the wider zone yielded higher poststimulation production. These authors and many others (Fisher et al., 2004; Downie et al., 2009; Barree et al., 2002; Xu and Calvez, 2009; Warpinski et al., 2005; Tezuka et al., 2008) have considered the spatial/temporal progression of microseismic activity to interpret the fracture height, length, azimuth, zonal coverage, and fracture complexity in terms of a simple, planar fracture, or a complex fracture network. The mentioned authors have also tried to correlate production data with the dimensions of the microseismic clouds and volume estimates based on the density of microseismic events. However, other content of microseismic events can potentially provide more insight into the fracturing process.

Aims & Research Methods: Microseismicity caused by fracking is recorded during different stages of stimulation. We demonstrate how such data can be used to characterize the fracture network to provide us with better understanding of the fracture network geometry, connectivity, and density. We go beyond the existing methods that use the origination points of the microseismic events for locating the fracture network. Our technical analysis on microseismic data involves an integrated workflow to utilize other information content of the events such as their size, relationship with other events, their attributes and their relationship with other data (conventional seismic, well data) The additional information allows to optimize the stimulation treatment plan for improved recovery. The new approach also provides useful information for the well spacing plan, the well design, and the completion design.

The workflow starts with calculating hypocentral location of events and detecting first arrival times for both P-and S-waves. Then, we carry out fractal analysis, fuzzy clustering, tomographic inversion, stress analysis, and shear wave splitting analysis. We show the incremental benefit of each step and how they can be used to estimate the reservoir properties. We demonstrate how we can validate the results using other types of data, such as production, well data, seismic, and geological data. Integration of different types of data should result in higher accuracy in the estimates. With the advent of new and cost effective geophone sensor arrays and improvement in the analysis and interpretation techniques, use of microseismic data is expected to become a more routine process for fast, efficient, and accurate characterization of shale gas/oil reservoir and improvement in production methods.

Citation: Aldo Vesnaver, Lara Lovisa and Gualtiero Böhm, OGS (Italy), 'Full 3D Relocation of Microseisms For Reservoir Monitoring' (Paper presented at 2008 SEG Annual Meeting, Las Vegas, Nevada, November 9 - 14, 2008)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: Global

Abstract: An optimal hydrocarbon production is achieved by injecting fluids (as brine or CO2) in the reservoir. The resulting pressure gradient may induce cracks that cannot be imaged by conventional surface or borehole seismic, but only by a seismological approach. The hypocenter location of induced microseisms reveals the pathways of fluids. Petroleum engineers have been measuring microseismicity to check the fracking fluid efficiency in the last decade, but only very close to the wells, where 1D reservoir models from well logs only may be sufficient. Monitoring an entire reservoir requires an extended network of receivers, placed both at the surface and in wells, and the capability of modelling complex 3D structures as salt domes or stratigraphic traps. Classical seismological tools as Hypo71 (Lee and Lahr, 1972) HypoInverse-2000 (Klein, 2002) can deal with 1D models only, composed of plane parallel layers, without sharp lateral variations of P- and S-wave velocities, nor 3D variations of the Vp/Vs ratio. Limitations exist also for receivers" geometry, as the must be placed on a plane only. A more recent and flexible tool as NonLinLoc (Lomax et al., 2000) can deal with regular grids only. Here we present an algorithm able to deal with irregular 3D models and arbitrary recording geometries, which allows integrating any kind of active seismic (3D surface, VSP, and crosswell surveys) with passive seismic from surface and boreholes.

Aims & Research Methods: Reservoirs are highly inhomogeneous 3D structures, and monitoring their productions involves 3D both surface and borehole measurements. Here we present a method for enhancing the location of microseisms induced by production. The method may jointly exploit 3D surface seismic, VSP, and cross-well data, together with permanent receivers, placed both at the surface and in boreholes.

Citation: Ruud Schulte, Jan Lutgert and Annemiek Asschert, EBN B.V, 'Stranded Gas in the Netherlands: What is the Potential?' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Gas Development Methodologies

Jurisdiction: EU (Netherlands)

Abstract: In recent years, gas production in the Netherlands has peaked and appears to have gone into a slow but continuous decline. In an attempt to arrest this decline the Dutch government is investigating possibilities to tap into a previously unattractive class of reservoirs: the stranded fields.

Since the fifties, some 440 gas fields and 45 oilfields have been discovered in the on- and off-shore sectors of the Netherlands. Total gas reserves amount to over 4500 BCM of which some 71% has been produced. Oil reserves amount to 1.15 billion barrels of which 75% has been produced. From the 485 proven fields around 120 accumulations have not been developed and are considered stranded fields. Total volumes in these "contingent resources" amount to over 200 BCM GIIP and over 60 million m^3 STOIIP. Tight reservoirs, distant infrastructure, small volumes, and anomalous gas qualities are amongst the main reasons why these resources have not yet been developed.

Aims & Research Methods: In this paper, a screening methodology will be presented showing which of these fields might still qualify for development given recent technological and economic changes. By applying a hybrid methodology of GIS tools, data-mining applications and a quick screening economic evaluation the most attractive candidates for development are highlighted. In addition, the impact of new/improved technology, CAPEX changes or tax changes on the development economics are being modelled. In order to renew interest in these stranded fields it is the intention of the Dutch Government to share results both on the data used for the analysis and any notional development options resulting from this exercise.

Citation: Jason Baihly, SPE, Raphael Altman, SPE, and Isaac Aviles, SPE, Schlumberger, 'Has the Economic Stage Count Been Reached in the Bakken Shale?' (Paper presented at SPE Hydrocarbon Economics and Evaluation Symposium, Calgary, Alberta, Canada, 24-25 September 2012)

Topic Area: Completion Equipment, Economic Evaluations, Horizontal/Multilateral Wells, Hydraulic Fracturing and Gravel Packing, Downhole Tools and Equipment

Jurisdiction: USA

Abstract: The Bakken is one of the most active basins in the world in terms of number of rigs, with over 200 operating on the US side of the US-Canadian border. Production has rapidly increased from 100,000 BOPD in 2005 to 600,000 BOPD in 2012 in the state of North Dakota with the majority of production coming from the Bakken (Uptream Online, 2012). Greater horizontal drilling activity and a continuing increase in the number of hydraulic fracture stages per lateral have helped North Dakota grow its oil production six-fold in just seven years.

The Bakken is a fairly tight dolomitic siltstone requiring hydraulic fractures to produce economically. The stage count for hydraulic fracture treatments averaged nearly three stages in early 2007 and increased steadily over time to nearly 30 stages in late 2011. Some wells have even been completed with 40 or more stages. With the ever increasing stage count, the question remains: has the economic stage count limit been reached in the Bakken?

Aims & Research Methods: This paper analyses the stage count versus the production impact of horizontal Bakken wells to determine if the economic stage count has been reached in the play. Wells are grouped and analysed based on geographic considerations to help normalize for changes in geologic attributes such as natural fractures, reservoir quality, and net pay. Lateral length was also taken into account as varied lengths can impact stage spacing and interference issues.

Analyses were run with various oil and well service costs to determine how the economic stage count may change over time. If the economic limit was not reached under certain circumstances, this paper analyses possible scenarios to determine when the economic stage count would be reached. This approach should provide insight into how other unconventional oil plays can evolve in the future.

Citation: J. Zhu, Shell China; J. Chen, PetroChina; G. de Blok, Shell China, 'Drilling and Frac Stimulation Waste Management in Unconventional Gas Projects in Sichuan, China' (Paper presented at IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition, Tianjin, China, 9-11 July 2012)

Topic Area: Waste Management

Jurisdiction: Global

Abstract: Waste management will play an important role in delivering an environmentally sound well. If, however, a project requires the operator to drill hundreds of deep development wells and in close vicinity of communities, waste management even becomes a critical success factor. There is simply no room for error. The drilling and stimulation of these large number of wells will generate large volumes of solids and fluid waste, which must be managed efficiently, strictly controlled and comply with the requirements of local regulators.

Waste generated during the drilling phase constitutes of Water Based Mud [WBM] cuttings, Synthetic Based Mud [SBM] cuttings and WBM fluids, whereas frac flow back water will be the constituent following frac stimulation. To encompass all of these waste streams in an integrated waste management system, the project team of Fushun and Jinqiu [Sichuan, China] initiated a plan to cover waste generation, waste transportation, final disposal process and a waste tracking system as per ISO guidelines and in agreement with the Company's global Health, Safety & Environment [HSE] policy and procedures. The waste management is divided in two phases. In Phase I the solution sought is to utilize a recycling method in the field to minimize the generated waste volumes. This comprises a disposal waste stream for each waste category. For WBM cuttings, solidification and burial in-situ would minimize the impact on drilling operations. For WBM waste fluid and frac flow back water, in-situ pre-treatment and then transporting these effluents to industrial waste plants has proven to be a workable and efficient solution. In contrast, OBM cuttings are treated as hazardous waste and are incinerated in a hazardous waste disposal plant.

Aims & Research Methods: There are a number of challenges to face, such as heavy land transportation, resistance from local farmers in a populated area, meeting the strict and the mandatory requirement from the Environmental Protection Bureau [EPB], whilst at the same time aiming for overall well cost reduction and project delivery. Another limiting factor is the number of qualified local waste disposal vendors in the Sichuan area. But when there are challenges, there will also be opportunities. This paper aims to focus on these opportunities and will thus home-in on Phase II, currently under development, which comprises a pit-less drilling and stimulation approach, with all waste transported to a dedicated waste plant and waste disposal location.

Citation: Melvyn R. Giles, Daniel Nevin, Bud Johnston and Mark Hollanders, Shell Exploration and Production Company, 'Understanding Volumes, Economics and Risk Mitigation in Unconventional Gas Projects' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Management of Unconventional Gas Projects

Jurisdiction: Global

Aims & Research Methods: A great deal has been written on the volumes of unconventional gas trapped in the subsurface, this paper examines: 1) The relationship between the huge GIIP volumes, technically recoverable volumes and economically recoverable volumes 2) The barriers to achieving economically viable projects 3) Lifecycle and drivers for creating economically viable projects 4) The use of decline curves to estimate the productivity and the pitfalls associated with their use 5) Strategies for mitigation of economic risk in taking an exploration project through to development New unconventional gas projects all come with considerable uncertainties and therefore risk, but careful de-risking strategies enable companies to steer their way toward clear go/no go decisions at multiple points in the lifecycle enabling them to progress with minimum exposure.

Citation: George E. King, Apache Corporation, 'Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 6-8 February 2012)

Topic Area: Hydraulic Fracturing and Gravel Packing, Wellbore Design/Construction, Risk Management and Decision-Making and Chemical Tracers

Jurisdiction: USA

Abstract: Identification of risk, the potential for occurrence of an event and impact of that event, is the first step in improving a process by ranking risk elements and controlling potential harm from occurrence of a detrimental event. Hydraulic Fracturing has become a hot environmental discussion topic and a target of media articles and University studies during development of gas shales near populated areas. The furor over fracturing and frac waste disposal was largely driven by lack of chemical disclosure and the pre-2008 laws of some states. The spectacular increase in North American natural gas reserves created by shale gas development makes shale gas a disruptive technology, threatening profitability and continued development of other energy sources. Introduction of such a disruptive force as shale gas will invariably draw resistance, both monetary and political, to attack the disruptive source, or its enabler; hydraulic fracturing. Some "anti-frack" charges in media articles and university studies are based in fact and require a state-by-state focused improvement of well design specific for geology of the area and oversight of overall well development. Other articles have demonstrated either a severe misunderstanding or an intentional misstatement of well development processes, apparently to attack the disruptive source.

Aims & Research Methods: Transparency requires cooperation from all sides in the debate. To enable more transparency on the oil and gas side, both to assist in the understanding of oil and gas activities and to set a foundation for rational discussion of fracturing risks, a detailed explanation of well development activities is offered in this paper, from well construction to production, written at a level of general public understanding, along with an initial estimation of frac risk and alternatives to reduce the risk, documented by literature and case histories. This discussion is a starting point for the well development descriptions and risk evaluation discussions, not an ending point.

Citation: T. McLean, SPE, E. Dalrymple, SPE, M. Muellner, S. Garcia-Swofford, SPE, Nalco, an Ecolab Company, 'A Method for Improving Chemical Product Risk Profiles as Part of Product Development' (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility and Integrating HSE into the Business

Jurisdiction: Global

Abstract: A robust chemical product comparative scoring process (CSP) has been developed that facilitates continuous improvement in human and environmental hazard reduction. The method is simple and quick enough to use during development of new products, is adaptable to changing needs and visually communicates the hazard profile improvements of new products.

The CSP is used during product development. Human and environmental hazard profiles of developmental products are compared to current products used for similar purposes. Since the CSP requires little additional time, it allows hazard profiles to be determined during project development and identifies areas of potential improvement to the hazard profile. The CSP uses specified categories of concern for which public databases exist. For substances that have no database information, US EPA computer models are used. Using the CSP method, hazard profiles of formulations may be improved during the development phase of the project and the results are reported in a visual, qualitative, comparative format.

The CSP has been used to improve the human and environmental hazard profiles of several types of chemical products.

Aims & Research Methods: This paper will outline how the CSP is used for hazard profile improvement as a part of a development project, reducing delays due to testing or reformulating. The unique visual presentation format of the CSP allows hazard profile improvements over existing products to be easily identified by, and communicated to customers and other concerned parties. The CSP yields the most valid comparisons when data is available for the existing and proposed substances. Computer models are effective if used by personnel trained to use them. The process must include communication with (and validation by) regulatory and toxicology specialists.

Citation: Mark A. Parker and Kumar Ramurthy, Halliburton; Patricio W. Sanchez, Energen Resources, 'New Proppant for Hydraulic Fracturing Improves Well Performance and Decreases Environmental Impact of Hydraulic Fracturing Operations' (Paper presented at SPE Eastern Regional Meeting, Lexington, Kentucky, USA, 3-5 October 2012)

Topic Area: Reservoir Description and Dynamics

Jurisdiction: USA

Abstract: Fracture conductivity in many hydraulic-fracturing treatments can be inadequate. It is greatly affected by the concentration of the packed proppant in the fracture. Higher concentrations yield higher conductivity by virtue of a wider fracture. However, there are practical limitations to the amount of proppant that can be placed into any particular reservoir, and therefore production is often conductivity limited.

An alternate approach to achieve high conductivity is to create a fracture by placing well-distributed, low-density particles characterized by a proppant concentration less than 0.1

lbm/ft^2. Low particle concentrations result in fractures that have high porosity and are fundamentally different from fractures with packed beds of conventional proppants.

Aims & Research Methods: In this paper, the theoretical basis for the conductivity of these fractures is presented. A 3-D model has been developed to simulate high-porosity fractures created with these particles. Test data used to refine the model can be used to predict the conductivity of the fracture based on the porosity level, the closure stress, and the material properties.

Production data from two application areas in North America are shown to highlight the benefits of using this type of fracturing proppant.

A screening life cycle analysis (LCA) is included to evaluate and highlight the beneficial attributes of using a low-density proppant to achieve fractures with high conductivity. The LCA considers the impact of logistics and fracture design on the environment.

Citation: Mark A. Parker and Kumar Ramurthy, Halliburton; Patricio W. Sanchez, Energen Resources, 'New Proppant for Hydraulic Fracturing Improves Well Performance and Decreases Environmental Impact of Hydraulic Fracturing Operations' (Paper presented at SPE Eastern Regional Meeting, Lexington, Kentucky, USA, 3-5 October 2012)

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Production data from two application areas in North America are shown to highlight the benefits of using this type of fracturing proppant.

A screening life cycle analysis (LCA) is included to evaluate and highlight the beneficial attributes of using a low-density proppant to achieve fractures with high conductivity. The LCA considers the impact of logistics and fracture design on the environment.

Citation: Kun Cheng, SPE, Wenyan Wu, SPE, Stephen A. Holditch, SPE, Walter B. Ayers, Jr., SPE, and Duane A. McVay, SPE, Texas A&M University, 'Case Study of Using Basin Analysis to Evaluate Unconventional Gas Resources in Frontier Basins' (Paper presented at Canadian Unconventional Resources Conference, Alberta, Canada, 15-17 November 2011)

Topic Area: Reservoir Description and Dynamics

Jurisdiction: USA

Abstract: As gas production from conventional gas reservoirs in the United States decreases, the industry is turning more attention to the exploration and development of unconventional gas resources (UGRs). This trend is expanding quickly worldwide. However, unlike in many mature North American basins where significant development of UGRs is now routine, many countries are just turning to UGRs exploration. Insightful resource assessment is important for tapping UGRs in these frontier basins.

Aims & Research Methods: To evaluate the UGRs in frontier basins that are underexplored, we developed basin analysis methodology to 1) characterize basins; 2) establish analogy between frontier basins and mature North American basins; 3) estimate conventional and unconventional resources in mature North American basins; and 4) quantitatively predict UGRs in frontier basins by using information from analogous North American basins. This comprehensive basin analysis study not only validates the resource triangle, which is characterized by a large ratio of unconventional TRR (technically recoverable resources) to conventional TRR, but also makes it possible to quantitatively assess unconventional resources in under-explored basins worldwide.

To demonstrate use of basin analysis in evaluating the UGRs of frontier basins, two world hotspots for UGRs exploration were selected as the target basins: Neuquén basin in South America and Berkine basin in North Africa. Recent assessment reports and exploration activities indicate that the two basins have substantial unconventional gas resources. As a case study, basin analysis was used to identify the North American reference basins that are analogous to the Neuquén and Berkine basins, and to characterize the distributions of UGRs in these frontier basins. Furthermore, the quantitatively estimated unconventional TRR were compared with those from EIA (Energy Information Administration) and companies to support the effectiveness of basin analysis results.

Citation: George J. Moridis, SPE, Lawrence Berkeley National Laboratory, Heidi Anderson Kuzma, SPE, East Donner Research LLC, Matthew T. Reagan, SPE, Lawrence Berkeley National Laboratory, Thomas A. Blasingame, SPE, Texas A&M University, Y. Wayne Huang, Linear Time Informatics LLC, Ralph Santos, Katie Boyle, Lawrence Berkeley National Laboratory, Craig M. Freeman, SPE, Dilhan Ilk, SPE, Texas A&M University, Manuel Cossio, SPE, Texas A&M University, Srimoyee Bhattacharya and Michael Nikolaou, SPE, University of Houston, 'A Self-Teaching Expert System for the Analysis, Design, and Prediction of Gas Production From Unconventional Gas Resources' (Paper presented at Canadian Unconventional Resources Conference, Alberta, Canada, 15-17 November 2011)

Topic Area: Information Systems and Data Use and Data Integration

Jurisdiction: Global

Abstract: Unconventional gas resources (UGRs) are best described as gas accumulations that are hard to characterize and commercially produce by common exploration and production technologies. These resources are typically located in very tight, heterogeneous, extremely complex, and often poorly understood geologic systems, often easy to find but difficult to produce. Thus, while it is not difficult to find extensive UGRs in many basins, it is very difficult to determine their flow properties from petro physical well surveys and to design effective completion procedures. Furthermore, because of their very low permeability, establishing gas flow at commercial rates requires costly well stimulation operations. These considerations (low permeability and complex geology) are responsible for the high risk factors and unpredictable results often associated with UGR exploration and development projects, and hamper industry investment in these resources despite their potentially vast magnitude.

Aims & Research Methods: SeTES is a self-teaching expert system that (a) can incorporate evolving databases involving any type and amount of relevant data (geological, geophysical, geomechanical, stimulation, petro physical, reservoir, production, etc.) originating from unconventional gas reservoirs, i.e., tight sands, shale or coal beds, (b) can continuously update its built-in 'public' database and refine the its underlying decision-making metrics and process, (c) can make recommendations about well stimulation, well location, orientation, design, and operation, (d) offers predictions of the performance of proposed wells (and quantitative estimates of the corresponding uncertainty), and (e) permits the analysis of data from installed wells for parameter estimation and continuous expansion of its database. Thus, SeTES integrates and processes any available information from multiple and diverse sources on a continuous basis to make recommendations and support decision making at multiple time-scales, while expanding its internal database and explicitly addressing uncertainty. It receives and manages data in three forms: public data that have been made available by various contributors, semi-public data, which conceal some identifying aspects but are available to compute important statistics, and a user's private data, which can be protected and used for more targeted design and decision making. SeTES can be a vital and easy-to-use tool in gas production from unconventional gas resources, and presents a new paradigm for communicating research and technology to the public and distributing scientific tools and methods. It is expected to result in a significant improvement in reserve estimates, and increases in production by increasing efficiency and reducing uncertainty.

Citation: Y. Beaudoin, J.K. Serry, Blake, Cassels & Graydon, ‘Shale Gas Development in Canada: The Regulatory Landscape’ (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Canada

Abstract: In the fall of 2010, shale gas exploration and development in Canada is just getting started. Engineering advances are making unconventional gas plays more attractive. Provincial governments are looking to tap the economic benefits. Regulators are adjusting existing oil and gas regulations or drafting entirely new legislation. This paper covers a selection of topics for each of the seven Canadian provinces where shale gas development has started or is about to begin. So far, regulation of shale gas is not very different from the

regulation of conventional gas exploration and development. Interest groups and regulators are following U.S. trends.

Citation: J. Daniel Arthur, B.J. Coughlin, B.K. Bohm, ALL Consulting, 'Summary of Environmental Issues, Mitigation Strategies, and Regulatory Challenges Associated With Shale Gas Development in the United States and Applicability to Development and Operations in Canada' (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: USA and Canada

Abstract: Natural gas has been produced from shales in North America for over 150 years (Harper 2008). Development of shale gas plays began with the Devonian shales of the Eastern United States in the 1800s. Modern shale gas development has been defined by the Antrim Shale in Michigan and the Barnett Shale in Texas, which started to see an expansion in development in the late 1980s. In recent years, shale gas development has grown in the Fayetteville, Woodford, Marcellus, Haynesville and Eagle Ford Shales of Arkansas, Oklahoma, Pennsylvania, Louisiana, and Texas, respectively (See map in Figure 1). Although Canada's shale gas potential has been known for nearly as long as that of the United States, development of shale plays in Canada has only occurred over the last few years (Canadian Energy Advantage n.d.). Estimates of Canada's shale gas potential exceed 28 trillion cubic metres of natural gas (A Primer for Understanding 2009). Unconventional production of natural gas from sources like shale gas, tight gas and coal-bed natural gas (CBNG) account for between 20% and 30% of Canada's current natural gas production (Canadian Energy Advantage n.d.). In the United States, unconventional gas accounts for over 40% of gas production (GWPC and ALL Consulting 2009). Shale gas is expected to provide over half the natural gas production in North America by 2020. While the potential for Canadian Shale Gas development is still being evaluated, the principal Canadian shale gas plays identified to date are the Horn River Basin and Montney Shales in northeast British Columbia, the Colorado Group in Alberta and Saskatchewan, the Utica Shale in Quebec, and the Horton Bluff Shale in New Brunswick and Nova Scotia (See map in Figure 1) (Canadian Energy Advantage n.d.).

Aims & Research Methods: This paper will summarize key environmental and regulatory issues associated with Shale Gas development in major shale plays in the United States, actions taken by environmental non-governmental organizations, government, and industry on these issues (including mitigation strategies). Further, the paper will present the current and future pictures of these issues and the applicability of these issues to Shale Gas development in Canada.

Citation: S.T. Cham, P. Stone, Gas Industry Social and Environmental Research Alliance and CSIRO, 'How Can Understanding Community Concerns About Hydraulic Fracturing Help to Address Them?' (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Hydraulic fracturing Activities

Jurisdiction: Australia

Abstract: Hydraulic fracturing has been the focal point of widespread and global public debate. While the resources sector typically sees hydraulic fracturing as a low-risk method for accessing the coal seam and shale gas reserves required to meet growing public demand for energy, some in the community perceive it as an unmanageable and unacceptable risk. Concerns about hydraulic fracturing and the coal seam gas (CSG) industry include the health impacts of chemicals used, contamination of water supplies from fugitive gas after hydraulic fracturing, equity of land and water access, long term impacts on groundwater, and the full life cycle emission of greenhouse gases from CSG compared to that of coal.

Aims & Research Methods: This paper highlights the main psychological drivers behind some of these concerns and a possible approach to effectively address them.

Citation: Thomas Bennett, Arrow Energy, 'Innovation of Coal Seam Gas Well-Construction Process in Australia: Lessons Learned, Successful Practices, Areas of Improvement' (Paper presented at IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition, Tianjin, China, 9-11 July 2012)

Topic Area: Australia

Jurisdiction: Performance Measurement, Technical Limit, Drilling and Well Control Equipment, Horizontal/Multilateral Wells, Strategic Planning and Management and Personnel Competence

Abstract: From by-product to multi-billion dollar industry, the Coal Seam Gas (CSG) industry in Australia has recently experienced rapid growth however is still facing many challenges. The Australian CSG industry is approaching a cross-road; the transition from a Domestic Gas business to exporting the CSG resources, requiring a significant scale up of current operations. Well design innovation is one of the necessary levers to maximize the full potential of CSG as a competitive energy resource. This paper focuses on the technical challenges associated with driving continuous improvement in drilling and completion practices as a key success factor for competitive performance.

The growth expected in the CSG industry over the next few years will be rapid. Arrow Energy plans to increase its production from 150 TJ/day in 2012 to 1350 TJ/day in 2018. This will require increases in drilling performance. Much of the early success will likely be obtained from the transfer of benchmark practices, where relevant, from the more mature global oil and gas industry – rather than from true CSG innovation. However, given the lower cost margins and economics of CSG, this knowledge transfer will need to be coupled with innovative application and new approaches.

Aims & Research Methods: This paper will discuss the importance of innovation in basis of well design as a lever to drive improvements in CSG in Australia and outline some of the key areas that Arrow Energy is focusing on to achieve this, including:

- The need for fit for purpose rigs to meet well design criteria and well safety requirements.- Standardization of well designs and equipment aligned to local government regulations and American Petroleum Institute (API) regulations.
- Vendor alignment and incentivized performance to meet company targets.

- Problems associated with innovation and difficulties of implementation in short time frames as well as the application of lessons learned from trials.
- Well design evolution and optimization of gas recovery.
- The importance of adopting a culture of learning and flexibility to implement changes as design standards progress.

Citation: Ray Hatley, Golder Associates, 'Coal Seam Gas (CSG): What Becomes of Produced Water? Regulation and Strategies' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility, Groundwater

Jurisdiction: Australia

Abstract: Strong LNG demand, both here in Australia and overseas, *fuelled* by worldwide transition to a low carbon economies is driving unprecedented growth in *coal seam gas* (CSG) exploration and development of east coast resources, not to mention the other conventional gas resources around Australia. With this accelerated growth in demand for gas, particularly with the onshore CSG production, comes the matter of the associated environmental affects and the need for socially responsible environmental management and mitigation of impacts.

Why do I single out the CSG industry in this regard – after all the oil and gas industry has been the subject of considerable environmental regulation during the many decades of production in this country, and has a very proud record in doing the right thing.

Aims & Research Methods: This paper relates specifically to one unique attribute associated with the production of CSG, namely the need to extract groundwater from the gas production wells in order that they be depressurised as a precursor to gas release. Pumping groundwater from of the coal seam 'aquifers' targeted for the resource reduces the hydraulic pressure to the point that the adsorption bonds holding the methane to the surfaces of the coal cleats (or micro-fractures) are reversed and the gas moves into the gaseous phase, and is hence available to flow to the well under the prevailing hydraulic gradients. Typically, a CSG well is pumped for its groundwater, producing its peak flows early in the life of the well, with flows of water tapering off with time, as gas flows increase and peak some years into its life.

Citation: R. Singh & R. Kumar, Central Mining Research Institute (CMRI), 'Pillar Stability During Underground Mining of the Complete Thickness of a Thick Coal Seam In a Single Lift - Indian Experiences' (Paper presented at 1st Canada - U.S. Rock Mechanics Symposium, Vancouver, Canada, May 27 - 31, 2007)

Topic Area: Pillar Stability During Underground Mining

Jurisdiction: India

Abstract: In India, coal mining by opencast methods attracted mechanization and automation due to favourable geotechnical conditions; the method provided better production, productivity and safety compared to underground mining. The importance of underground coal mining is increasing, not only due to growing environmental concerns, but also because the mineable opencast coal reserve is becoming exhausted. However, the performance of underground coal mines of the country is relatively poor, mainly due to a lack of mechanization. Underground mining of a thick coal seam, by total extraction of the whole seam in a single pass, has always had the edge over multi-pass working, due to favourable economics and safety.

Aims & Research Methods: In India, Blasting Gallery (BG) and Cable Bolting (CB)-based pillar extraction methods are adopted for the single-lift underground extraction of total thickness of a thick coal seam, developed on pillars along the floor. Here thick coal seams are, first, developed with normal height pillars along the floor and then the overlying coal band is taken during retreat of the face by longhole drilling and blasting. This pattern of roof coal winning created a higher goaf, resulting in an increase in the height of pillars. In particular, barrier pillars, between exhausted panels and panels being mined, encountered considerable increases in their height. The adverse effects of the increase in the height of barrier pillars affected production, productivity and safety. Two case studies, the Cable Bolt (CB) method at the North Chirimiri Ponri Hill (NCPH) colliery in the Chirimiri area, and the Blasting Gallery (BG) method at the GDK10 Incline in the Rmamagundam area, are briefly presented in this paper to demonstrate the influence of the indirect increase in the height of pillars and the caving nature of overlying strata on the stability of the natural support.

Citation: S.K.Choi & M.B.Wold, CSIRO Petroleum, ‘A mechanistic study of coal and gas outbursts’ (Paper presented at DC Rocks 2001, The 38th U.S. Symposium on Rock Mechanics (USRMS), Washington D.C, July 7 - 10, 2001)

Topic Area: Coal and gas outbursts

Jurisdiction: Australia

Abstract: Coal mining under conditions of high gas pore pressure can produce the hazard of dynamic coal failure known as coal and gas outbursts. It is a dynamic phenomenon that may involve the expulsion of large volume of gas and fractured coal. Gas outburst has been a potential hazard for underground miners of gassy coal seams in many countries, from the mid nineteenth century up until the present day. In Australia, the first recorded outburst happened in 1895 at Metropolitan Colliery in the Southern Coal fields of New South Wales, and many outburst events have since occurred in New South Wales and Queensland. Lives have been lost and mines have been closed, at severe cost to the community. Efforts to understand and manage the problem have been hindered by the complexity of the physical mechanisms involved, the difficulty in determining the various contributing factors and how they interact, and the need to continuously measure and monitor underground conditions as mining progresses. Nevertheless, in the last decade outburst risk has been brought under control in Australia by the introduction of in-seam gas drainage ahead of mine development and production. Under strict government regulation, drainage to meet safe gas content threshold values is carried out in all mines assessed as at risk. Mining can only proceed if the gas content at the coal face has been drained to below certain threshold values depending on gas composition. This concept is based on the work of Lama particularly with respect to the outburst problems at West Cliff Colliery (Lama, 1995). The requirement to mine at gas contents below the threshold can pose problems where drainage is difficult, and there is a need to understand the mechanics of gas and coal outbursts in order to provide a more rational approach for determining suitable threshold values and whether they can be modified under different mining conditions.

Aims & Research Methods: In modelling the initiation of coal and gas outbursts, the coal seam is treated as a gas reservoir, and the mechanical responses of the seam to mining-induced changes in pore fluid pressure and effective stress fields are studied within the framework of poroelastoplasticity theory. Results are presented from numerical modelling studies, conducted using a dual porosity multi-component coal bed methane simulator which has been coupled to a coupled geomechanical-fiuid flow analysis code. The model is 3-dimensional and simulates the strength and deformation properties of coal, compressibility and single and two-phase flow properties of pore gas and water, mass transport of mixed gases in the adsorbed and free states, stress dependent permeability, and large strain deformation. Coupled mechanical deformations and fluid flow in ubiquitous jointing and discrete joints and faults are also simulated.

Citation: King, G.R., Chevron U.K. Ltd., 'Measurement of Inflow Performance Parameters for Coal Seam and Devonian Shale Gas Reservoirs and Its Implication in Numerical Reservoir Simulation' (Paper presented at SPE Annual Technical Conference and Exhibition, Houston, Texas, 3-6 October 1993)

Topic Area: Measurement of Inflow Performance Parameters for Coal Seam and Devonian Shale Gas Reservoirs

Jurisdiction: USA

Abstract: For unconventional gas reservoirs undergoing non-equilibrium (dual-porosity) desorption, inflow performance parameters measured from deliverability tests may not be appropriate for numerical reservoir simulation. This is because the static pressures used in deliverability testing are influenced by the effects of pressure depletion in the fractures (during flowing conditions) and blow-down from the rock matrix (during shut-in). Under flowing conditions, the inflow performance in numerical reservoir simulators is governed solely by the cleat (fracture) pressure of the grid block.

Consequently, if non-equilibrium desorption formulation is used in the simulation study, then the use of inflow performance parameters derived by deliverability testing may yield erroneous results.

The inconsistencies and analysis techniques discussed in this paper are applicable for all reservoir studies involving the inflow performance from unconventional gas reservoirs (analytical or numerical), however, they are more critical for numerical studies. These techniques are believed to be useful for understanding the need for representative inflow performance parameters for unconventional gas reservoirs.

The inflow performance parameters of wells in conventional gas reservoirs are generally derived from two sources, transient pressure data and stabilized deliverability data. Traditionally, unconventional gas reservoirs, particularly coal seams, have been evaluated early in the field life when water saturations are high (in many cases Sw = 100) using transient tests. This is because any analysis technique involving water injection can be treated

as single-phase flow. Consequently, slug tests and injectivity/falloff tests are generally used to evaluate wells at virgin conditions.

Aims & Research Methods: This paper describes potential inconsistencies between the traditional methods used to estimate inflow performance parameters for conventional gas reservoirs and the way these parameters are used in analysing coal seam and Devonian shale gas reservoirs, particularly in numerical reservoir studies. These inconsistencies arise because of the unique reservoir characteristics and mechanisms associated with unconventional gas reservoirs.

Citation: Barry Goldstein, Michael Malavazos, Alexandra Wickham, Michael Jarosz, Dominic Pepicelli, Mieka Webb, Dale Wenham, State Government of South Australia, 'Regulatory Nirvana for Hydraulic Fracture Stimulation' (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: Australia (SA)

Abstract: Governments are challenged to deploy trustworthy regulation to enable profitable and environmentally sustainable unconventional petroleum projects. A key activity under scrutiny during the development of these projects is hydraulic fracture stimulation. Regulatory Nirvana for unconventional projects and conventional projects alike entails:

- Pragmatic licence tenure;
- Regulatory certainty and efficiency without taint of capture;
- Regulators and licensees with trustworthy competence and capacity;
- Effective stakeholder consultation well-ahead of land access;
- Public access to details of significant risks and reliable research to backup risk management strategies so the basis for regulation is contestable anytime, everywhere;
- Timely notice of entry with sufficient operational details to effectively inform stakeholders;
- Potentially affected people and organisations can object to land access - without support for vexatious objections;
- Fair and expeditious dispute resolution processes;
- Fair compensation to affected land-users;
- Risks are reduced to low or as low as reasonably practicable (ALARP) while also meeting community expectations for net outcomes;
- Licensees monitor and report on the efficacy of their risk management, and the regulator probes same;

- Regulator can prevent and stop operations, require restitution, levy fines and cancel licences; and
- Industry compliance records are public, so the efficacy of regulation is transparent.

These principles are deployed in South Australia where:

- 24 unconventional gas plays are being explored, each with giant gas potential;
- Hundreds of wells have been safely hydraulically fracture stimulated;

Since implementing South Australia's *Petroleum and Geothermal Energy Act 2000* [1] (PGEAct), more than 11,000 notices of entry for petroleum operations led to just one court action, and that was to establish a legal precedent that geophysical surveys can extend outside a licence to enable a complete understanding of the potential resources within a licence.

Citation: Sofia Oliver, Santos Limited, ''Wild Thing: The Challenges of Regulatory Change Under Wild Rivers' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Australia (Qld)

Abstract: In late 2011 the Queensland State Government of Australia declared the Cooper Creek Basin in South West Queensland to be a Wild River Area under the *Wild River Act 2005*. The Wild River Area covers a significant proportion of Santos' current tenements and future development interests in the area.

The Wild Rivers Declaration is a highly prescriptive regulatory regime that sets out significant restrictions which would detrimentally impact on existing operations and future oil and gas development opportunities, including emerging coal seam and shale gas prospects in the proposed declaration area. It includes general prohibitions on certain activities across extensive areas of channel country and the imposition of setbacks for activities in proximity to watercourses.

The issue first arose in late 2010 when the Queensland Government indicated its intent to declare the Cooper Creek Basin as a Wild River through its issue of a Declaration Proposal. During the 12 month consultation period that followed, Santos engaged with the Queensland Government regulators and Ministers to assist the Government to make a Wild Rivers Declaration that achieves a balance between protecting the natural values of the Cooper Creek and allowing the continuation of the sustainable development of the petroleum resources within the Cooper and Eromanga Basins.

Aims & Research Methods: The paper will provide insight into Santos' experience in taking a lead role in responding to the significant new legislative regime proposed by Government. Key insights include the need for industry to be proactive and take a role in educating the Government on the industry's operations and the changes required to ensure compliance with the new regulatory requirements. It will also discuss broadly the challenges associated with the changing regulatory environment including the role that politics can play and observes that we should continue to expect a 'Wild' ride when participating in the legislative development process.

The significance of the Declaration is that the restrictions for petroleum activities imposed in the Cooper Creek Basin Wild Rivers Declaration may be imposed upon all Wild Rivers areas in Queensland. In addition, other Australian state governments are watching the implementation of Wild Rivers' legislation in Queensland and are considering the need for similar regulatory regimes in their jurisdictions

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Citation: Roberto F. Aguilera and Ronald D. Ripple, Centre for Research in Energy and Mineral Economics (CREME), Curtin University; Roberto Aguilera, Schulich School of Engineering, University of Calgary, 'Link between Rocks, Hydraulic Fracturing, Economics, Environment, and the Global Gas Portfolio' (Paper presented at SPE Canadian Unconventional Resources Conference, Calgary, Alberta, Canada, 30 October-1 November 2012)

Topic Area: Economic Analysis Guidelines

Jurisdiction: Global

Abstract: Figure 1 is a pentagon showing the link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio. Our view is that there must be an equilibrium in the pentagon to provide a win-win situation for society at large. All corners in the pentagon are interrelated and there is no need to sacrifice one for benefit another. It has been shown that there is a significant gas endowment in conventional reservoirs. However, we have to also unlock natural gas stored in unconventional formations to ensure that gas plays an important role in satisfying future energy consumption. We cannot produce it economically without hydraulically fracturing the unconventional formations. At the same time, we cannot sacrifice the environment solely for economic gain and nothing but the highest environmental standards are acceptable. All stakeholders must act responsibly to generate the win-win situations.

Aims & Research Methods: This paper presents a methodology for connecting geology, hydraulic fracturing, economics, environment and the global natural gas endowment in conventional, tight, shale and coal bed methane (CBM) reservoirs. The volumetric estimates are generated by a variable shape distribution model (VSD). The VSD has been shown in the past to be useful for the evaluation of conventional and tight gas reservoirs. However, this is the first paper in which the method is used to also include shale gas and CBM formations.. Results indicate a total gas endowment of 70000 tcf, split between 15000 tcf in conventional reservoirs, 15000 tcf in tight gas, 30000 tcf in shale gas and 10000 tcf in CBM reservoirs. Thus, natural gas formations have potential to provide a significant contribution to global energy demand estimated at approximately 790 quads by 2035.

A common thread between unconventional formations is that nearly all of them must be hydraulically fractured to attain commercial production. A significant volume of data indicates that the probabilities of hydraulic fracturing (fracking) fluids and/or methane contaminating ground water through the hydraulically-created fractures are very low. Since fracking has also raised questions about the economic viability of producing unconventional gas in some parts of the world, supply cost curves are estimated in this paper for the global gas portfolio. The curves show that, in some cases, the costs of producing gas from unconventional reservoirs are comparable to those of conventional gas. The conclusion is that there is enough natural gas to supply the energy market for nearly 400 years at current rates of consumption and 110 years with a growth rate in production of 2% per year. With appropriate regulation, this may be done safely, commercially, and in a manner that is more benign to the environment as compared with other fossil fuels.

Citation: Emil D. Attanasi and Philip A. Freeman, US Geological Survey, 'Role of Stranded Gas From Central Asia, Russia, Southeast Asia, and Australia in Meeting Asia' (Paper presented at SPE Hydrocarbon Economics and Evaluation Symposium, Alberta, Canada, 24-25 September 2012, Calgary)

Topic Area: Economic Analysis Guidelines, Economic Evaluations, Strategic Planning and Management, Gas Monetization and Liquefied Natural Gas (LNG)

Jurisdiction: Global

Abstract: The extraction and transport costs to a liquefaction plant for gas from stranded gas fields located in Australia, Indonesia, Malaysia, and the basins of eastern Siberia are then evaluated. The resource cost functions presented show development and extraction costs as a function of the volume of stranded gas developed for each country. The analysis demonstrates that, although the Russian fields in areas of eastern Siberia are large with relatively low extraction costs, distances to a potential liquefaction plant at Vladivostok make them initially the high cost suppliers of the liquefied natural gas (LNG) market. For the LNG markets examined, Australia and Malaysia are initially the lowest cost suppliers. For the Shanghai market, a comparison of the cost of supplying gas by pipeline with the cost of supplying LNG shows that the pipeline costs from areas of eastern Siberia and Central Asia are generally lower than delivered cost of gas as LNG from the LNG supply sources considered.

Aims & Research Methods: Demand for natural gas is increasing more rapidly than anticipated in Far East markets because (1) China has modified its policies in order to increase reliance on gas, in part to mitigate the growth in its coal consumption (which now stand at almost half of world coal production), (2) Japan has announced its intention to eventually shut down its nuclear power industry, and (3) India, which currently has more than 400 million people without electricity, desires to accelerate electrification. This analysis investigates the potential role of stranded gas from Central Asia, Russia, Southeast Asia, and Australia in meeting Asia's future demand for gas imports. It initially surveys the discovered or known gas in stranded gas accumulations in Central Asia, Russia, Australia, Indonesia, and Malaysia. It then examines the primary gas import markets of China, India, Japan, and South Korea by describing energy use, gas demand trends, and domestic gas supplies to establish boundaries that encompass the wide variation in gas import demands in these markets during the two decades following 2020.

Then the cost of developing and delivering gas through overland pipelines from selected stranded gas fields in Central Asia and Russia to China is examined. Analysis shows that for the Shanghai market in China, the costs of developing and delivering Russia's stranded gas from the petroleum provinces of eastern Siberia are competitive with costs estimated for stranded gas from Central Asia. However, for the Western Siberian Basin, delivered gas costs are at least 3 US dollars per thousand cubic feet (USD/Mcf) higher than delivered gas from Central Asia.

Citation: Wen Qingyang, Yang Xiujuan, Yan Xiangzhen, China University of Petroleum; Li Gensheng, State Key Laboratory of Petroleum Resource and Prospecting China University of Petroleum Beijing, 'A Method to Determine the Negative Pressure Difference And the Drilling Fluid Density In Coal-bed Methane Underbalanced Drilling' (Paper presented at International Symposium on In-Situ Rock Stress, Beijing, China, August 25 - 27, 2010)

Topic Area: Drilling Operations

Jurisdiction: Global

Abstract: Because of the low mechanical strength, the coal rock cannot brace the pressure of overlying strata, and is easily to collapse. As the microporosity, micro crack and joints are quite developed, and the formation pore pressure is low, it is easy to have the leakage. The coal liquid has the acid property, but the drilling fluid shows the alkalinity, so it is easy to cause acid-base neutralization producing metal salts and block coal bed methane channel. Therefore, in order to protect the coal reservoir effectively, reduce the pollution on coal reservoir, and improve the recovery efficiency, the underbalanced drilling technology is used in coal-bed methane mining more and more in recent years.

Aims & Research Methods: According to the relationship of the percolation ability and the pore pressure of coal reservoir, an interpretation method of analysing the pressure attenuation testing data is derived by use of the Duhamel principle. Consequently, the pore pressure of coal reservoir is obtained by the method. Depending on mechanics of porous elastic medium and rock mechanics, mechanical mechanism of borehole instability is analysed for underbalanced drilling. Based on Hoek-Brown strength failure criteria, the limit drilling pressure difference mathematical model for keeping borehole stability is established. By calculating the annular pressure loss of drilling fluid in the laminar flow, the method for determining the proper drilling fluid density is proposed combined with the pore pressure of coal reservoir and drilling negative pressure difference. Comparing the measured values with the theoretical results of pressure difference and drilling fluid density of a coal-bed methane well in QinShui basin, the result shows the high degree of coincidence, verifies the correctness of the method and model in this paper, and supplies the theoretical basis for parameter design during underbalanced drilling.

Citation: George Demian, BP Canada Energy Company, 'Unlocking the Potential of CBM: An Exploration of Alberta's Royalty Treatment of Unconventional Gas' (Paper presented at 19th World Petroleum Congress, Madrid, Spain, June 29 - July 3, 2008)

Topic Area: Royalty Regulation

Jurisdiction: Canada

Abstract: As conventional gas production in Alberta continues to decline, it is estimated by the Alberta Geological Survey that the province's coal bed methane (CBM) resource base could contain approximately 75 trillion cubic feet of natural gas. An estimated 60% of that gas is located in the Manville region of Alberta, which offers better gas concentration, pay thickness and permeability, yet represents a mere 8% of current CBM exploration activity due to the additional expense of disposing the associated saline water into deep water-injection wells.

Aims & Research Methods: Research CBM exploration and development carries a considerably higher risk profile than conventional gas due to its significant upfront research & development costs, more complex horizontal completions and longer payback periods. The resulting price-sensitive environment together with historically low natural gas prices and a lack of financial incentives has rendered many deep well projects uneconomic. An evaluation of financial data, stakeholder information and past royalty history focuses primarily on the following questions: Assuming that the Alberta government wants to encourage CBM development,

1. Based strictly on the development and production costs in dry and wet Alberta coals, should the Alberta government provide financial incentives for CBM development?

2. If it is determined that the Alberta government should provide such an incentive, what type of financial incentive would be most effective in stimulating CBM development? An economic comparison of shallow well versus deep well exploration examines the effects of saline water disposal on a host of economic indicators including NPV, IRR and Payback Period. A real options analysis examines the optimal conditions for exploration and development of CBM from the perspective of a junior natural gas producer. In addition, Alberta's ongoing royalty review presents a new set of parameters upon which sensitivity analyses are conducted in order to determine whether a government-sponsored financial incentive is appropriate. Finally, a comparison of CBM best practices is explored between Canada, the United States and India. Introduction Alberta is Canada's energy capital, leading the nation in oil and natural gas production and contributing to its reputation as an innovative and responsible resource steward. Traditionally, the province's natural gas production has come from conventional shallow gas wells. In recent years, conventional gas production has declined and producers have begun to explore for new sources of natural gas.

Citation: J.Daniel Arthur, Jason Patton, ALL Consulting, Inc.; Tom Richmond, Montana Board of Oil and Gas Conservation, ‘Overview of Coalbed Methane Best Management Practices and Mitigation Techniques Using Geospatial Techniques’ (Paper presented at SPE/EPA/DOE Exploration and Production Environmental Conference, San Antonio, Texas, 10-12 March 2003)

Topic Area: Coalbed Methane Best Management Practices and Mitigation Techniques

Jurisdiction: Global

Abstract: In recent years, the exploration and development of CBM has been under intense scrutiny in many parts of the country. The heightened concern of environmental issues related to present-day production practices - including water production, hydraulic fracturing, pipeline construction, storage facilities, water impoundment and disposal facilities, underground injection activities, compressor station operations, etc. - increases the importance of using practices and mitigation strategies that facilitate resource development in an effective, timely, and environmentally sound manner. These issues have placed increased pressure on federal, state, and local regulatory agencies; land and resource managers; industry; landowners; and the general public to develop methodologies to accurately define specific areas of environmental risk along with defining Best Management Practices (BMPs) and mitigation strategies to aid in minimizing and alleviating these risks.

Aims & Research Methods: During the second half of the 1990's, Coalbed Methane (CBM) production increased dramatically nationwide to represent a significant new source of income and natural gas for many independent and established producers. Matching these soaring production rates during this period were the advancements in Geographical Information Systems (GIS) technologies generating terra-bytes of new data for the oil & gas industry. Coupled to these accelerating initiatives are many environmental concerns relating to production wastes and water table depletion of fresh water resources. It is these concerns that have prompted the conceptualization of this project for the development of Best Management Practices (BMP) and mitigation strategies utilizing GIS technologies for efficient environmental protection in conjunction with effective production of CBM. This has been accomplished by developing a framework to take advantage of a combination of investigative field research joined with leading edge GIS technologies for the creation of environmentally characterized regions of study. This paper will provide a summary of CBM BMPs as well as the use of an Internet-Based GIS application for geospatial analysis relative to CBM development and evaluation of various mitigation techniques and best management practices.

Citation: J. Wilde, Baker Hughes; T. Ellis, BJ Services, 'Cementing Through Capillary Tubing to Meet Regulatory Requirements: A Novel Approach for Plug and Abandonment' (Paper presented at 6th International Petroleum Technology Conference, Beijing, China, March 26 - 28, 2013 2013)

Topic Area: Downhole Operations (Casing, Cementing, Coring, Geosteering, Fishing) and Materials Selection (Casing, Fluids, Cement)

Jurisdiction: Australia

Abstract: Capillary tubing has traditionally been used for various down hole chemical treatments applied to enhancing fluid loading, treating corrosion and scale build-up, and preventing paraffin and emulsion formation. Capillary tubing provides an advantage over coiled tubing due to its lighter weight, smaller footprint, mobile structure, faster running speeds, and more economical costs. One drawback however, is the increased friction pressures when pumping abrasive fluids. Typical capillary tubing is sized from ¼ to ¾ in. OD versus the more common coiled tubing, which ranges from 1 to 3 ½ in. OD. Therefore, the use of capillary tubing for cementing operations has not been considered until recently.

Aims & Research Methods: This paper will feature a project in Australia where a capillary unit was employed to abandon a well with cement, while concurrently installing down hole pressure gauges to comply with local regulations. The cement design criteria along with two case histories will be described, and lessons learned will be evaluated.

Data that has been collected through the various jobs will demonstrate that current simulation software will need to be modified to match pressure outputs witnessed in the field. A comparison of simulated versus actual job pressure data has shown as much as a 70% friction reduction in actual pressure readings. The witnessed pressure values are shown to be consistent over several operations; therefore a theoretical correlation can be drawn so more realistic values can be simulated in the future. Additionally, slurry designs which were proven successful and operational considerations for improved job quality will be discussed.

This paper will discuss two case histories in which capillary tubing was used for the first time in Australia. Methodology, limitations, and future improvement possibilities will be discussed in detail throughout this paper.

Citation: P. Paquet, T. Bews, E. Viala, M. Pearson, Miller Thompson, 'Overview of The Emerging Unconventional Oil and Gas Regulatory Framework in Quebec Vis-a-vis Its Western Canadian Counterparts' (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Pipelines, Flowlines and Risers

Jurisdiction: Canada

Abstract: The regulation of unconventional oil and gas is emerging throughout North America.

In the St-Lawrence valley in the past 5 years, there has been a thriving exploration push. This exploration could lead in the medium to longer term to the securing of defined reserves for consumption in the local market. There had been anecdotal evidence of this over the years; however, recently this possibility has become very real indeed. Millions of dollars had been invested over the years by local entities such as Petrolia and Gastem Inc. These juniors have partnered with western Canadian or American players which have confirmed their participation and are motivated to further exploration and development of shale gas discoveries and unconventional oil plays.

Aims & Research Methods: Western Canada has had a thriving conventional energy industry for many decades. It encompasses the exploration, development, transformation and transportation of hydrocarbons to markets across North America. In Quebec, until recently the oil and gas industry was limited to distribution and transportation activities. As an industry, it regulated the infrastructure needed to process hydrocarbons and the legislation had very little to do with the exploration and development of hydrocarbons. However, with shale gas development, technological breakthroughs, and more favourable pricing conditions, Quebec has witnessed the birth of an unconventional oil and gas industry which now includes intense activity by exploration companies, developers and possibly, over the next few years, producers.

The Western Canadian regulatory framework will be reviewed and contrasted with the emerging Quebec regulatory framework to highlight the different challenges that may arise.

We will outline the legislative framework that governs the unconventional oil and gas industry in Quebec. Also, we will address the potential liability of officers and directors regarding the reclamation and abandonment of upstream facilities. We will comment on Quebec laws regulating land use, planning and the environment which may pose specific challenges depending on whether or not local gas lines, or processing plants need to be built or implemented. The oil and gas industry in Quebec is made subject to mining laws that are not entirely compatible with industry practices of traditional players.

Citation: István Lakatos, SPE and Julianna Lakatos Szabó, Research Institute of Earth Sciences, University of Miskolc and Geoengineering Research Group of the Hungaian Academy of Sciences, 3515 Miskolc-Egyetemváros, POB 2., Hungary, 'Role of Conventional and Unconventional Hydrocarbons in the 21st Century: Comparison of Resources, Reserves, Recovery Factors and Technologies' (Paper presented at EUROPEC/EAGE Conference and Exhibition, Amsterdam, The Netherlands, 8-11 June 2009)

Topic Area: Strategic Planning and Management, Design and Optimization, Production Enhancement, Fundamental Research in Production and Operations and Reserves Evaluation

Jurisdiction: Gas Development

Abstract: Energy demand is expected to quadruple in the 21st century (Fig. 1). An energy mix that is undergoing a transition from the current dominance of fossil fuels to a more balanced distribution of energy sources will meet the energy demand. Although the relative importance of hydrocarbons apparently will decrease from 60% (present) to 15% (in 2100), roughly 250−260 billion t of crude oil (annually 2.5 billion t on average through the whole century) must be produced to meet the worldwide demand. That task is enormous if we consider that a little bit than 100 billion t of crude oil has been produced since 1850 and the average production rate was about 0.7 billion t/y. As we will see in the next chapter, only 390 109 t crude oil may exist in proven and probable reservoirs. Namely, the converging opinion of different agencies1-7 is that the recovery rate of conventional hydrocarbons must be increased from 33−35% at present to 65−70%. Obviously, sophisticated recovery technologies must be routinely used at mostly matured oil fields in the future, however, a serious concern still exists whether that goal might be fulfilled or not.

Through the past two decades, the global economic growth and oil demand increased on average by 3.73% and 1.95%, respectively (Fig. 2). Consequently, as a short analysis made by Yergin8 a minimum 0.5% increase in oil production is needed to boost the world economy by 1%. Based on that prediction, the industrial oil demand will increase from 20 to 38 MBD (from 1.3 to 2.31 Gt/y) between 1980 and 2030; meanwhile the total oil production probably drops to less than 3 Gt/y by the end of that period1. Therefore, the sceptic opinions are supported by the facts that just the fuel consumption of transportation or hydrocarbon demand by industry alone will exceed the total crude oil production expected after 2040. It is no doubt, that additional hydrocarbon resources and industrial reserves are keenly necessary to maintain the rate of progress, otherwise the *"dwindling supplies of oil and gas, obsolete power net-works and new environmental regulations threaten the western word into a new energy crisis. Consequently, the mankind is becoming again vulnerable to shortage in hydrocarbons, price shock, supply interruptions, and in the worst case, political and military blackmail"* (Emerson T.: Newsweek, April 2002).

Aims & Research Methods: The paper deals with the availability of natural hydrocarbons until 2100. Starting point of the evaluation is that the global demand will not be met by production of conventional oil and gas. Basis of the discussion is the comparison of available resources and reserves, recovery factors and technologies. The analysis comprised oil shale, tar sand, gas shale, tight sand gas, coal bed methane and gas hydrates. Taking the data of competent organizations into account, obviously the global resources of unconventional oil and gas significantly exceed the availability of conventional natural hydrocarbons in spite of the fact that their recovery efficiency is extremely low. Although the production cost (operation expenditure) of unconventional hydrocarbons is usually much higher than those of the conventional ones, industrial scale production of tar sand oil, tight sand gas and coal bed methane has started over two decades ago and their contribution to total oil and gas production is already substantial in several countries (US, Canada). The authors stated, however, that wider application of sophisticated technology to recover unconventional hydrocarbons needs more extensive and intensive R&D activity and further, new paradigms are necessary in education, research, production, field management, and governmental regulation.

Citation: Elaine T. Cullen, National Institute for Occupational Safety and Health, 'Developing the Art of Listening: Studying Occupational Cultures' (Paper presented at ASSE Professional Development Conference and Exhibition, San Antonio, TX, June 28 - July 1, 2009)

Topic Area: Occupational Safety and Health

Jurisdiction: USA

Abstract: Workers in high-risk industries like mining, commercial fishing, construction, or oil and gas extraction experience injury and fatality rates far higher than workers in other industries. While it is true that the nature of those industries includes exposure to more risk, it is also true that these types of industries put a much higher emphasis on hazard recognition and safety and health training than do other industries, and that many of them employ safety directors or trainers to help mitigate the problem. Why, then, are the accident/injury rates still so high? Federal and state laws require that workers in most high-risk industries receive some sort of basic safety and health training in addition to the skills training they need to do the work, yet miners and loggers, roughnecks and fishermen, iron workers and construction workers are still getting hurt and killed on the job. Companies involved in high-risk work often have well-designed safety programs, spending valuable resources on protecting their employees. Yet we still cannot seem to approach the elusive goal of zero occupational fatalities or injuries. Is the problem that workers in these industries are just risk-takers and therefore injured more often? (This is a common belief among those not employed in high-risk industries.) Are regulations not strong enough? Do safety training materials miss the mark? Are the work environments and the equipment used in drilling oil wells, mining coal, harvesting timber, catching salmon, or erecting skyscrapers inherently dangerous and in need of more engineered controls to keep workers safe? Do we need more and better personal protective equipment? All of these "solutions" will have their proponents, and all may be true to some degree. There is reason to believe, however, that none of them can solve the problem alone, and that protecting workers without involving workers is simply not going to work.

Trying to "sell" safety to high-risk workers can be a challenge. It can be argued that those who chose to work in industries like these have a higher than normal tolerance for risk, and that convincing them to be more cautious would be difficult at best because they view risk as just part of the job. In fact, discussions with these workers suggest that many choose to work in high-risk occupations precisely because they love the thrill, and are convinced that not everyone has what it takes to do this work. There are many excellent programs and training courses available that provide the facts about common hazards such as Lockout/Tagout or working in confined spaces, but research done by NIOSH suggests that training must be customized to work within the specific occupational culture or it will not be taken seriously (Cullen, 2008). People who have worked as miners, roughnecks, fishermen, etc. have a high

tolerance for risk, and believe they know more about how to do this work than others do, and they can be quite resistant to "outsiders" telling them how to do their work.

Citation: Ramin Lakani, SPE, and Daniel Brown, SPE, Baker Hughes, 'An Integrated Approach to Managing Risks and Uncertainties: Combining Technical and Commercial Analysis' (Paper presented at 2013 North Africa Technical Conference & Exhibition, Apr 15 - 17, 2013 2013, Cairo, Egypt, InterContinental Citystar)

Topic Area: Gas to Liquids, Unconventional Resources and Energy Economics

Jurisdiction: Africa

Abstract: As engineers and scientists, we are very familiar with analysing technical risks, developing mitigation plans and implementing the plans that are safe and technically feasible. At the same time, dealing with subsurface projects has made us adept at analysing and understanding technical uncertainties. Furthermore, because of the large investments involved in upstream projects we are regularly exposed to commercial issues. However, the optimum situation is when the technical and commercial risks and uncertainties are evaluated in an integrated fashion.

Although many organisations combine technical and commercial evaluations, there are many examples that such integration is either superficial or is done in a series. Often the economic evaluation is performed at the end of the process, by which time it may be too late to influence the decisions or the changes may be too expensive to implement.

Techno-economic integration becomes absolutely essential when our industry faces "game changing" technologies, for example:
• Unconventional resource developments: Shale gas/oil
• Isolated gas monetisation: Gas to Liquid (GtL), Floating Liquefied Natural Gas (FLNG)
• Heavy oil developments: In-situ combustion, Steam Assisted Gravity Drainage (SAGD), Cold Heavy Oil Production with Sand(CHOPS)

Aims & Research Methods: Examples will be given to demonstrate the successes and failures of game changing technologies, where the failures are generally less advertised. It is important to discuss the 'lessons learnt' from these important events in our recent history: How can we apply techno-economic evaluation in an integrated fashion (and at an earlier stage) to better evaluate risks and uncertainties associated with implementing game-changing technologies? How can we influence the outcome of these projects?

This discussion is particularly relevant to the North Africa region as governments, National Oil Companies (NOCs) and International Oil Companies (IOCs) try to harness unconventional resources and seek alternative ways to monetise their gas resources.

Citation: R. J. Kimball, and A. L. Locke, SPE, CDM Smith Inc, 'Innovations in Sustainable Shale Gas Water Management High Recovery Reverse Osmosis Case Study' (Paper presented at SPE European HSE Conference and Exhibition, London, United Kingdom, 16-18 April 2013)

Topic Area: Sustainable Shale Gas Water Management

Jurisdiction: Global

Abstract: Natural gas production from low permeability shale formations (shale gas) has recently become economically viable due to technological advancements in horizontal drilling and hydraulic fracturing. Shale gas is present in numerous and large “basins” around the world, including across the United States, and has been largely untapped due to the very “tight” nature of shale rock. With horizontal drilling and hydraulic fracturing, previously inaccessible natural gas is made to flow through newly formed fractures in the shale to production wells.

As a result of this technology, natural gas is now one of the world’s fastest growing energy sources. The development of unconventional sources, such as coal seam gas, will grow dramatically due to vast basins in the United States, and Europe. These reserves are being tapped with new techniques for detection, hydraulic stimulation and extraction.

Aims & Research Methods: Leveraging any natural resource requires responsible environmental management. Development includes many protective measures, with special concern for water resources and water quality. There is considerable debate about environmental concerns related to produced water. Our industry has a role to identify and apply robust, reliable and efficient scientific and engineering methods to help protect water supplies and the environment.

Water management is one of the biggest operating issues for resource developers. While well development may require 4-5 million gallons of water per horizontal well, more liquid is produced throughout the gas well’s lifecycle containing constituents at concentrations much higher than in surface water—all of which requires management through treatment and beneficial use. To protect fresh water resources and control treatment costs, resource developers are seeking innovative treatment and reuse options.

This paper provides detailed information and context from case studies including references of relevance to the gas field produced water characteristics of representative Europe and American gas fields.

Citation: Amit D. Nakhwa, Boots & Coots, Ken Huggins, Halliburton, Ronald Sweatman, Consultant, ‘Shale Gas Well Fracturing Technologies Help Address HSE Concerns’ (Paper presented at Offshore Mediterranean Conference and Exhibition, , Ravenna, Italy, March 20 - 22, 2013)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: Global

Abstract: To further address these HSE concerns, members of Oil & Gas (O&G) industry associations, including the American Petroleum Institute (API), Society of Petroleum Engineers (SPE), International Association of Drilling Contractors (IADC) and the International Association of Oil & Gas Producers (OGP) based in London and Brussels,

continue to develop sound science and field-proven best practices in the form of industry standards, such as those referenced in this paper. Technical publications by O&G service companies have provided numerous case histories highlighting these applicable technologies. These presented technologies and practices have helped to demonstrate the positive impacts for shale gas development projects.

Aims & Research Methods: This paper discusses how applied science, historically safe operations, advancements in technology and standard processes are helping to address and reduce health, safety, and environmental (HSE) concerns for hydraulic fracturing in shale gas wells. The technologies presented include an improved method of removing total suspended solids in order for water recycling, UV light equipment used for bacteria control in fracturing fluids, fracturing fluids comprised of ingredients sourced from the food industry, aquifer protection using 3D fracture mapping and microseismic fracture monitoring and equipment footprints allowing for smaller well locations. This combination of scientifically-derived technologies and standards (a.k.a. best practices) is assisting in lowering the risk for HSE incidents and addressing misconceptions about hydraulic fracturing.

Citation: A. Darishchev, SPE, E.N.S.G. de Nancy, Beicip-Franlab ; P. Lemouzy, SPE, and P. Rouvroy, Beicip-Franlab, France, 'On Simulation of Flow in Tight and Shale Gas Reservoirs' (Paper presented at 2013 SPE Middle East Unconventional Gas Conference & Exhibition, Muscat, Sultanate of Oman, Jan 28 - 30, 2013 2013)

Topic Area: Reservoir Engineering of Subsurface Storage, Unconventional Hydrocarbon Recovery, Management of Challenging Reservoirs, Risk Management and Decision-Making and Design and Optimization

Jurisdiction: Global

Aims & Research Methods: Applicability of existing numerical simulation methodologies to unconventional reservoirs is questionable and requires investigation and research.

We have focused on gas flow simulation of a highly heterogeneous fractured reservoir with extremely low matrix permeability. First of all we have considered the key roadmap components, natural gas composition, rock properties, critical elements and the main features inherent in tight and shale gas reservoir engineering. Using field reference data and a reservoir simulator, different scenarios of gas production have been modelled. This paper presents results from a sensitivity study of the dimension of hydraulic fracturing stimulated reservoir volume (SRV), matrix and propped fracture permeability which is spatially varied as one of the most realistic approaches, and of the bottom hole pressure. The approaches "dual porosity - single permeability", "dual porosity - dual permeability" and key reservoir properties have been reconsidered for specific geological and technological conditions in order to support decision making in unconventional reservoir management. Assuming pseudo-steady state gas flow, the simulation time step and gridblock size have been adjusted with a sector model represented by a logarithmically refined grid. In comparison with previous studies, it has been stated that the proposed approach of discrete fracture network modelling can be used in cases where the dual medium approach is questionable or inappropriate. The simulations of flow that have been performed, showed that the contribution of unstimulated reservoir volume (in the vicinity of the SRV) to gas production is non-negligible and can be a significant part of gas production to be taken into account in some field cases.

The results of this study can be used in unconventional reservoir modelling and flow simulation to identify development, stimulation, and completion strategies aimed at optimization of gas production, reservoir performance and gas recovery. The proposed approach also supports risk and uncertainty analysis, revenue estimation and economic performance evaluation.

Citation: J. Wilde, Baker Hughes; T. Ellis, BJ Services, ‘Cementing Through Capillary Tubing to Meet Regulatory Requirements: A Novel Approach for Plug and Abandonment’ (Paper presented at 6th International Petroleum Technology Conference, Beijing, China, Mar 26 - 28, 2013 2013)

Topic Area: Downhole Operations (Casing, Cementing, Coring, Geosteering, Fishing) and Materials Selection (Casing, Fluids, Cement)

Jurisdiction: Australia

Abstract: Capillary tubing has traditionally been used for various down hole chemical treatments applied to enhancing fluid loading, treating corrosion and scale build-up, and preventing paraffin and emulsion formation. Capillary tubing provides an advantage over coiled tubing due to its lighter weight, smaller footprint, mobile structure, faster running speeds, and more economical costs. One drawback however, is the increased friction pressures when pumping abrasive fluids. Typical capillary tubing is sized from ¼ to ¾ in. OD versus the more common coiled tubing, which ranges from 1 to 3 ½ in. OD. Therefore, the use of capillary tubing for cementing operations has not been considered until recently.

Aims & Research Methods: This paper will feature a project in Australia where a capillary unit was employed to abandon a well with cement, while concurrently installing down hole pressure gauges to comply with local regulations. The cement design criteria along with two case histories will be described, and lessons learned will be evaluated.

Data that has been collected through the various jobs will demonstrate that current simulation software will need to be modified to match pressure outputs witnessed in the field. A comparison of simulated versus actual job pressure data has shown as much as a 70% friction reduction in actual pressure readings. The witnessed pressure values are shown to be consistent over several operations; therefore a theoretical correlation can be drawn so more realistic values can be simulated in the future. Additionally, slurry designs which were proven successful and operational considerations for improved job quality will be discussed.

This paper will discuss two case histories in which capillary tubing was used for the first time in Australia. Methodology, limitations, and future improvement possibilities will be discussed in detail throughout this paper.

Citation: Amit D. Nakhwa and Ken Huggins, Halliburton, Ronald Sweatman, Consultant, ‘New Technologies in Fracturing for Shale Gas Wells are Addressing Environmental Issues’

(Paper presented at 18th Middle East Oil & Gas Show and Conference (MEOS), Mar 10 - 13, 2013 2013, Manama, Bahrain, Bahrain International Exhibition Centre)

Topic Area: Environmental Issues

Jurisdiction: USA

Abstract: To further address these environmental issues, members of Oil & Gas (O&G) industry associations, including the American Petroleum Institute (API), Society of Petroleum Engineers (SPE), International Association of Drilling Contractors (IADC) and the International Association of Oil & Gas Producers (OGP) based in London and Brussels, continue to develop sound science and field-proven best practices in the form of industry standards, such as those referenced in this paper.

Technical publications by O&G service companies have provided numerous case histories highlighting these applicable technologies. These presented technologies and practices have helped to demonstrate the positive impacts for shale gas development projects.

Aims & Research Methods: This paper discusses how applied science, historically safe operations, advancements in technology and standard processes are helping to address and reduce environmental issues (EI) for hydraulic fracturing in shale gas wells. The technologies presented include equipment footprints allowing for a reduced risk for environmental effects, 3D fracture mapping, microseismic fracture mapping, "green" fracturing fluids, bacteria control through UV light technology and an improved method of water recycling. This combination of scientifically-derived technologies and best practices (a.k.a standards) is assisting in lowering the risk for EI and addressing misconceptions about hydraulic fracturing.

Citation: Deborah Shields, Colorado State University and Politecnico di Torino, Francesca Verga, SPE, and Gian Andrea Blengini, Politecnico di Torino, 'Sustainability Versus Sustainable Development: The Case of Shale Gas' (Paper presented at 75th EAGE Conference & Exhibition incorporating SPE EUROPEC , London, United Kingdom, June 10 - 13, 2013 2013)

Topic Area: Sustainability/Social Responsibility

Jurisdiction: Global

Abstract: The term sustainability is applied to energy resources in multiple ways. One thread of discourse focuses on the sustainability of oil and gas production, the need for exploration, and the consequences of resource depletion. It is widely believed that conventional oil and gas production have already or will peak in the foreseeable future, and will then enter a long term decline. Maggio and Cacciola (2012) predict that conventional oil will peak between 2009 and 2021 and conventional natural gas between 2024 and 2046. They also suggest that coal will peak between 2042 and 2062. The exact peak dates are less important than is the reality of eventual depletion because energy is essential for virtually every sector of every economy. Much of that needed energy is currently generated by burning fossil fuels. Given that alternative energy technologies, such as nuclear and renewables, will be unable to fully meet society's needs in the short to medium terms, concerns about the availability of oil, gas, and coal are wholly appropriate.

Fortunately, we will not run out of fossil fuels soon; due to scientific and technological advances, extraction of unconventional forms of oil and gas are now feasible. Conventional oil and gas deposits consist of porous reservoirs in geologic formations, capped by an impervious rock 'trap' within which migrating fluids such as oil, natural gas and water accumulate. The distribution of oil or natural gas throughout a geologic formation over a wide area, but not in a dicrete reservoir, is called an unconventional deposit (Whitney, et al. 2010). These resources, which include oil sands, oil shale, coal bed methane, and shale gas, may be very large, but their recovery is complex and often expensive. In this paper we focus on shale gas, an unconventional deposit type in which natural gas is distributed throughout low-permeability shale formations. Gas occurrences of this type require special production techniques that often involve horizontal drilling into the gas-bearing formation, followed by hydraulic fracturing of the rock to release the gas from the rock.

Aims & Research Methods: There is an ongoing dialogue in society about the place of energy resources in sustainability. One aspect of that discussion focuses on resource sustainability, the ability of governments and industry to ensure continued supply of needed resources. A related topic centres on the economic benefits and costs of fossil fuel production. Concerns about negative impacts on environmental social sustainability drive other parts of this conversation, and often lead to opposition to fossil fuel production and use. This paper uses the example of shale gas to argue that concentration on single sustainability aspects is inappropriate. Rather, development and production of these resources needs to be considered in the context of sustainable development, which necessitates integrating environmental and development strategies so as to satisfy current and future human needs. Integrated Sustainability Assessment (ISA) is proposed as a way to analyse the net contributions of a shale gas play to economic, environmental, social and resource sustainability. The latter topic is considered and variables that could be used in an ISA are proposed. Understanding, quantifying and communicating the nature and magnitude of the net contribution of shale gas to society will be a challenging, but essential, task in the process of responding to opposition in an open and constructive manner, one which ISAs can support.

Citation: Michael D. Max, Arthur H. Johnson, Hydrate Energy International, 'Natural Gas Hydrate (NGH) Arctic Ocean Potential Prospects and Resource Base' (Paper presented at OTC Artic Technology Conference, Houston, Texas, USA, 3-5 December 2012)

Topic Area: Gas Production in the Artic

Jurisdiction: Artic

Abstract: The compact Arctic Ocean region is the last major hydrocarbon frontier area in the Northern Hemisphere and may possibly be the single richest natural gas hydrate (NGH) province on Earth. Because of the extreme weathering and erosion conditions associated with the alternating glacial and interglacial conditions, much of the sediment in accessible gas hydrate stability zones (GHSZ) may have the same well bed-differentiated, coarse grained character of excellent NGH reservoir hosts. These reservoirs are of the same type that may host conventional hydrocarbon deposits in more deeply buried sediments. Existing industry exploration techniques have been used to identify potential NGH drilling targets, and drilling in the northern Gulf of Mexico has validated the exploration technique. The Nankai deposits off SE Japan and the deposits drilled in the northern Gulf of Mexico are excellent examples of the sand-turbidite continental margin paratype. It is estimated from examples and application of NGH petroleum system analysis that over 6,000 Tcf of natural gas in place may be present in NGH-enriched deepwater turbidite sands within deep continental shelf and slope sediments of the Arctic Ocean. In addition to deepwater turbidites, which are well known from other continental margin areas, such as the Gulf of Mexico, two other prospective zones may exist in the Arctic Ocean. Troughs, which are glacially excavated depressions that generally deepen toward the shelf margins, may host NGH in sediments that are transitional between the deepwater turbidites and continental shelf sedimentation. Concentrations of NGH may also be accessible from isolated outliers, which are upstanding continental crust fragments that are present within the Amerasia and Eurasia Basins.

Citation: M. Baker, SPE, S. Mazumder, SPE, and H. Sharma, SPE, J.A. Philpot, SPE, M. Scott, SPE, and R. Wittemeier, SPE, Arrow Energy, 'Well Design and Well Spacing Optimisation in Unconventional Plays' (Paper presented at SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 22-24 October 2012)

Topic Area: Evaluation of Uncertainties

Jurisdiction: Global

Abstract: Coalbed methane (CBM) is an unconventional gas resource, different from conventional gas reservoirs due to its physical gas storage mechanism and its complex characteristics. Coal is typically described as two systems: the matrix rock and the cleats (natural fractures providing secondary porosity and a fluid transport path). In coal, the majority of the gas is stored within the coal matrix via physical adsorption, with a small percentage existing as free gas within the cleats. Due to this physical storage mechanism, the gas must be desorbed from the rock by reducing the pressure through the removal of water prior to gas production. This mechanism results in a unique three stage production profile for CBM wells: an initial 'dewatering' period of high water production and increasing gas rate; a point of peak gas production; and a more conventional gas rate decline with low water production.

CBM reservoirs often extend over large geographical areas, with significant changes in depth and reservoir quality due to the inherent heterogeneity of the coal. As such, early development planning with a low density of subsurface data presents unique challenges.

Aims & Research Methods: The risk profile for an unconventional resource play differs from a conventional opportunity in that the reducibility, per well Estimated Ultimate Recovery (EUR) and Unit Technical Cost (UTC) are more important for identifying potential success than proving the presence of in-place volumes.

Unconventional plays are often characterised by a large number of wells, lower density of subsurface data, large geographical extent and corresponding large range of uncertainty in subsurface parameters. The rapid economic screening of well design and spacing parameters for multiple subsurface realisations is integral in the planning stages of large unconventional plays. An additional complexity is the use of horizontal or complex geometry well designs which may limit or complicate the application of full field reservoir simulation methods.

Recoverable volumes are strongly dependent on the proposed well design and spacing. These should be systematically evaluated and optimised by identifying the well density beyond which the incremental recovery and commerciality benefit begins to erode due to the extra well costs and/or interference between wells.

A method for efficient analysis and comparison of complex well design and well spacing options has been designed to assist in unconventional play planning and evaluation. The method involves the automatic generation and analysis of a large number (thousands) of dynamic reservoir simulation models. The models are analysed systematically for major value drivers to: identify the most efficient well design and optimal spacing factors; select the most economic well designs; assess the impact of subsurface uncertainties; and assist in rig selection and surface planning.

Citation: Dirk Nuyens, SPE, Walter Heinz, SPE, & Dieter Hiller, SPE, Environmental Resources Management, 'License To Operate: Nontechnical Risks and Shale Gas Development in Europe' (Paper presented at SPE Hydrocarbon Economics and Evaluation Symposium, Calgary, Alberta, Canada, 24-25 September 2012)

Topic Area: Reservoir Description and Dynamics

Jurisdiction: EU

Abstract: Initial experience in Europe has shown that the non-technical challenges have initially been underestimated, and that huge efforts are necessary to gain public acceptance and political support. A lot of efforts have already been put on stakeholder engagement, public information on technical processes, disclosure of chemicals and initial promotion campaigns, but the acceptance in most parts of Europe – Poland being the only exception - remains challenging. Besides technical and regulatory requirements, obtaining a "social license to operate" is thus of increasing importance for the success of a project.

Aims & Research Methods: This paper discusses how non-technical risks are impacting shale gas developments in Europe and how challenging it is to obtain the Social License to Operate. Although still at the early exploration phase, most European developments are already significantly hit by stakeholder concerns, lack of public acceptance and often lack of government support. Some European countries have even halted early exploration – at least temporarily - by political decision. Most of the public concerns are of environmental nature, especially linked to the use of chemical additives in the hydraulic fracturing process and related concerns about potential groundwater impacts, but hardly any is based on real events in Europe. Most concerns have developed on the back of perception and experiences in the US. This paper also takes a critical look at the discrepancy between public environmental concerns and real environmental risks.

Citation: Geert M. van der Kraan, The Dow Chemical Company, Philip A. Keene, The Dow Chemical Company, Malcolm James, The Dow Chemical Company, Bei Yin, The Dow Chemical Company, Terry M. Williams, The Dow Chemical Company, Otto P.J. van Ruiten, The Dow Chemical Company Donald J. Love, The Dow Chemical Company, 'Water Management and Microbial Control Programs in the Exploitation of Unconventional Hydrocarbons' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Produced Water Use, Discharge and Disposal, Chemical Treatments, Standards, Regulations and Codes and H2S Management

Jurisdiction: Global

Abstract:

Worldwide, the production of natural gas and now oil from shale basins (source rock) has been embraced as a commercially viable way of producing unconventional energy resources leading to a revolution in gas production in the US. Developments to invest in and tap into this alternative way of gas production are taking off in Europe and Asia. Hydraulic fracturing is a proven technology, used for many years to develop hydrocarbon resources. Successful strategies with hydraulic fracturing include the safe and effective use of chemical additives, proper well casing and robust water management programs. During the exploitation of hydrocarbons from shales, chemical additives such as corrosion inhibitors, gelling agents, biocides etc., have to be used in the fracturing of wells. Sustainable chemistries and effective product stewardship programs are required to minimize environmental and human exposure hazards. The addition of water with organic molecules to the actual fractured wells makes these environments subject to unwanted growth of microorganisms and biofilm development, which has detrimental effects on hydrocarbon flow and leads to pipeline/equipment corrosion. Often the presence of sulphate reducing microorganisms leads to unwanted H2S production and subsequently souring. Due to this, water cycle management and properly designed microbial control programs for all water sources including injected water or produced water, are required. Because the microbial challenges and environmental parameters of these water sources vary, different microbial control strategies and treatments are required for each source.

Aims & Research Methods: New formulations of biocides and control programs aimed at the needs of the gas and oil industry have been developed, e.g. improved heat stability and the reduction in biocide levels to achieve the same level of microbial control. These newly developed microbial control technologies will be presented in this paper, and the related regulatory and product stewardship support will be shortly addressed.

Citation: O. Hausberger, SPE, L. A. Högn, SPE, K. Soliman, SPE, Mining University of Leoben, 'Management Decision Matrix for Shale Gas Projects in Europe' (Paper presented at SPE Hydrocarbon Economics and Evaluation Symposium, Calgary, Alberta, Canada, 24-25 September 2012)

Topic Area: Strategic Planning and Management and Social Responsibility

Jurisdiction: Global

Abstract: The world energy demand is increasing gradually and E&P companies are forced to increase their resources. In the last few years a worldwide increase in shale gas projects could be recognized, especially in the US. This hype of shale gas is coming over to Europe. The situation in Europe is mainly different than that in the US. Consequential an adaptation of the project management has to be done, to fit into the European requirements.

To achieve a general overview on shale gas projects, an understanding of the relevant techniques and geological issues need to be established. The authors intend to highlight the difference in project management between conventional and unconventional projects, particularly for shale gas projects. Furthermore the difference of social, ecological, technical and economic issues is presented in the 3D matrix. The developed matrix acts as a decision tool for the project management level and should help to implement the shale gas project in a more sustainable way. To guaranty the transformation of the three columns of sustainability the matrix covers the main tasks of an E&P project for the particular project phase. The matrix should act as an impulse for discussions in the E&P business. It is important to notice that this matrix is based on interviews with University Professors as well as engineers from different petroleum companies in Europe, which are currently realizing shale gas projects.

Aims & Research Methods: On the today's global market it is an important issue to have an adapted management system, due to the fast change of beliefs in social communities and politics. In the last few years a significant change in E&P business could be recognized from conventional sources to unconventional ones. With this extensive change the degree of resistance and possible problems for E&P companies increase, especially in Europe.

To realize an unconventional project in Europe, like shale gas, it is very important to adjust the project management to the given situation. There is a lot of resistance and fear from the population in Europe against shale gas projects, which is somehow unfounded.

To maintain a high acceptance of the communities and governments, the emphasis lies on the adaption of this operation.

The projects have to be operated in a more sustainable way. Observation of economic and technical issues is important, but the management has to look further beyond. To account for the overall sustainability, two further levels have to be considered, especially in shale gas projects. Ecological and social aspects for unconventional projects have to be introduced and interconnected in a higher degree compared to conventional projects in the oil and gas industry.

This paper introduces a 3D matrix, where the three major points of sustainability are imbedded into a workflow chart of a shale gas project. The matrix should act as a sort of subsidiary to the management of a shale gas project in Europe.

Citation: Roberto F. Aguilera and Ronald D. Ripple, Centre for Research in Energy and Mineral Economics (CREME), Curtin University; Roberto Aguilera, Schulich School of Engineering, University of Calgary, 'Link between Rocks, Hydraulic Fracturing, Economics, Environment, and the Global Gas Portfolio' (Paper presented at SPE Canadian Unconventional Resources Conference, Calgary, Alberta, Canada, 30 October-1 November 2012)

Topic Area: Economic Analysis Guidelines

Jurisdiction: Global

Abstract: Figure 1 is a pentagon showing the link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio. Our view is that there must be an equilibrium in the pentagon to provide a win-win situation for society at large. All corners in the pentagon are interrelated and there is no need to sacrifice one for benefit another. It has been shown that there is a significant gas endowment in conventional reservoirs. However, we have to also unlock natural gas stored in unconventional formations to ensure that gas plays an important role in satisfying future energy consumption. We cannot produce it economically without hydraulically fracturing the unconventional formations. At the same time, we cannot sacrifice the environment solely for economic gain and nothing but the highest environmental standards are acceptable. All stakeholders must act responsibly to generate the win-win situations.

Aims & Research Methods: This paper presents a methodology for connecting geology, hydraulic fracturing, economics, environment and the global natural gas endowment in conventional, tight, shale and coal bed methane (CBM) reservoirs. The volumetric estimates are generated by a variable shape distribution model (VSD). The VSD has been shown in the past to be useful for the evaluation of conventional and tight gas reservoirs. However, this is the first paper in which the method is used to also include shale gas and CBM formations.. Results indicate a total gas endowment of 70000 tcf, split between 15000 tcf in conventional reservoirs, 15000 tcf in tight gas, 30000 tcf in shale gas and 10000 tcf in CBM reservoirs. Thus, natural gas formations have potential to provide a significant contribution to global energy demand estimated at approximately 790 quads by 2035.

A common thread between unconventional formations is that nearly all of them must be hydraulically fractured to attain commercial production. A significant volume of data indicates that the probabilities of hydraulic fracturing (fracking) fluids and/or methane contaminating ground water through the hydraulically-created fractures are very low. Since fracking has also raised questions about the economic viability of producing unconventional gas in some parts of the world, supply cost curves are estimated in this paper for the global gas portfolio. The curves show that, in some cases, the costs of producing gas from unconventional reservoirs are comparable to those of conventional gas. The conclusion is that there is enough natural gas to supply the energy market for nearly 400 years at current rates of consumption and 110 years with a growth rate in production of 2% per year. With appropriate regulation, this may be done safely, commercially, and in a manner that is more benign to the environment as compared with other fossil fuels.

Citation: George E. King, Apache Corporation, 'Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 6-8 February 2012)

Topic Area: Production and Operations, Hydraulic Fracturing and Gravel Packing, Wellbore Design/Construction, Risk Management and Decision-Making and Chemical Tracers

Jurisdiction: USA

Abstract: Identification of risk, the potential for occurrence of an event and impact of that event, is the first step in improving a process by ranking risk elements and controlling potential harm from occurrence of a detrimental event. Hydraulic Fracturing has become a hot environmental discussion topic and a target of media articles and University studies

during development of gas shales near populated areas. The furor over fracturing and frac waste disposal was largely driven by lack of chemical disclosure and the pre-2008 laws of some states. The spectacular increase in North American natural gas reserves created by shale gas development makes shale gas a disruptive technology, threatening profitability and continued development of other energy sources. Introduction of such a disruptive force as shale gas will invariably draw resistance, both monetary and political, to attack the disruptive source, or its enabler; hydraulic fracturing. Some “anti-frack” charges in media articles and university studies are based in fact and require a state-by-state focused improvement of well design specific for geology of the area and oversight of overall well development. Other articles have demonstrated either a severe misunderstanding or an intentional misstatement of well development processes, apparently to attack the disruptive source.

Aims & Research Methods: Transparency requires cooperation from all sides in the debate. To enable more transparency on the oil and gas side, both to assist in the understanding of oil and gas activities and to set a foundation for rational discussion of fracturing risks, a detailed explanation of well development activities is offered in this paper, from well construction to production, written at a level of general public understanding, along with an initial estimation of frac risk and alternatives to reduce the risk, documented by literature and case histories. This discussion is a starting point for the well development descriptions and risk evaluation discussions, not an ending point.

Citation: L. M. Smith and G. Lunt, Intetech Ltd., ‘Case Histories of Life Cycle Well Integrity Management Using iWIT Software’ (Paper presented at SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 22-24 October 2012)

Topic Area: Knowledge Management, Operations Management, Data Integration, Monitoring and Control

Jurisdiction: Global

Abstract: The Intetech Well Integrity Toolkit (iWIT) is a web-based program which provides a comprehensive approach to well integrity management covering all potential integrity threats to the whole well. Using its own or existing client databases, this software carries out quantitative data analysis in real-time and provides feedback to the operator about the condition of individual wells and also overviews of the whole field integrity status to support timely, informed, decision-making.

Case histories are described of seven different operations introducing the software. The diverse reasons for introducing the software and the direct and indirect benefits ensuing are described. Each is a unique story, highlighting how flexible and comprehensive this successful software product has been. A common element is the management of data spread across multiple 3rd party data systems which have been successfully integrated in each case, sometimes utilizing data entered in tablet PCs in the field directly linked to iWIT. More challenging is the vast range of data analysis and presentation which has been customized for each client to achieve their goal. This includes risk evaluation against complex criteria, determination of tubing condition based upon varying production conditions, calculating MAASP values per well per annulus, managing and generating well handover documentation from the software, tracking scaling issues, determining mean time to failure of equipment to establish risk-based inspection frequencies and many more detailed analyses.

The iWIT software has allowed these operators to prove their adherence to Well Integrity Management policies and provides numerous report formats including email alerts for engineers and managers. By ensuring well problems are proactively identified and responded to within guideline timeframes the software ensures that well integrity related shut-downs are reduced, thus providing improved productivity from the well stock and at the same time raising safety within the operations.

Aims & Research Methods: Key Benefits of the iWIT Software Identified from Case Histories

1) Reduction in number of wells shut in for well integrity reasons by about 80% over two years resulting in higher productivity and major cost saving.

2) Clear indication of wells' integrity status customised to meet company philosophy and local regulatory requirements.

3) Maximising value of all data about the well by making it available to all users in the company.

4) Integration of data from multiple sources by interfacing to existing 3rd party databases.

5) Real-time evaluation of environmental conditions which could result in failure of tubing in wells with variable production conditions.

6) Common system suitable for managing both brand-new field and mature field with aging wells.

7) Continuously updated risk status of all wells as data updates are made in real time.

8) Comprehensive scope capable of handling every type of data relevant to well integrity status; one-system covers all.

9) Common standards systematically applied throughout the company raising confidence in decision-making.

10) Reduction in data-gathering effort and report preparation by engineers, freeing them to carry out more detailed evaluation of work over options to resolve well issues; better utilization of skilled personnel.

Citation: Nicolas Strauss, Buenos Aires Technological Institute (ITBA), 'The Role of the Oil and Gas Industry in the Transition Toward a Sustainable World' (Paper presented at S PETT 2012 Energy Conference and Exhibition, Port-of-Spain, Trinidad, 11-13 June 201)

Topic Area: Onshore Projects Planning and Execution, Fundamental Research in HSE, Primary and Enhanced Recovery Processes, Intelligent Completions and Platforms and Floating Systems

Jurisdiction: EU

Abstract: Einar Steensnaes, Minister for Petroleum and Energy of Norway, said during a speech given at the 2002 World Summit on Sustainable Development and speaking about the Petroleum Industry's perspectives for the future that "Increasingly, good ethics is good business". This simple and brief statement might be one of the clearest and most accurate ways of perceiving where the Energy Industry stands today and how it is preparing to face the challenges that the decades to come will bring. Today, the energy playing field is changing. Technology is advancing at the most vertiginous rate in history and it is only likely to accelerate. Energy has become an integral and fundamental part of human modern society and, most probably, man-kind's dependence and demand of energy will dramatically increase throughout this century. So, how will the Energy Indus-try overcome the complex challenges that ensuring energy security for such a fast moving world mean? The answer is right there: with good ethics.

Aims & Research Methods: Throughout the decades to come world's population is expected to rise as well as the energetic, food and water demand. All that, together with the everyday more rigid international environmental regulations alongside with the ongoing vertiginous technological advancement, will induce to a restructuration of global economy on the inter-governmental and institutional level in order to reinforce the fundamental pillars of sustainability: the environmental, social and economical. New energy systems will be implemented and scarcity of resources will be more severe, leading the economy not only to shift but to adapt to unconventional energy carriers and commodities. This combined with the targeted impact of these policies, concerning living standard improvements, social inclusion and carbon mitigation among others, will raise new and demanding challenges to face. This paper intends to present an overview of the energetic playing field throughout the transition towards a more sustainable world and the role of the Oil & Gas industry within this period. This article will identify and explain the challenges and constraints to be faced as well as the opportunities of undertaking ventures in this shifting environment. Also, the paper will broaden the concept of Green Economy, main theme of the 2012 UN's Conference on Sustainable Development, and present strategies to develop an energy system to function and sustainably endure in time within the mentioned framework and ex-plain why the O&G industry is a fundamental participant and a major "game changer" in this process. Petroleum holds a key role in this transition as being the most widespread energy carrier and the most competitive element of the current energy system. Therefore, the O&G industry has the opportunity to become the main "driver of change" and to impulse a more prosper and sustainable energy network for the world. It’s imperative that the O&G sector keeps a long-term perspective in order to remain in force and profitable. This paper pro-poses some guidelines to do so and intends to raise awareness on the fact that sustainability is not only changing the way we analyse a project but moreover the way we do business in the O&G industry.

Citation: Christopher Burns (Gaffney, Cline & Associates), Adrian Topham SPE (Baker Hughes), Ramin Lakani SPE (Gaffney, Cline & Associates), ‘The Challenges of Shale Gas Exploration and Appraisal in Europe and North Africa’ (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria

20-22 March 2012)

Topic Area: Reservoir Description and Dynamics, Exploration, Development, Structural Geology, Petrology and Well Logging

Jurisdiction: EU

Abstract: The shale gas revolution on North America has created an incentive for the rest of the world to chase this challenging hydrocarbon resource. Currently around 44% of the 20.6 tcf annual gas production in the US occurs from unconventional resources, with this forecast to rise to 65% by 2020. The pitfalls and challenges faced by North American development projects provide a wealth of experience, which can be used to understand how we can apply technology more effectively in Europe and North Africa. However, there are differences in both operating environments and gas markets between North America and Europe and North Africa, and we aim to highlight these differences as well as the similarities. Unconventional oil and gas projects in Europe and North Africa are currently at an early stage of their life cycle, exploration and appraisal.

Aims & Research Methods: We identify the following key challenges for the European region:

• The potential spread of the North American unconventional gas revolution to Europe and North Africa could create competition and depress gas prices. Reduced gas prices and increased costs will considerably reduce the margin for error in exploring for unconventional gas. Therefore there is a need to apply technology effectively, to avoid having to learn “by the drill bit”.

• A lack of infrastructure and specialised equipment, particularly in North Africa, leading to a higher cost base for developing the region’s unconventional resources.

• The regulatory environment in Europe is not presently conducive to development of shale gas resources together with the negative public perception of the environmental risk associated with shale gas development.

Aside from these medium to long term challenges, Europe at present is facing a more critical short term challenge: the need to prove the concept by completing and producing the first economic shale gas wells.

Citation: Piers Touzel, SPE, Environmental Resources Management, ‘Managing Environmental and Social Risks in China’ (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Sustainability/Social Responsibility

Jurisdiction: China

Abstract: China has the largest reserves of unconventional gas in the world. Led by Chinese National Oil Companies (NOCs), and with participation from International Oil Companies (IOCs), exploration and appraisal activities for unconventional gas, in particular shale gas, have ramped up significantly since 2009. Eager to exploit domestic gas reserves and reduce its reliance on imports, the Chinese Government has implemented policies to support the industry and has announced ambitious plans for the development of the country’s shale gas reserves to 6.5 billion cubic meters (bcm) per annum by 2015, rising to 60-100 bcm by 2020.

China's unconventional gas reserves are concentrated in four areas: the Ordos Basin on China's northern plain, the Tarim and Junggar Basins in western Xinjiang and the densely populated Sichuan Basin in the south. Each of these areas faces significant environmental and social constraints, including availability of water for hydraulic fracturing and its subsequent disposal, land access and resettlement, and community relations (including those with indigenous peoples in some areas).

While China has adopted policies to support the development of unconventional gas resources, technical and administrative standards are yet to be released. Outside of the oil and gas companies and their service providers, there is little understanding of the potential environmental and social impacts associated with unconventional gas development.

Chinese officials are concerned with maintaining social stability in rural farming communities and are keenly aware that environmental issues are today a leading cause of community protests. Sensitive to issues that may affect farmland or the groundwater required to sustain the livelihoods of China's rural residents (and the potential for ensuing social unrest) Chinese regulators are beginning to scrutinize more closely activities associated with the exploration and development of unconventional resources. Similarly, local communities are concerned about the environmental impacts from exploration and development activities and are becoming more vocal in their demands that they too are beneficiaries of upstream activities.

Aims & Research Methods: Demonstrating to regulators and to the community that unconventional resources can be developed in an environmentally and socially responsible manner will be critical to the future success of the industry. The paper concludes that the current round of exploration, appraisal and pilot testing activities being undertaken for unconventional gas in China represents a window of opportunity for this to be demonstrated at a small scale prior to scaling up future field developments.

Citation: Harold D. Brannon, Daniel J. Daulton, Matthew A. Post, Harold G. Hudson, and Andrew K. Jordan, Baker Hughes, 'The Quest to Exclusive Use of Environmentally Responsible Fracturing Products and Systems' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 6-8 February 2012)

Topic Area: Hydraulic Fracturing and Gravel Packing

Jurisdiction: USA

Abstract: Hydraulic fracturing processes have recently been the subject of increasing scrutiny with particular concern directed towards protection of water resources. Operators and fracturing services companies in the United States have been targeted by both federal and state legislators and the EPA with audits, inquiries, and regulations requiring disclosure of the chemicals pumped in fracturing treatments and banning the use of certain chemistries, such as diesel oil. Much effort has been expended to identify alternative, more environmentally acceptable products which maintain the needed material performance characteristics and cost basis.

Aims & Research Methods: A new quantitative process based upon the Globally Harmonized System for Classification and Labelling of Chemicals (GHS) has been employed to evaluate and rank the hazards posed by various treating fluid additives and potential alternatives. The GHS is a process is which has been adopted by the United Nations to standardize information regarding the hazards and toxicities of chemicals. Once the respective material hazards have been quantified, they may be ranked for comparison with like purposed additives for their anticipated safety, health, and environmental impact. The best candidates by that measure may then be assessed for performance and cost. The process has become a valuable tool to guide fracturing R&D and oilfield chemical suppliers toward development of more environmentally acceptable products and systems. The progress towards the objective of full implementation of environmentally acceptable chemistries in fracturing applications is documented. Working examples of the more acceptable chemical additive selections resulting from the applications of the hazard assessment process are provided. Furthermore, the migration to more environmentally responsible fracturing processes through quantification of hazardous risk "removed" from applications by replacement with more favourable alternatives is discussed. The fruits of the process will be discussed in this endeavour, providing working examples of the chemical additive selection. Furthermore, the progress to more environmentally responsible fracturing processes through quantification of hazardous risk 'removed' from applications, i.e. amount of hazardous material removed by replacement with more favourable alternatives

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Citation: Melvyn R. Giles, Daniel Nevin, Bud Johnston and Mark Hollanders, Shell Exploration and Production Company, 'Understanding Volumes, Economics and Risk Mitigation in Unconventional Gas Projects' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Management and Information

Jurisdiction: Global

Aims & Research Methods: A great deal has been written on the volumes of unconventional gas trapped in the subsurface, this paper examines:

1) The relationship between the huge GIIP volumes, technically recoverable volumes and economically recoverable volumes

2) The barriers to achieving economically viable projects

3) Lifecycle and drivers for creating economically viable projects

4) The use of decline curves to estimate the productivity and the pitfalls associated with their use
5) Strategies for mitigation of economic risk in taking an exploration project through to development

New unconventional gas projects all come with considerable uncertainties and therefore risk, but careful de-risking strategies enable companies to steer their way toward clear go/no go decisions at multiple points in the lifecycle enabling them to progress with minimum exposure.

Citation: Timothy P. Daigle, SPE, Savanna N. Hantz, Brian Phillips, Rafique Janjua, Fluor Offshore Solutions, 'Treating and Releasing Produced Water at the Ultra Deepwater Seabed' (Paper presented at Offshore Technology Conference, Houston, Texas, USA, 30 April-3 May 2012)

Topic Area: Subsea Processing, Subsea Production Equipment, Flow Assurance in Subsea Systems, Separation and Treating and Produced Water Use, Discharge and Disposal

Jurisdiction: Global

Abstract: Tomorrow's energy needs are driving the Oil and Gas Industry to achieve 'No oil left behind'. This comes at a cost as the pressures in remote deepwater reservoir pockets are depleted and the water cuts increases. Existing technology is evolving to meet the challenges to automate water separation and purification in deepwater for environmentally safe discharge at the seabed. To solve the problems the objectives must be defined; the best available solutions must be selected and the technology gaps must be identified and closed. Environmental protection is a priority and the translation of the existing Statutory Regulations to include the requirements to be met by discharged water quality is the starting point. Safety and Reliability will follow along with the flexibility to tailor the system to match the reservoir's changing needs and incorporate the best, new and fast developing technology. Equipment relocation may also prove commercially attractive. Major challenges will be remote process train control and monitoring and the ability to perform routine maintenance while the wells still flow. Some of this technology could have immediate benefits to surface processes that would in turn provide ideal proving grounds before the technology ventures into deepwater.

Aims & Research Methods: This paper explains the challenges facing the subsea processing technologies to be able to handle and treat produced water at the seabed between 5,000 and 8,000 feet of water depth. It will discuss the regulatory standards used throughout the industry today to oversee produced water treatment. The paper will look at the marine life in this ultra deepwater environment at the seabed conditions. It will review the latest produced water treatment technologies used throughout the topside offshore production industry. The paper will illustrate various concepts to perform subsea produced water treatment and look at the many challenges and gaps to be addressed, to make this technology viable and effective.

The paper will identify the gaps and challenges to applying produced water treatment and discharge at the seabed in ultra deepwater environments. Research and compiled information will be presented to support the concepts proposed to meet the challenges of produced water treatment and discharge at the seabed in an ultra deepwater production system.

Seabed discharge of produced water and/or solids can provide many benefits, but this paper has been created with the focus on the three main benefits:

1.) Eliminate the need to transport huge volumes of water from deep water production sites to the tieback hosts which may be many miles away. Therefore, significantly reducing the production system costs.

2.) Decreasing the hydrostatic pressure on the subsea production flow lines will help reduce the back pressure on the subsea wellhead and ultimately allow for more subsea production from the reservoirs.

3.) Installations of Subsea Produced Water Handling systems will minimize the topside equipment footprint and protect the equipment for being vulnerable to damaging tropical hurricanes and harsh weather systems.

Citation: Mark A. Miller, SPE, Cuadrilla Resources Ltd., Eric Vaughan, SPE, Cuadrilla Resources Ltd., 'European Shale Gas, Getting Buy-in From The Public and Stakeholders' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Management and Information

Jurisdiction: EU

Abstract: Obtaining public acceptance for a European shale gas program requires that we address a wide variety of issues and public concerns. Topping the list of concerns are potential for chemical contamination of aquifers, natural gas migration to shallow water wells, and small earthquakes induced during hydraulic fracturing operations. Additional concerns include disposal of post-frac flow back fluids, large consumption of fresh water resources during the hydraulic fracturing process, excessive road traffic during the drilling and completion phases, industrial noise, and property devaluation.

In the UK, these concerns were largely escalated when shale gas opponents launched the movie, "GasLand", in early 2011. Since then, getting buy-in from the stakeholders and public requires tackling a number of complex issues and questions. But the complexity can be managed if the issues are broadly grouped into the following three simple questions that are in the minds of the public.

• Can we trust them? (the other oil/gas company)

• Is it safe? (with regard to the operations and technologies to be used)

• What's in it for us? (both at the personal and community levels)

Understanding how to wrap the list of public concerns into one of these simple questions is the beginning of a successful public relations program, which ultimately results in public acceptance for the shale gas program. The discussions here focus specifically on shale gas, firstly because that's what Cuadrilla is currently working on, and secondly, because of the worldwide attention that shale gas programs are receiving. Additionally while we will be working in more than one European country, we are focusing our discussions primarily on UK examples, as that is where we have developed a work history. Many of the discussions and recommendations given in this paper are applicable to any oil and gas exploration or development program, regardless of the reservoir type, or location in Europe or elsewhere in the world.

Aims & Research Methods: During the past 10 years shale gas development projects have proven to be highly successful in a number of North American basins, and have become a game changer for the energy supply there. Because of these successes, shale gas exploration and development technologies are being deployed around the globe, including Europe. But while there appears to be vast shale gas resources across Europe, many industry analysts express concerns about the probability of repeating the North American successes in Europe. These concerns are based on the denser population in Europe, different safety and environmental regulations, and the doubts of many European residents about the overall safety of shale gas development. Moreover, unlike North America where landowners often are entitled to significant lease payments and royalties for their mineral rights, the mineral rights throughout most of Europe are owned by the governments, rather than the landowners. The combination of these factors adds to the difficulty of building public support for a shale gas program.

This paper provides a discussion of a shale gas exploration program currently being conducted by Cuadrilla Resources in England. It examines the concerns of the local residents, and how these have affected media coverage, and support (or opposition) from politicians. It discusses the strategy and approach used by Cuadrilla for addressing questions and concerns from the local residents, various UK regulatory bodies, politicians and the media. While this paper focuses on a UK shale gas case, the conclusions and recommendations are applicable to any shale gas program in Europe or elsewhere.

Citation: Robert L. Kennedy, SPE, William N. Knecht, SPE, and Daniel T. Georgi, SPE, Baker Hughes, 'Comparisons and Contrasts of Shale Gas and Tight Gas Developments, North American Experience and Trends' (Paper presented at SPE Saudi Arabia Section Technical Symposium and Exhibition, Al-Khobar, Saudi Arabia, 8-11 April 2012)

Topic Area: Shale Gas and Tight Gas Developments

Jurisdiction: USA

Abstract: Unconventional shale and tight gas development in the US was sparked by the 1980 introduction of The Alternative Fuel Production Credit of the Internal Revenue Code (an income tax credit). "The 1980 WPT (windfall profit tax) included a \$3.00 (in 1979 dollars) production tax credit to stimulate the supply of selected unconventional fuels: oil from shale or tar sands, gas produced from geo-pressurized brine, Devonian shale, tight formations, or coal bed methane, gas from biomass, and synthetic fuels from coal. In current dollars this credit, which is still in effect for certain types of fuels, was \$6.56 per barrel of liquid fuels and about \$1.16 per thousand cubic feet (mcf) of gas in 2004" (Lazzari 2006). Initially, the credit was set to run until 1989; however, it was extended twice until the end of 1992 (Martin and Eid 2011).

Higher gas price was another reason for the continued development of tight gas and especially shale gas. Figure 1 shows Henry Hub spot prices from 2000 until January of 2012. The "spot price" represents the price for natural gas sales contracted for next day or weekend delivery and transfer at a given trading location. Henry Hub is the primary trading location, centralized point, for natural gas trading in the United States, and is often a representative measure for wellhead prices. Higher prices are reflected by the six year (2003-2009) run of gas prices over \$6 per MMBtu after generally hovering around \$2 per MMBtu for the prior twenty-year period, 1980 to 2000. During this time, two significant peaks in gas prices occurred. In the summer of 2005, hurricanes along the U.S. Gulf Coast caused more than 800 billion cubic feet (Bcf) of natural gas production to be shut in between August 2005 and June 2006. As a result of these disruptions, natural gas spot prices at times exceeded \$15 per million Btu (MMBtu) in many spot market locations and fluctuated significantly over the subsequent months, reflecting the uncertainty over supplies (Mastrangelo 2007). In 2008, due to physical and financial market factors, spot prices broke from the \$6-\$8 per MMBtu

range of the two previous years and peaked at $13.32 per MMBtu, but ended the year at $5.63 per MMBtu

Aims & Research Methods: All Shale Gas reservoirs are not the same. There are no typical Tight Gas reservoirs. These two statements can be found numerous times in the literature on shale gas and tight gas reservoirs. The one common aspect of developing these unconventional resources is that wells in both must be 'hydraulically fractured' in order to produce commercial amounts of gas. Operator challenges and objectives to be accomplished during each phase of the Asset Life Cycle (Exploration, Appraisal, Development, Production, and Rejuvenation) of both shale gas and tight gas are similar. Drilling, well design, completion methods and hydraulic fracturing are somewhat similar; but formation evaluation, reservoir analysis, and some of the production techniques are quite different.

Much of the experience in shale and tight gas has been developed in the US and in Canada, to a lesser extent; and most of the technologies that have been developed by operators and service companies are transferable to other parts of the world. However, the infrastructure, including equipment and service company availability, governmental regulations, logistics, processing, environmental considerations, and pricing are not the same as in the US. This may impact the rate of the technology transfer as well as the selection of some of the technology. This paper is focused on operations challenges, technologies, and experience associated with shale and tight gas projects. It is likely that environmental concerns and the drive to reduce development costs of tight and shale gas reservoirs will drive new approaches to the development of these reservoirs in China, Latin America, Middle East, North Africa, and other parts of the world.

Citation: D Long, M Akhurst, British Geological Survey, 'The Role of Site Surveys In Carbon Capture And Storage' (Paper presented at Offshore Site Investigation and Geotechnics: Integrated Technologies - Present and Future, London, UK, September 12 - 14, 2012)

Topic Area: Site Surveys

Jurisdiction: EU

Abstract: It is a recognised concern that carbon dioxide (CO2) concentrations are increasing both in the atmosphere and the oceans, and that there are consequent adverse effects on the climate (Intergovernmental Panel on Climate Change (IPCC), 2007). The rising CO2 concentrations are raising global temperatures because of their greenhouse gas effect, as well as increasing acidity in the world's oceans. Targets for reducing national emissions of greenhouse gases to the atmosphere have been set by legislation within the UK by the *Climate Change Act* 2008 and the *Climate Change (Scotland) Act* 2009. Plans to achieve the targets include greater efficiency in the use of electricity, decreased electricity use and implementation of low-carbon technologies for power generation, such as generation of electricity from renewable resources (wind, wave, solar, nuclear powered and hydro-electrical generation schemes).

Aims & Research Methods: To constrain the increase in atmospheric carbon dioxide (CO2) concentrations, there is European and national drives to develop carbon capture and storage (CCS) schemes for the permanent geological storage of CO2 from industrial sources in deeply buried strata. Currently, offshore sites are considered preferable to geological store in strata onshore. Although the target storage reservoirs, saline aquifers or former hydrocarbon fields are often at depths of 1km or more, knowledge of the shallow area is important. This is not only for the positioning of infrastructure, wells, pipelines, etc., but also in the monitoring of any potential leakage from the reservoir over the site's lifetime, which may span 25–50 years. Baseline and repeat surveys are necessary and may need to cover a considerably wider area than the expected plume extent in the reservoir, depending on the predicted gas leakage pathways. Hence a complete geological model is required from the proposed reservoir at a depth that is up to and includes the seabed.

Citation: Juan C. Glorioso, Aquiles Rattia, Repso, 'Unconventional Reservoirs: Basic Petrophysical Concepts for Shale Gas' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Reservoir Description and Dynamics

Jurisdiction: Global

Abstract: In sedimentary terms, shales are fine-grained clastics rocks formed by consolidation of silts and clays. In log interpretation of conventional reservoirs, it is very common to observe that the clay parameters used to correct porosity and resistivity logs for clay effects are in fact read in shaly intervals rather than in pure clay. Although no considerable deviation have been observed in shaly sandstones, anyway these concepts and procedures must be reviewed to run log analysis in shale gas. Organic matter deposited with shales containing kerogen that matured as a result of overburden pressure and temperature, giving rise to source rocks that have yielded and expulsed hydrocarbons. Shale gas reservoir type is a source rock that has retained a portion of the hydrocarbon yielded during its geological history so that to evaluate the current hydrocarbon storage and production potential it is necessary to know the kerogen type and the level of TOC - total organic carbon - in the rock. Produced gas comes from both adsorbed gas in the organic matter and "free" gas trapped in the pores of the organic matter and in the inorganic portions of the matrix, i.e. quartz, calcite, dolomite.

In these unconventional reservoirs, gas volumes are estimated through a combination of geochemical analysis and log interpretation techniques. TOC, desorbed total gas content, adsorption isotherms, and kerogen maturity among other things can be measured in cores, sidewall samples and cuttings, in the laboratory. These data are used to estimate total desorbed gas content and adsorbed gas content which is part of the total gas. Also in laboratory, porosity, grain density, water saturation, permeability, mineral composition and elastic modules of the rock are measured. Laboratory measurement uncertainty is high and consistency between different providers appears to be low, with serious suspicions that procedures followed by different laboratories are the source of such differences. The permeability is one of the most important parameters, but at the same time, one of the most difficult to measure reliably in a shale gas. Core calibrated porosity, mineral composition, water saturation and elastic modules can be obtained through electric and radioactive logs. All these information is used to estimate log derived total gas volume which results are also subject to a high degree of uncertainty that must be overcome.

Once this key information is obtained, it is possible to estimate different gas in-situ volumes. Indeed, an estimate of porosity-resistivity based total gas in-situ and, on the other hand,

geochemical based adsorbed gas in-situ can be performed. Log total gas in-situ can be, and it is advisable to do, compared with adsorbed gas estimations and also with another gas measurement called direct method - total gas desorption performed on formation samples. The difference between log total gas in-situ and adsorbed gas in situ should be the "free" gas in situ. Free gas occupies the pores of kerogen and matrix; also it can be stored in open natural fractures if such fractures are present.

Aims & Research Methods: Unconventional reservoirs have burst with considerable force in oil and gas production worldwide. Shale Gas is one of them, with intense activity taking place in regions like North America. To achieve commercial production, these reservoirs should be stimulated through massive hydraulic fracturing and, frequently, through horizontal wells as a mean to enhance productivity.

Citation: S.L. Sakmar, Esq., University of San Francisco Law School, 'Shale Gas Development in North America: An Overview of the Regulatory and Environmental Challenges Facing the Industry' (Paper presented at North American Unconventional Gas Conference and Exhibition, The Woodlands, Texas, USA, 14-16 June 2011)

Topic Area: Shale Gas Development

Jurisdiction: USA

Abstract: The development of unconventional resources such as shale gas is one of the most promising trends in U.S. energy supplies that could have great potential for enhancing our energy independence and reducing carbon emissions. Many experts have called shale gas an "energy game changer" that could dramatically alter the energy supply picture for North America and potentially the world as other countries are just beginning to determine the extent of their own unconventional resources and are closely watching developments in North America.

At the same time, however, the hydraulic fracturing technology that is critical to unlocking the vast tracks of shale gas located throughout the United States has drawn intense criticism from environmentalists and lawmakers concerned about the potential impact of hydraulic fracturing on water supplies and the environment.

As a result of numerous health and environmental concerns raised, legislation commonly known as the FRAC Act was introduced in the 111th Congress (2009-2010) calling for greater federal regulation over hydraulic fracturing and disclosure of the chemicals used in hydraulic fracturing operations. Additionally, in March 2010, the U.S. Environmental Protection Agency (EPA) announced that it will conduct a comprehensive research study to investigate the potential adverse impacts that hydraulic fracturing may have on water quality and public health. While the FRAC Act did not reach the floor of the 11th Congress, some members of the 112th Congress (2010-2012) have recently expressed their intention to re-introduce the FRAC Act in 2011. In the meantime, hydraulic fracturing continues to draw criticism from environmentalists and EPAs scrutiny over the industry is intensifying as EPAs study starts to take shape.

Aims & Research Methods: This presentation will provide an overview of the legal, policy and environmental challenges associated with shale gas development in the United States.

The presentation will first address the existing federal and state laws pertain to shale gas development in the United States and will also provide an analysis of any pending legislation. This presentation also provides a detailed analysis of the current EPA Study and the various environmental concerns that have been raised pertaining to hydraulic fracturing.

Citation: J. Daniel Arthur, H. William Hochheiser, and Bobbi Jo Coughlin/ALL Consulting, LLC, 'State and Federal Regulation of Hydraulic Fracturing: A Comparative Analysis' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 24-26 January 2011)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: USA

Abstract: Hydraulic fracturing is a critical component of shale gas development and has led to the current success of the active shale gas plays in North America. However, it is often the subject of significant controversy surrounding the large volumes of water used and concerns about the protection of groundwater and surface water resources (Arthur, Coughlin, and Bohm 2010).

Hydraulic fracturing is not a new technology. Records indicate that it was first developed in 1903, but the first commercial application occurred in 1948. Since 1998, the United States has seen an increase in horizontal drilling and hydraulic fracturing as a result of the advancement of the Barnett Shale development in Texas. With the increase in hydraulic fracturing operations came an increase in environmental groups expressing concerns over groundwater and surface water contamination, water sourcing, and community impacts such as increased truck traffic and noise (See Figure 1).

The negative public perception surrounding shale gas and hydraulic fracturing has stemmed from a lack of technical awareness of how shale gas extraction occurs. Environmental Non-governmental Organizations (ENGOs) have questioned the effectiveness of the existing regulations for hydraulic fracturing and such questions have led the public to believe that it is a generally unregulated activity. ENGOs have called for increased federal regulation of hydraulic fracturing to ensure protection of groundwater resources, even though it is regulated by nearly every state oil and gas agency where development occurs.

In 2005, the Energy Policy Act clarified the definition of underground injection under the Safe Drinking Water Act (SDWA). Opponents of hydraulic fracturing have misinterpreted this clarification, insisting that hydraulic fracturing was previously regulated but is now exempt, and have designated it the "Halliburton Loophole." This is in fact not the case. The 2005 Energy Policy Act did not change previous law or regulations by providing an exemption for hydraulic fracturing under the SDWA. In fact, hydraulic fracturing was never regulated by the SDWA. The clarification amended SDWA's Underground Injection Control (UIC) definition to exclude "the underground injection of fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing operations related to oil, gas, or geothermal production activities" (U.S. Congress 2005). The U.S. Environmental Protection Agency (EPA) had not previously regulated the process of hydraulic fracturing for oil and gas wells under the SDWA's UIC program (EID 2009).

Aims & Research Methods: While hydraulic fracturing is a well-developed technology that has been used for more than 40 years, its wide-spread use for coal-bed natural gas and shale gas development has raised questions about the appropriate regulatory approach to ensure that groundwater resources are protected. In response to recent public concerns about hydraulic fracturing, Congress introduced the Fracturing Responsibility and Awareness of Chemicals Act (FRAC Act). The FRAC Act would amend the Safe Drinking Water Act (SDWA) to regulate hydraulic fracturing under the same laws and regulations that are used for the Underground Injection Control (UIC) program. Proponents of the FRAC Act assert that federal regulation is necessary to ensure protection of groundwater resources. Opponents argue that federal regulation creates a one-size-fits-all approach that is inefficient and protects poorly. In addition, they argue that states are best suited to regulate hydraulic fracturing given their ability to tailor regulatory requirements to local conditions. This paper will provide an overview of state regulation of hydraulic fracturing including some of the various approaches taken, different levels of regulatory detail, and recently adopted changes as well as changes that have been proposed, but not yet adopted. The paper will also examine how hydraulic fracturing would likely be regulated under the SDWA and discuss the pros and cons of federal regulation of hydraulic fracturing from the stand point of both regulatory burden to the industry and the potential for improved environmental protection.

Citation: David R Percy, University of Alberta, 'Attitudes Towards Resource Ownership in Alberta' (Paper presented at Canadian Unconventional Resources Conference, Alberta, Canada, 15-17 November 2011)

Topic Area: Health, Safety, Security, Environment and Social Responsibility and Management and Information

Jurisdiction: USA

Aims & Research Methods: Although the modern Alberta petroleum industry has been in existence for 65 years, the past decade has seen the courts and the legislature wrestle with some fundamental issues relating to the ownership of resources. Indeed, some of the most contentious issues have arisen within the last year.

The first part of this paper is based on the approach taken by the Canadian courts as they were required to resolve subsurface ownership issues. In the earliest days of the industry, this process began with the initial determination that it was possible to distinguish between the ownership of petroleum and natural gas within the same reservoir. The paper will examine the extension of this approach as novel issues arose in more recent times, including the ownership of evolved (or secondary associated) gas, coal bed methane and gas found in association with bitumen.

The bulk of the paper will discuss controversial recent changes instituted by the government of Alberta between 2007 and 2011. They deal with the clarification of resource rights, the direct removal of resource rights and the rate of return from the exploitation of resource rights. The recent actions of the Alberta government have been seen as a departure from the traditionally favourable legal and policy environment enjoyed by the energy industry. The paper will demonstrate that the controversial initiatives of the government do represent a break in the tradition that was followed between 1981 in 2007, but they are consistent with the attitude of the provincial government over the long term.

The paper will provide guidance on the existing state of law in Alberta and some of the legal and policy consequences of the recent government actions. It will examine the reasons for the changed approach adopted by the government over the last four years with parallels to the period of rising energy prices that occurred between 1971 and 2001.

Citation: Abu M. Sani, SPE, and Efe A. Ejefodomi, SPE, Schlumberger, 'Horizontal Wells Drilling Activity in South Texas Unconventional Gas Resources and Microseismic Hydraulic Fracturing Monitoring Application to Reduce Risk and Increases the Success Rate' (Paper presented at SPE/DGS Saudi Arabia Section Technical Symposium and Exhibition, Al-Khobar, Saudi Arabia, 15-18 May 2011)

Topic Area: Horizontal Wells Drilling Activity

Jurisdiction: USA

Abstract: Unconventional gas resource plays continue to have a significant impact on natural gas production in the US due to recent technological advances and higher demand for gas. In the US, 22% of the total energy consumed comes from natural gas. The US domestic production of natural gas is around 85% of the demand; currently about half of that comes from unconventional resources. Primary unconventional sources are tight gas, shale gas, and coal bed methane (CBM). Tight gas, shale gas and CBM production accounts for approximately 28%, 14% and 8%, respectively, of total US gas production. Total US production for 2010 is 21.57 tcf. Achieving sustainable production from unconventional gas resources requires reaching extended areas of the reservoir and performing effective hydraulic fracturing, with its associated technologies, to help reduce risk and increase the success rate.

Compared to production in vertical wells, the production of tight gas and shale gas in horizontal wells has increased significantly due to the ability to reach extended areas as a result of enhanced drilling technologies. Horizontal wells represent a large portion of the well count in US plays, with rigs for horizontal wells increasing from 10% to 58% of the total drilling rigs within the last 6 years (2005–2010). This increase in activity was achieved through careful engineering designs and use of new technologies to address the complexities involved in planning, drilling, completing, and stimulating horizontal wells. In recent years, microseismic hydraulic fracture monitoring (HFM) has become a key technology in understanding the propagation mechanism of the created fractures during stimulation treatments.

Aims & Research Methods: The paper discusses horizontal well drilling activity in a south Texas play over a 6-year period beginning in 2005. Drilling activity trends and completion practices in some tight gas and shale gas formations in the south Texas basin are highlighted. Additionally, the paper takes a look at the application of microseismic HFM to increase the success rate of horizontal wells in the south Texas basin by reducing some of the completion risks and challenges. Finally, the paper discusses ways to improve the overall completion and stimulation designs of horizontal wells in unconventional gas formations to ensure efficient recovery.

Citation: A. Zolotukhin, SPE, and V. Gavrilov, SPE, Gubkin Russian State University of Oil and Gas, 'Russian Arctic Petroleum Resources: Challenges and Future Opportunities' (Paper presented at OTC Arctic Technology Conference, Houston, Texas, USA, 7-9 February 2011)

Topic Area: Artic Petroleum Resources

Jurisdiction: The Artic

Abstract: The Arctic continental shelf is believed to be the area with the highest unexplored potential for oil and gas as well as to unconventional hydrocarbon resources such as gas hydrates.

Despite a common view on plentiful of hydrocarbon resources in the Arctic there are ongoing debates on the potential of this region as a future energy supply base. A driving force for such discussions is multiple: geopolitics, environmental concern, assessment and delineation of Arctic resources, technology available for their successful development and the market demand for energy supply.

Russian slice is recognized to be the largest among oil and gas resources owned by Arctic nations. However, scarce information and available geological data create uncertainty regarding a future role of Russian Arctic as main base of energy supply in the second part of the XXI century.

A further uncertainty is the pace at which production from northern areas including arctic offshore, will be brought onstream – either because of national policy, infrastructure development or investment by the state and the oil companies. These areas embrace those where development have already been started (Offshore Sakhalin, northern Timan Pechora and Northern Caspian) and those awaiting future involvement, like Barents and Pechora seas, East Siberia, Yamal, Kara Sea and Kamchatka.

Offhore production levels are likely to be very important to Russia in mid and long terms, especially as most (if not all) of production will go for export and, in the process, open doors to new markets. In this way offshore production will introduce a new and very significant component to Russia's export strategy. However, active involvement of the Russian Arctic resources in the global energy supply process needs a detailed analysis and clear understanding of the market potential for the Russian gas and oil (required volumes, time frame, transportations routes) and requires close attention of the government to the most important issues that should be in place, like national standards and guidelines for Arctic resources development, stable, transparent and predictable law as a necessary precondition for massive investments in exploration and production and, not least, active involvement of foreign companies into development of the Arctic resources that could bring along with investments an indispensible competence and experience, available technology and HSE principles.

Aims & Research Methods: Development of oil and gas field in the arctic seas located few hundreds miles from shoreline is according to experts' opinion the most challenging project in the world. Without international cooperation, coordination of all activities and use of modern and proven technologies for production of hydrocarbons, their transport, efficient safety and environmental protection tools realization of such project would be questionable.

Citation: K.M. Mutz, K.L. Rice, L. Walker, A.C. Palomaki, and K.D. Yost, Natural Resources Law Centre, University of Colorado Law School, 'BMPs for Minimizing Environmental Impacts: A Resource for Communities, Government and Industry' (Paper presented at SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, 30 October-2 November 2011)

Topic Area: Environmental and Social Impact Assessments

Jurisdiction: Global

Abstract: he Intermountain West Oil and Gas BMP Project (BMP Project) is a collaborative effort of the Natural Resources Law Centre and its partners, including the Environmentally Friendly Drilling Program. The BMP Project has developed a comprehensive, free-access, searchable, web-based database of oil and gas best management practices (BMPs) for the Intermountain West (http://www.oilandgasbmps.org). The database includes over 7,000 BMPs addressing air and water quality, soils, visual aesthetics, health and safety, wildlife, and other resources. These BMPs are currently required or recommended for responsible resource management by various levels of government, communities, conservation organizations, industry groups, or individual companies. The project website includes resource pages on development issues and controversies as well as case studies of industry efforts to minimize environmental impacts. A community page illustrates community-industry efforts to negotiate, rather than litigate the best options for rational development. The BMP database focuses on source materials regarding both conventional and unconventional development from the Intermountain West states of Montana, Wyoming, Utah, Colorado and New Mexico. The website resource pages also focus on the Intermountain West, but draw on information from unconventional gas developments beyond this region.

Aims & Research Methods: This paper describes the Intermountain Oil and Gas BMP project resources and addresses the role of BMPs within the range of law and policy options available for facilitating development while promoting environmental and community health and safety. The paper also summarizes what is known of the efficacy and cost effectiveness of BMPs.

Communities embrace development for the economic benefit it brings to their areas, but both communities and conservation groups vigorously work to prevent oil and gas development from recklessly disrupting their lives and destroying sensitive environments. Governments consider new means to control impacts while still promoting development. Many companies work to balance cost effective production with practices that protect the environment and the communities they impact.

The Intermountain BMP project helps these stakeholders identify appropriate practices for minimizing impacts to surface resources during planning, design, construction, drilling, operations, reclamation, and monitoring. BMP Project resources can also help stakeholders learn to work together to fuel the country's energy requirements and address the economic needs of communities without sacrificing the quality of their environment.

Citation: Ankit Agarwal, SPE, Indian School of Mines; Ajay K singh, Central Institute of Mining and Fuel Research, 'Evaluation of Fugitive Methane Emission factor for Oil and Gas in India' (Paper presented at SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, 30 October-2 November 2011)

Topic Area: Air Emissions

Jurisdiction: India

Abstract: The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as a transformation, which is attributed directly or indirectly to human activities that alters the composition of the global atmosphere. Among the several causes of climate change, increasing loads of greenhouse gases (GHG) in the atmosphere is considered as the foremost one. The most abundant greenhouse gases are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). It has been reported that atmospheric concentration of these greenhouse gases are increasing over the years. Summary of the pre-industrial and present atmospheric concentrations of these gases is presented in Table 1.

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Aims & Research Methods: This project aims at estimating the Emissions of Methane from the Industry. For this proper activity data and methodology is required. National activity data in respect of oil and natural gas systems for the years 1990 to 2009 was collected. Methane emissions have been calculated for all the activities listed above. The methane emission factor used for calculating the emissions from the various activities are either used directly from the IPCC or they have been particularly calculated. For activities including oil refining, transportation and storage of oil, gas production, processing, transmission and other leakages default emission factors of Tier 1 Approach of IPCC have been considered.India specific methane emission factors have been evaluated for oil production and venting and flaring activities. This method is clearly defined in the IPCC under Tier 2 approach. The future scope of this work is also to formulate emission factor using Tier 2 Approach of IPCC guidelines for the country. For other activities for which some study has already been done and Tier 2 factors have already been calculated in this work, the next work is to implement Tier 3 approach of the IPCC guidelines for continuous monitoring of the emission of methane to the atmosphere.

Citation: A. N. Martin and R. Eid, Baker Hughes, 'The Potential Pitfalls of Using North American Tight and Shale Gas Development Techniques in the North African and Middle Eastern Environment' (Paper presented at SPE Middle East Oil and Gas Show and Conference, Manama, Bahrain, 25-28 September 2011)

Topic Area: Strategic Planning and Management and Production Enhancement

Jurisdiction: USA

Abstract: Many companies operating in the upstream gas industry in the Middle East and North Africa (MENA) are interested in the outstanding successes achieved by the US and Canadian tight and shale gas producers. It seems almost miraculous that companies can obtain economic gas production rates from rocks with permeabilities measured in nanodarcies so- low, in fact, that it becomes almost impossible to accurately assess. Operators in MENA, who are accustomed to working in formations with permeabilities 5 or 6 orders of magnitude greater, have recently realised that they may be sitting on top of huge untapped gas reserves that had previously been evaluated as sub-economic.

In recent years, several major MENA-based operating companies have bought interests in US and Canadian tight and shale gas operations, with the objective of acquiring experience and technology that can be applied to similar formations in MENA and elsewhere. This seems to be an obvious and wise strategy; unfortunately, the problem is not the strategy, it is the tactics ("the devil in the details"). In many instances, operating companies have been disappointed to discover that they cannot simply transplant an American-style development in MENA. Similarly, many North American independents have viewed the untapped low-permeability gas reserves of MENA as a natural territory for expansion, only to find themselves frustrated at almost every turn.

Aims & Research Methods: This paper seeks to highlight the potential pitfalls of trying to use North American development techniques in MENA and to promote strategies and tactics that are more suitable. In addition, this paper will suggest structural changes that could have a significant positive impact on low-permeability gas developments in MENA.

Citation: Bjørn Bøye, Audhild Rygg, Caroline Jodal, and Iselin Klungland, SPE, Halliburton, 'Development and Evaluation of a New Environmentally Acceptable Conformance Sealant' (Paper presented at SPE European Formation Damage Conference, Noordwijk, The Netherlands, 7-10 June 2011)

Topic Area: Production and Operations

Jurisdiction: EU

Abstract: Water production from hydrocarbon reservoirs is a serious problem in the oil industry. High water cut reduces the economic life of producing wells and costs the industry billions of dollars each year (Curtice and Dalrymple 2004). Throughout the years, several techniques and chemicals have been developed to control undesired water production.

The industry has developed and applied a variety of chemical systems to reduce or shut off unwanted water production. However, most of these chemical systems are often quickly categorized as environmentally damaging according to the environmental laws and regulations, particularly in the North Sea area. This means that service companies must keep pushing technology development in a more environmentally acceptable direction. The recent development of a "green," environmentally acceptable colloidal silica-based sealant system is an example of this process. This sealant system is a two-component system containing a liquid silica and an activator. The system is easy to mix and easy to pump because of its low viscosity. Once it is placed into the water-bearing zone, the system forms a stiff gel to block the flow of water. Any under displaced gel left in the tubing can also be easily washed out using coiled tubing (CT). The system can also be viscosified or slurried with polymer or particulates, respectively, if diversion is required in longer intervals with high permeability

and pressure contrast. In addition to water and gas shutoff, this new system shows potential in other areas, such as formation consolidation, temporary gel plugs, annular barrier re-establishment, as well as stopping severe losses while drilling and recompleting.

The gel-setting time can be tailored for a wide temperature range from 20 to 150°C by varying the concentration of the activator. Extensive laboratory research has been performed to develop and qualify this sealant system. Simple, static-sealed tube tests were first run to qualitatively evaluate the gel strength and gelation time. Then, gradually, the formulation was refined and rheological data was measured and collected using a Brookfield viscometer. Further, core-flooding tests were conducted both in sandpack and carbonate cores to determine the effectiveness of the system in blocking water flow.

Aims & Research Methods: This paper describes the development of this environmentally acceptable sealant system and the qualification process including laboratory test methods and results.

Citation: C.P. Flores, SPE, PB Energy Storage Services, Inc.; S.A. Holditch, SPE and W.B. Ayers, SPE, Texas A&M University, 'Economics and Technology Drive Development of Unconventional Oil and Gas Reservoirs: Lessons Learned in the United States' (Paper presented at SPE Annual Technical Conference and Exhibition, Denver, Colorado, USA, 30 October-2 November 2011)

Topic Area: Management and Information

Jurisdiction: USA

Abstract: Advances in technology and better economics have supported the exploitation of unconventional reservoirs in the United States. The concept of the energy resource triangle (Masters, 1979) explains that unconventional oil and gas are abundant, but the exploitation of these resources is particularly sensitive to both technology and commodity prices (Fig. 1). In this paper, we assess the effects of technology and various geopolitical and economic events on U.S. unconventional production, in the context of Master's resource triangle theory (RTT).

Aims & Research Methods: Development of unconventional hydrocarbons is increasingly important as conventional resources decline and oil and gas demand increases. The concept of the energy resource triangle (Masters 1979) suggests unconventional oil and gas are abundant, but the exploitation of these resources is particularly sensitive to both technology and commodity prices. In this paper, we assess the effects of technology and various geopolitical and economic events on historic U.S. unconventional oil and gas production, in the context of Master's resource triangle theory (RTT).

We used the Austin Chalk as the base case and then extended the study to seven other unconventional plays. The two approaches used to evaluate the RTT were: (1) correlation of commodity prices and technology with drilling activity, and (2) production forecasting using decline curve analysis. Spearman's Rank Correlation Coefficient was used technique to establish the dependence between active wells, rig count, and commodity price variables. Decline curve analyses allowed us to estimate the increase in production from different scenarios of high price or technology.

Results support the RTT concept: higher commodity prices encouraged the introduction of new technologies, and increased drilling activity and boosted production from unconventional plays. For example, horizontal drilling revived older plays, such as the Austin Chalk. Moreover, the combination of horizontals wells and advanced fracture stimulation techniques led to the expansion of shale plays such as the Barnett and the Bakken. Correlation of commodity prices with drilling activity demonstrated that, during periods of high commodity prices, the number of producing wells increased an average of 75%. Using decline curve analysis, a maximum of $50 billion oil and gas production was forecasted via vertical, fractured wells (conventional technologies) and an economic cutoff of 5 BOE/d/well. However, current production plans, using improved technologies, suggest that the assessed plays may produce an additional $320 billion oil plus gas. U.S. production from unconventional reservoirs, stimulated by a federal tax credit, technology advances, and high commodity prices, encourage operators to dip lower into the resource triangle. Lessons learned in the U.S. may encourage the exploitation of unconventional oil and gas worldwide.

Citation: H. Williams, SPE, D. Khatri, SPE, R. Keese, SPE, S. Le Roy-Delage, SPE, J. Roye, SPE, D. Leach, SPE, P. Rottler, SPE, O. Porcherie, SPE, J. Rodriguez, SPE, Schlumberger, 'Flexible, Expanding Cement System (FECS) Successfully Provides Zonal Isolation Across Marcellus Shale Gas Trends' (Paper presented at Canadian Unconventional Resources Conference, , Alberta, Canada, 15-17 November 2011)

Topic Area: Wellbore Integrity/Geomechanics and Horizontal/Multilateral Wells

Jurisdiction: USA

Abstract: Marcellus gas-shale trends have transformed the regional and national outlook for natural gas supply and are particularly attractive for their proximity to high demand markets and existing pipeline infrastructure. Marcellus shale plays offer unique operational and regulatory challenges during mud removal, cementing, and completion operations. Sustained casing pressure (SCP) is one of the greatest challenges encountered after completion. The Department of Environmental Protection (DEP) in Pennsylvania has enacted strict policies regulating cementing practices in Pennsylvanian Marcellus shale trends to reduce the risk of inter-zonal communication and SCP due to substandard annular cement sheath integrity.

Aims & Research Methods: To ensure compliance with DEP cementing guidelines, a flexible, expanding cement system (FECS) was developed with fit-for-purpose mechanical properties. A further FECS blend modification included an additive to promote bulk cement expansion during hydration. Since implementation, this approach, coupled with good mud removal and cementing best practices, resulted in rapid static gel strength (SGS) development, acceptable compressive strength development and waiting on cement (WOC) time, and improved flexible and expansive properties.

Since introduction in 2010, six jobs (two intermediate and four production strings) have been successfully cemented with FECS technology. A Marcellus shale trend case study will be presented in this paper that discusses the successful application of FECS during cement placement around a production casing. After completion of each job, a successful shoe test was performed. After stimulation/fracturing treatments, SCP was not reported by the client in Marcellus wells cemented with FECS.

Since implementation in 2010, FECS technology has become a proven approach for cementing Marcellus horizontal tight gas shale environments where long-term zonal isolation and minimal SCP are required. This approach has been applied to Marcellus shale and Permian Basin formations while other applications are currently being explored.

Citation: John P de Wardt, Jim Rogers, Apache Corporation, 'Drilling Systems Automation - A Technology That is at a Tipping Point' (Paper presented at International Petroleum Technology Conference, Bangkok, Thailand, 7-9 February 2012)

Topic Area: Drilling and Completions, Drilling Equipment and Operations and Drilling Project Management

Jurisdiction: Global

Abstract: Automation of drilling systems offers significant value through many arenas: consistency in performance, maximizing performance, reduction in operating costs, improved safety. Pursuit of drilling systems automation is growing rapidly with many applications being published but equally as many or more going unpublished as companies seek to gain the advantage in application. This "hidden" growth will result in a faster adoption rate than the industry perceives from public knowledge.

Drilling automation can be traced back to early applications in the 1970's / 80's. The earliest complete drilling rig automation application is the National Automated Drilling Machine (NADM) – a singles rig with hydraulic power under central control built and tested circa 1980. Although this early leader was not commercialized due to technical issues operating fragile sensors in a drilling environment, it was certainly a bold step in technology application. The significant application of variable frequency electric drives and the advancement in sensor technology provides the basis for rapid and successful application of automated control systems.

In the 1990's, significant work has been accomplished in the application of control systems to surface equipment particularly in handling pipe. Rotary steerable systems also demonstrated closed loop control. While these progressed, areas of significant opportunity involving automation of drilling processes are only recently being addressed.

Aims & Research Methods: This paper covers the recent developments of drilling systems automation and demonstrates that this technology application is at a tipping point; this is a point at which immense change is about to occur. The authors are key members of the SPE Drilling Systems Automation Technology Section; one organizes key industry workshops and panel sessions, the other implements autonomous drilling systems. Knowledge of the status and imminent growth of this revolutionary application of technology is vitally important to businesses within the upstream oil and gas industry.

Understanding the recent history, the drivers and barriers and the expected future applications of automation in drilling and completion operations is critical to extracting maximum value from oil and gas field developments. Automated drilling of shallow multi-lateral wells using down hole directional data as surface equipment input has been demonstrated. Improvements in re-entry operations using automation of down hole processes have also been proven. Significant increases in reliability of down hole drilling tools (a doubling of mean time between failure) have been accomplished by improvements in drilling control systems.

The paper provides a review of recent developments in drilling systems automation and describes how this technology is expected to evolve. This information is current, known to a small group within the industry and of huge value to everyone involved in reducing drilling and completion costs.

The subject matter will enable customers to take good decisions on selecting new technology, reduce drilling and completion costs by applying a technology that can consistently operate at best in class performance and offset the limitations in the number of experienced industry personnel available for hire.

Citation: A. N. Martin, Baker Hughes, 'The Potential Pitfalls of using North American Tight and Shale Gas Development Techniques in the European Environment' (Paper presented at Offshore Mediterranean Conference and Exhibition, , Ravenna, Italy, March 23 - 25, 2011)

Topic Area: American Tight and Shale Gas Development Techniques

Jurisdiction: EU

Abstract: Many companies operating in the European gas industry are interested in the outstanding successes achieved by the US and Canadian tight and shale gas producers. It seems almost miraculous that companies can obtain economic gas production rates from rocks with permeabilities measured in nanodarcies - so low, in fact, that it becomes almost impossible to accurately assess. Operators in Europe, who are accustomed to working in formations with permeabilities 5 or 6 orders of magnitude greater, have recently realised that they may be sitting on top of huge untapped gas reserves that had previously been evaluated as sub economic. In recent years, several major European operating companies have bought interests in US and Canadian tight and shale gas operations, with the objective of acquiring experience and technology that can be applied to similar formations in Europe and elsewhere. This seems to be an obvious and wise strategy; unfortunately, the problem is not the strategy, it is the tactics (the devil is in the details). In many instances, operating companies have been disappointed to discover that they cannot simply transplant an American-style development into Europe. Similarly, many North American independents have viewed the untapped low permeability gas reserves of Europe as a natural territory for expansion, only to find themselves frustrated at almost every turn.

Aims & Research Methods: This paper seeks to highlight the potential pitfalls of trying to use North American development techniques in Europe and to promote strategies and tactics that are more suitable. In addition, this paper will suggest structural changes that could have a significant positive impact on low-permeability gas developments in Europe

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Citation: Mark Mulkern SPE, EQT Production, Bob Masnyk SPE, Tracermax Scientific, Hermann Kramer SPE, Roke Technologies, and Joseph Sites SPE, Horizontal Wireline Services, 'A Green Alternative for Determination of Frac Height and Proppant Distribution' (Paper presented at SPE Eastern Regional Meeting, Morgantown, West Virginia, USA, 12-14 October 2010)

Topic Area: Drilling and Completions, Completion Planning, Design and Installation, Design and Optimization and Artificial Lift Systems

Jurisdiction: Global

Abstract: An effort is being made to eliminate the use of open source radiochemicals as tracer materials in various oilfield applications. These applications include the following:
- Tracing cement: Boron Carbide is definitive with respect to proving the presence of lightweight cement slurries (<1500 kg / m3) typically used for surface cement and remedial intervention.

-Tracing fluid placements in hydraulic fracturing operations.

- Production logging for proving casing integrity, material flow and velocity rates.

- Subsurface location of down hole jewellery such as float shoes, collars, etc.

Aims & Research Methods: As regulations and public awareness regarding hydraulic fracture operations continue to change, it is important to continue to look for options to reduce risk to both the environment and personnel. Current fracture diagnostic technology uses radioactive materials which can pose a high risk from a health, safety and environment (HSE) perspective. Exposures to people and the environment to radioactive chemicals; and the potential to cause pollution or long term detrimental health problems, are great. A technology has been developed to allow fracture diagnostics to be performed with zero-risk to the environment and personnel.

The technology involves using Boron Carbide particles added to the frac slurry as a tag material. Boron Carbide is a ceramic compound that has a 75% abundance of Boron by weight and the same density as Silica. It is a compound that is chemically inert under typical conditions of hydraulic fracturing.

Because Boron is a neutron absorber, post-frac detection is accomplished by using a neutron device utilizing an Am-241Be sealed source which detects descending neutron and gamma count rates, as well as, capture gamma validation by energy discrimination across tagged intervals. This method will give both near and not near well bore dimension and provides Neutron-Neutron (N-N) and Neutron-Gamma (N-G) differences against initial base line reference data.

Field data and analysis of results are presented for a vertical coal bed methane well in Virginia as well as a horizontal Berea Sandstone well in Kentucky.

Citation: G. Eynon, C. Hill, T. Goodman, Energy Resources Conservation Board, ‘Unconventional Resource Development and the Role of the Alberta Regulator’ (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Management and Information, Strategic Planning and Management, Social Responsibility, Operational Safety and Environment

Jurisdiction: Canada

Abstract: When regulators fail to regulate properly there can be serious consequences, as shown recently in the global financial markets and with the British Petroleum oilwell blowout in the US offshore Gulf of Mexico. Although regulators will never be able to prevent all

negative outcomes from human activity, it is clear that a good regulator should prevent most problems from arising or mitigate problems when they do arise.

With up to fifty percent of every government around the world composed of regulators in some form or another, their impacts can be profound. If they follow principles such as transparency, consistency and effectiveness, they can encourage the orderly development and production of natural resources and benefit both the public and the regulated industry.

Aims & Research Methods: lberta's Energy Resources Conservation Board (ERCB) has regulated oil and gas resource development for almost 75 years. Throughout most of that time the industry and the regulator were concerned with conventional oil and gas resources. In the last decade or so the emphasis has shifted, for several reasons, towards unconventional resources—in situ bitumen, tight oil, tight gas, deep- or basin-centred gas, coal bed methane (CBM), shale gas, and in situ coal gasification.

The characteristics of these resources, as well as the technologies required to develop them, create the need to modify the ERCB's regulatory framework. This is integral to reaching the ERCB's vision of being The Best Non-Conventional Regulator in the World, capable of dealing with the pressing issues of the future energy development in Alberta. Given the realities of the changing resource base, unconventional resources are a priority, and the ERCB needs to adopt non-conventional ways of regulating their development.

The ERCB has already adapted the regulatory framework to deep/basin-centred/tight gas, coal bed methane, and in situ bitumen. The ERCB responded with new regulatory structures—Development Entities for CBM and Deep Basin gas; control wells for CBM; commingling of production streams from coal-sand sequences—to more effectively manage the development of some of those resources. After only a few years of operational experience, and with industry feedback, we have already improved the efficacy of some of these approaches and continues this effort as an ongoing practice.

Moving to the next level, however, requires some substantively different approaches. The ERCB's Unconventional Gas Regulatory Framework Project is intended to identify new ways of regulating and facilitating such resource development. It is being done with the consultative input of knowledgeable stakeholders. We have already determined the major regulatory risks, and are focusing on developing ways to mitigate them with the appropriate level of necessary regulation or other, non-regulatory means.

Citation: Ana Luiza Saboia de Freitas & Luciano Claudio Lage G. Mendes, 'Brazilian Regulatory Framework Concerning Produced Water Final Disposal' (Paper presented at SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, , Rio de Janeiro, Brazil, 12-14 April 2010)

Topic Area: Produced Water Use, Discharge and Disposal

Jurisdiction: Brazil

Abstract: Due to strong environmental requirements concerning the quality of final effluent discharge in superficial water resources, effluent injection in geological layers has been a common practice regulated in many industrialized countries as a final disposal option.

The quality control requirements for monitoring effluents discharged from onshore oil and gas facilities to superficial water bodies has become more and more strict like the regulation of produced water discharged from oil and gas platforms in offshore fields. Environmental regulation regarding this matter usually takes into consideration many parameters and environmental studies over the effects of the discharge over the biota.

Under these circumstances injection of produced water for both purposes (enhancement of oil recovery and final disposal) will become more important in the world as well as in Brazil. The impacts that will be brought should not only be analysed over the changes and difficulties embraced in this operation, by itself, but also under the regulatory point of view. Despite the fact that Brazilian regulation of superficial discharge of produced water (from oil and gas platforms or from sea outfalls in oil terminals facilities) has been becoming tougher, the geological storage solution is a very new subject.

Regulation of underground water in Brazil is a very recent matter. In 2008 it was enacted by the Brazilian Council of the Environment (the Conselho Nacional do Meio Ambiente - CONAMA) a Rule of Groundwater Bodies Classification (CONAMA Resolution 396, of April, 2008). This rule does not mention the management of produced water in oil and gas fields, but for the first time it was established the directions for defining and managing a portion of an aquifer destined for geological storage of effluents in general

Aims & Research Methods: In the last two decades the environmental pressure over oil and gas companies regarding produced water1 final disposal has been increasing substantially. The regulation of discharges of effluents and produced water tends to become stricter. So injection of produced water for disposal of will become more important as part of oil and gas activities. Regulation of underground water in Brazil is a very recent matter. In 2008 it was enacted by the Brazilian Council of the Environment (the Conselho Nacional do Meio Ambiente - CONAMA) a Rule of Groundwater Bodies Classification (CONAMA Resolution 396, of April, 2008). This rule establishes the directions for defining and managing a portion of an aquifer destined for geological storage of effluents in general. There is no act or rule regulating specifically effluent injection in Brazil.

Citation: R.S. Taylor, Halliburton; P. Tertzakian, ARC Financial; T. Wall, J. Wilkinson, Apache; M. Graham, EnCana; P.J. Young, DYAD Consulting; S.W. Harbinson, Halliburton, ‘Natural Gas: The Green Fuel of the Future’ (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, , Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Management and Information

Jurisdiction: Canada

Abstract: Western Canadian Natural-Gas Potential. Recent discoveries in the Horn River basin and the Montney play are expected to triple British Columbia natural-gas production from ~2.8 B/D currently to ~7.6 B/D within approximately the next 10 years. The natural-gas resource base in British Columbia is expected to be on the scale of other major liquefied natural gas (LNG) producing nations, such as Indonesia and Australia. All of the major Canadian exploration companies together with several of the super majors and some independents are developing natural gas in the Montney and Horn River shale plays (Fig. 1 and 2).

This added resource has been unlocked primarily through use of horizontal drilling combined with multistage-fracturing treatments. This has allowed these nanodarcy-permeability formations to be produced at economic rates. Improvements in the efficiency of technologies used to conduct the fracturing treatments now routinely allows for 8 to 10 major fracturing treatments to be placed in two to three days using 24-hr operations (Fig. 3). Multiple transverse fractures are created along a horizontal lateral wellbore to provide the necessary exposed rock surface area (kh) for economic drainage rates (Fig. 4). Peter Tertzakian captures the potential shale gas provides in his book The End of Energy Obesity (2009).

To meet growing appetites around the world and address the need to shift to a healthier energy diet with the greatest leverage possible, we need to identify a fuel that is low carb, plentiful, scalable, and affordable. As fate would have it, we are very fortunate that such a fuel is emerging and is already being added to our diet in greater proportion, especially in North America. Actually, it's an old fuel, but we're finding new ways to accessing and using it. We used to call it "nature's gas."

Aims & Research Methods: As populations and economies continue to grow globally, energy demand will grow proportionally. Extensive work by Peter Tertzakian (2006, 2009) has shown crude oil supplies may not keep pace with this increased demand. The shortfall must be met by other energy sources. Only two current energy sources have the global capacity to, by themselves, address increased energy demand in a timely manner. These are natural gas and coal. Traditionally, the major use of crude oil has been for processing into transportation fuels, with lesser amounts being used for petro-chemicals and home heating. Natural gas and coal have been used primarily for electrical generation and heating. A pivotal transition will likely occur in which natural gas and coal begin to see increased use as transportation fuels. A battle for market share between primary fuels will likely ensue. The objective of this paper is to present data comparing the environmental impact of using methane vs. coal. A compelling case for the use of natural gas as the future "green fuel" emerges.

Citation: P. Paquet, T. Bews, E. Viala, M. Pearson, Miller Thompson, 'verview of The Emerging Unconventional Oil and Gas Regulatory Framework in Quebec Vis-a-vis Its Western Canadian Counterparts' (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Pipelines, Flowlines and Risers

Jurisdiction: Canada

Abstract: Western Canada has had a thriving conventional energy industry for many decades. It encompasses the exploration, development, transformation and transportation of hydrocarbons to markets across North America. In Quebec, until recently the oil and gas industry was limited to distribution and transportation activities. As an industry, it regulated the infrastructure needed to process hydrocarbons and the legislation had very little to do with the exploration and development of hydrocarbons. However, with shale gas development, technological breakthroughs, and more favourable pricing conditions, Quebec has witnessed the birth of an unconventional oil and gas industry which now includes intense activity by exploration companies, developers and possibly, over the next few years, producers.

The Western Canadian regulatory framework will be reviewed and contrasted with the emerging Quebec regulatory framework to highlight the different challenges that may arise. We will outline the legislative framework that governs the unconventional oil and gas industry in Quebec. Also, we will address the potential liability of officers and directors regarding the reclamation and abandonment of upstream facilities. We will comment on Quebec laws regulating land use, planning and the environment which may pose specific challenges depending on whether or not local gas lines, or processing plants need to be built or implemented. The oil and gas industry in Quebec is made subject to mining laws that are not entirely compatible with industry practices of traditional players.

Aims & Research Methods: The regulation of unconventional oil and gas is emerging throughout North America. In the St-Lawrence valley in the past 5 years, there has been a thriving exploration push. This exploration could lead in the medium to longer term to the securing of defined reserves for consumption in the local market. There had been anecdotal evidence of this over the years; however, recently this possibility has become very real indeed.

Millions of dollars had been invested over the years by local entities such as Petrolia and Gastem Inc. These juniors have partnered with western Canadian or American players which have confirmed their participation and are motivated to further exploration and development of shale gas discoveries and unconventional oil plays.

Citation: Dale A. Pierce, SPE - Brandt NOV Global Product Line Manager – Waste Management, Kelly Bertrand – NOV Mission Products Market Development Manager, Cornelia Cretiu Vasiliu, SPE – NOV Mission Products Market Development Engineer, ‘Water Recycling helps with Sustainability’ (Paper presented at SPE Asia Pacific Oil and Gas Conference and Exhibition, Brisbane, Queensland, Australia, 18-20 October 2010)

Topic Area: Environmental and Social Impact Assessments, Produced Water Use, Discharge and Disposal and Waste Management

Jurisdiction: Global

Abstract: The oil business uses a large quantity of water during the drilling and completion of an unconventional gas well. In many of the shale plays each well needs in excess of 4 million gallons of water (100,000 bbl) during the drilling and completions operations. Water is a precious resource and many areas are faced with water shortages. Water shortages extend to almost all the traditional oil and gas producing areas in the United States including Colorado, California, Wyoming, Texas and Oklahoma. Also, the arid areas of Australia, The Middle East, and Africa see even more severe shortages of fresh water than in the United States. Moreover, in areas where water is not in short supply such as Indonesia, Malaysia, and the Eastern United States, discharge of high salt content water is problematic. In order to assure itself of adequate water for drilling and completion operations, the oil business needs to change the ways it has traditionally transacted its business. As stated above many drilling areas are faced with water shortages, whereas many other producing areas are faced with high disposal costs for frac flow back water and produced water. In many traditional production areas disposal of water is simple and usually inexpensive since there are numerous injection wells in these traditional production areas. However, in some of the new Shale plays the access to injection wells for disposal of produced water and frac flow back water is very limited.

Aims & Research Methods: Part of the solution is to recycle the frac flow back water and the produced water for use as drilling fluid or for Frac Fluid. How clean does this water need to be for use as a drilling fluid or a frac fluid? What techniques are used to clean this water? How costly are the various techniques? These questions and others will be addressed in this paper.

Citation: R. Belvalkar and S. Oyewole, Pennsylvania State University, University Park, 'Development of Marcellus Shale in Pennsylvania' (Paper presented at SPE Annual Technical Conference and Exhibition, Florence, Italy, 19-22 September 2010)

Topic Area: Management and Information, Drilling and Completions, Production and Operations, Reservoir Description and Dynamics and Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: USA

Abstract: A review of technologies and practices used for exploration and production of natural gas from the Marcellus Shale in Pennsylvania is given while shedding light on the entire process of natural gas production in the Marcellus Shale region of Pennsylvania. Entailing drilling and completions operations, production operations and transportation of natural gas tied together with regulation and policy in Pennsylvania. Horizontal drilling technology is used in shale play development along with well stimulation which is also needed to produce economically from these wells. This is achieved through hydraulic fracturing. Water is predominantly used for this but the use of other fluids is also being explored. For the transport of natural gas a network is present in Pennsylvania but gathering stations and other infrastructure needs to be setup. This is not easy in Pennsylvania due to the hilly nature of the region. Most common practices are developed locally as is the case in the Marcellus, with local operators and not the big majors heading the development of the Shale play but even they used techniques applied in the Barnett Shale to great success in the Marcellus Shale which goes to prove that a lot can be gained from other similar plays. The history of this region in producing natural gas is more than a hundred years old and so a lot has done in this region with regards to experimentation and technology additions in producing natural gas. Apart from producing and transportation of natural gas, another important aspect is regulation and policy which is strict when it comes to Pennsylvania. Along with this it would be beneficial for companies to develop good relations with residents in the area as these wells typically produce for long periods of time. Typical land restoration projects are now mandatory which all adds up to a higher overall cost of energy. To summarize all the factors needed to produce natural gas in this region economically and safely with leaving as small as a footprint as possible is explored.

Aims & Research Methods: Oil and gas reservoirs can be classified based on various different characteristics they possess. This is based upon whether they produce mainly oil or gas or both and conventional and unconventional reservoirs. Unconventional gas reservoirs are basically those reservoirs which require higher technical expertise and are less economical. They are classified as deep gas, tight gas, gas containing shales, coal bed methane, geopressurized zones and Artic and sub-sea hydrates. (1) In the United States, unconventional gas resources constitute a large portion of the remaining natural gas resources. These unconventional natural gas resources include tight sands, coal bed methane and gas shales. (2) Gas shales are typically characterized by low permeability formations. A typical vertical well without stimulation would make it difficult to achieve economical production from the well.

Due to these reasons shale formations were often overlooked for the production of hydrocarbons. Shale is a fine-grained, fissile, detrital sedimentary rock which is formed as a result of deposition of clay and silt-sized particles over each other consolidated over time. This shale has ultra-low permeability. It often acts as a seal to many conventional reservoirs. (3) Gas shales are rich in organic matter and do have economical amounts of gas trapped in them. The formation serves as the reservoir and doesn't allow the gas to flow out. The gas is stored in the pore space as well as adsorbed on the organic matter. (4) The United States has plenty
of shales with oil and gas trapped inside them. The actual amount of hydrocarbons in place in these shales has not been estimated accurately. The net recoverable is a small amount of the hydrocarbons in place as is the case with most reservoirs.

Citation: G. Cau, U. of Cagliari; G. Girardi, ENEA, Italy; P. Macini, SPE, and E. Mesini, SPE, U. of Bologna; and S. Persoglia, OGS, Italy, 'The Italian Contribution to the European Initiative for the Capture, Transport, and Storage of CO2' (Paper presented at SPE Annual Technical Conference and Exhibition, Florence, Italy, 19-22 September 2010)

Topic Area: Global Climate Change/CO2 Capture and Management

Jurisdiction: Italy

Abstract: The need to update energy policies worldwide in order to deal with climate change effectively is now unanimously considered a priority by the scientific and political communities as well as by people. It is also unanimously believed that what is needed is an approach integrating energy usage and energy production. Such an approach requires that we speed up the transition towards an economy not any longer based on fossil fuels, but instead on an increased demand/supply efficiency and on renewable sources, while aiming at clean technologies and emissions closer and closer to zero wherever fossil fuels are used.

The International Energy Agency (IEA) has agreed that the world's energy demand will rise by 45% between today and 2030 (an average growth rate of 1.8% per year) falling back upon coal for over 1/3 of the total growth. On top of this, 97% of the forecasted emission increment between today and 2030 will be due to non-OECD countries, 3/4 of which will be due to China, India and Middle East Countries[1]. Therefore the energy and research policy in this field must take the following factors into account: a) fossil fuel demand will stay very high in the coming decades, above all in the Countries with an Emerging Economy; b) the development and widespread commercial deployment of intrinsically zero emission technologies at a competitive cost will take longer; c) it is necessary to act immediately to reduce the emissions into the atmosphere that fossil fuel usage will still bring about.

Aims & Research Methods: The need to update energy policies worldwide in order to deal with climate change effectively is unanimously considered a priority by the scientific and political communities as well as by the general public. It is also unanimously believed that what is needed is an approach integrating energy usage and production. Such an approach requires that Countries speed up the transition towards an economy not any longer based on fossil fuels, but instead on increased demand/supply efficiency and on renewable sources, while aiming at clean technologies and reducing emissions wherever fossil fuels are used. Italian universities and research centres have started specific studies and programmes regarding CO_2 Carbon Capture and Storage (CCS). Such initiatives have been financed thanks to European and National funding. The latter has financed a vast programme based on a strong synergy between national stakeholders, also via the participation to international initiatives like the Carbon Sequestration Leadership Forum (CSLF) and the European Technological Platform for Zero Emission Fossil Fuel Power Plants (ZEP). The main strength of the Italian system lies in the strong will of the Italian Government to adopt a new energy policy. The second strength is the starring of the main Italian industrial subjects, above all ENEL and ENI, which have started important demonstrative projects (not to mention Techint, Carbosulcis, and others). Another important issue is the large quantity of geophysical data available for many parts of the Italian territory that are strategic for assessing the CO_2 storage capacity. Finally, Italy is of great interest for the scientific community because of the presence (onshore and offshore) of numerous natural sites of CO_2 leaks, thus offering unique opportunities of evaluating its impacts on the natural environment, and of tuning up the monitoring techniques of CO_2 leaks.

Citation: Sagar V. Kale, SPE, Chandra S. Rai, SPE, and Carl H. Sondergeld, SPE, University of Oklahoma, 'Petrophysical Characterization of Barnett Shale' (Paper presented at SPE Unconventional Gas Conference, Pittsburgh, Pennsylvania, USA, 23-25 February 2010)

Topic Area: Reservoir Geology and Geophysics and Core Analysis

Jurisdiction: USA

Abstract: Conventional methods of rock typing based on porosity-permeability cross-plots do not work in shales due to lack of dynamic range and the difficulties involved in the direct measurements of most of the petro physical properties. Here, we have attempted rock typing in Barnett shale play by integrating geological core description with the petro physical parameters such as porosity, total organic carbon (TOC), mineralogy and mercury injection capillary pressure which are relatively easy to measure.

Dataset of petro physical measurements used for rock typing is acquired by sampling at every 2 feet interval from almost continuous 1600 feet of core recovered from four well in the Newark East Field, Texas. Porosity and mineralogy is measured at every 2 feet. For Hg injection capillary pressure measurement, sampling is done at every 10 feet. TOC measurements and Environmental Scanning Electron Microscope (ESEM) imaging is also carried out on samples from selected depths.

Lithofacies are assigned to all the samples used in this study using the stratigraphic columns developed by Singh (2008). We observed that certain lithofacies contributed very little thickness to the overall stratigraphic column. Based on the petro physical measurements, we also observed that some lithofacies had similar petro physical properties. We combined the lithofacies with similar petro physical properties into groups so that each group is unique in terms of its petro physical properties and also contributes significant thickness to the stratigraphic column. From the petro physical measurements, we observe three such groups or rock types. The three rock types so formed are termed as petrofacies and they are labelled as '1', '2' and '3'.

Aims & Research Methods: Petrofacies 1 represents the calcite lean (<10% wt.) – clay rich rock with high porosity and TOC. It has the highest quartz content as well; making it the most suitable reservoir rock for initiating a hydraulic fracture. Petrofacies 1 represents the best reservoir rock type in a petro physical sense. Petrofacies 2 represents reservoir rock with moderate calcite content (10 – 25% wt.). It also exhibits high porosity but its TOC content is rather low. Petrofacies 3 represents calcite rich rock (>25% wt.) with low porosity and low TOC. It represents the worst rock in the field and is not expected to contribute much to gas production.

ESEM imaging of the samples from three petrofacies shows that the petrofacies are not only distinct petrophysically, they are also observed to be unique texturally. Samples from each petrofacies also exhibit unique capillary pressure curve.

Comparing the thickness of the petrofacies with the overall gas production in two vertical wells (in the study area), with similar completions over the same time interval, shows that the well with long and continuous intervals of petrofacies 1, with minimum interference of petrofacies 2 and 3 over the perforated zone, produces better than the well with thick intervals of petrofacies 2 and 3 frequently separating petrofacies 1. This confirms that petrofacies 1 which is the best reservoir rock in a petro physical sense is also a better gas producer.

Citation: Y. Beaudoin, J.K. Serry, Blake, Cassels & Graydon, 'Shale Gas Development in Canada: The Regulatory Landscape' (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Canada

Abstract: In the fall of 2010, shale gas exploration and development in Canada is just getting started. Engineering advances are making unconventional gas plays more attractive. Provincial governments are looking to tap the economic benefits. Regulators are adjusting existing oil and gas regulations or drafting entirely new legislation.

Aims & Research Methods: This paper covers a selection of topics for each of the seven Canadian provinces where shale gas development has started or is about to begin. So far, regulation of shale gas is not very different from the regulation of conventional gas exploration and development. Interest groups and regulators are following U.S. trends.

Citation: R. Stefik, K. Paulson, British Columbia Oil & Gas Commission, 'When Unconventional Becomes Conventional' (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Reservoir Description and Dynamics

Jurisdiction: Global

Abstract: British Columbia has seen near exponential growth in the areas of the Horn River and Montney unconventional shale gas plays situated in North Eastern B.C. (figure 1). The

original gas in place volume for the Montney and the Horn River basins have not been formally calculated but have been estimated at more than 500 Tcf and continues to be revised upwards as new and more refined information is obtained as development takes place. The Cordova Embayment and Liard Basin, east and west respectively of the Horn River Basin, are at early stages of assessment but promise additional massive gas-in-place values.

Approximately 5 years ago, industry experts were predicting a drastic reduction in viable gas production from the Western Canada Sedimentary Basin, and North America in general. Market predictions were favouring investment in import terminals for liquefied natural gas (LNG) where gas from offshore suppliers could be imported and moved through the North American transportation grid to market. Regulators were anticipating an influx of LNG facility applications as well as a myriad of infrastructure modifications to handle the resulting new flow regime.

In five short years, this dire future has been completely reversed due to the advent of economically viable methods to access gas trapped in shales and similar tight formations. At the current rates of production and exploration, there are more than 20 year of gas reserves in BC, reversing a previous decline, as shown in Figure 2.

Citation: George E. King, Apache Corporation, 'Thirty Years of Gas Shale Fracturing: What Have We Learned?' (Paper presented at SPE Annual Technical Conference and Exhibition, Florence, Italy, 19-22 September 2010)

Topic Area: Drilling and Completions and Production and Operations

Jurisdiction: Global

Abstract: Although high gas flow rates from shales are a relatively recent phenomenon, the knowledge bases of shale-specific well completions, fracturing and shale well operations have actually been growing for more than three decades and shale gas production reaches back almost one hundred ninety years. During the last decade of gas shale development, projected recovery of shale gas-in-place has increased from about 2% to estimates of about 50%; mainly through the development and adaptation of technologies to fit shale gas developments. Adapting technologies, including multi-stage fracturing of horizontal wells, slickwater fluids with minimum viscosity and simultaneous fracturing, have evolved to increase formation-face contact of the fracture system into the range of 9.2 million m^2 (100 million ft^2) in a very localized area of the reservoir by opening natural fractures. These technologies have made possible development of enormous gas reserves that were completely unavailable only a few years ago. Current and next generation technologies promise even more energy availability with advances in hybrid fracs, fracture complexity, fracture flow stability and methods of re-using water used in fracturing. This work surveyed over 350 shale completion, fracturing and operations publications, linking geosciences and engineering information together to relay learnings that will identify both intriguing information on selective opening and stabilizing of micro-fracture systems within the shales and new fields of endeavour needed to achieve the next level of shale development advancement.

Aims & Research Methods: The first lessons from this study are:

- No two shales are alike. Shales vary aerially and vertically within a trend, even along the wellbore.

- Shale "fabric" differences, combined with in-situ stresses and geologic changes are often sufficient to require stimulation changes within a single well to obtain best recovery.
- Understanding and predicting shale well performance requires identification of a critical data set that must be collected to enable optimization of the completion and stimulation design.
- There are no optimum, one-size-fits-all completion or stimulation designs for shale wells.

Although gas shale completions literature is developing rapidly, the history of gas shale research offers a starting point that can help explain many phenomena seen in shales world-wide. To this point, many of the efforts in gas shale developments have been sheltered within a handful of companies that have pushed their own gas-shale learning envelopes as a competitive advantage. There are, however, many solid advances in shale that have been reported in the technical literature. Of the 350+ references reviewed for this report and the 250 included, >60% have been written in the last 36 months and learnings are increasing rapidly. This paper seeks to report and define many of these advances. Information from SPE, AAPG, consultant reports, academic and government work have been reviewed to establish a history of what we, as an industry, have done and hopefully provide commentary on what enabling technologies need to be developed and refined. In this spirit, discussion on geology, geochemistry and seismic have been briefly reported to lay a foundation for the fracturing discussion.

Citation: J. Daniel Arthur, B.J. Coughlin, B.K. Bohm, ALL Consulting, 'Summary of Environmental Issues, Mitigation Strategies, and Regulatory Challenges Associated With Shale Gas Development in the United States and Applicability to Development and Operations in Canada' (Paper presented at Canadian Unconventional Resources and International Petroleum Conference, Calgary, Alberta, Canada, 19-21 October 2010)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Canada and USA

Abstract: Natural gas has been produced from shales in North America for over 150 years (Harper 2008). Development of shale gas plays began with the Devonian shales of the Eastern United States in the 1800s. Modern shale gas development has been defined by the Antrim Shale in Michigan and the Barnett Shale in Texas, which started to see an expansion in development in the late 1980s. In recent years, shale gas development has grown in the Fayetteville, Woodford, Marcellus, Haynesville and Eagle Ford Shales of Arkansas, Oklahoma, Pennsylvania, Louisiana, and Texas, respectively (See map in Figure 1). Although Canada's shale gas potential has been known for nearly as long as that of the United States, development of shale plays in Canada has only occurred over the last few years (Canadian Energy Advantage n.d.). Estimates of Canada's shale gas potential exceed 28 trillion cubic metres of natural gas (A Primer for Understanding 2009).

Unconventional production of natural gas from sources like shale gas, tight gas and coal-bed natural gas (CBNG) account for between 20% and 30% of Canada's current natural gas production (Canadian Energy Advantage n.d.). In the United States, unconventional gas accounts for over 40% of gas production (GWPC and ALL Consulting 2009). Shale gas is expected to provide over half the natural gas production in North America by 2020. While the potential for Canadian Shale Gas development is still being evaluated, the principal Canadian shale gas plays identified to date are the Horn River Basin and Montney Shales in northeast British Columbia, the Colorado Group in Alberta and Saskatchewan, the Utica Shale in Quebec, and the Horton Bluff Shale in New Brunswick and Nova Scotia (See map in Figure 1) (Canadian Energy Advantage n.d.).

Development of shale gas resources requires an understanding of the environmental considerations associated with the drilling and production process. Many of the environmental considerations associated with shale gas development are common to all oil and gas activity. However, the widespread occurrence of shales with natural gas potential in North America bring unique considerations and challenges, including development in areas without prior oil and gas development, urban development, wildlife, traffic, water sourcing and water disposal.

Aims & Research Methods: This paper will summarize key environmental and regulatory issues associated with Shale Gas development in major shale plays in the United States, actions taken by environmental non-governmental organizations, government, and industry on these issues (including mitigation strategies). Further, the paper will present the current and future pictures of these issues and the applicability of these issues to Shale Gas development in Canada.

Citation: István Lakatos, SPE and Julianna Lakatos Szabó, Research Institute of Earth Sciences, University of Miskolc and Geoengineering Research Group of the Hungaian Academy of Sciences, 3515 Miskolc-Egyetemváros, POB 2., Hungary, 'Role of Conventional and Unconventional Hydrocarbons in the 21st Century: Comparison of Resources, Reserves, Recovery Factors and Technologies' (Paper presented at EUROPEC/EAGE Conference and Exhibition, Amsterdam, The Netherlands, 8-11 June 2009)

Topic Area: Strategic Planning and Management, Design and Optimization, Production Enhancement, Fundamental Research in Production and Operations and Reserves Evaluation

Jurisdiction: Global

Abstract: Energy demand is expected to quadruple in the 21st century (Fig. 1). An energy mix that is undergoing a transition from the current dominance of fossil fuels to a more balanced distribution of energy sources will meet the energy demand. Although the relative importance of hydrocarbons apparently will decrease from 60% (present) to 15% (in 2100), roughly 250−260 billion t of crude oil (annually 2.5 billion t on average through the whole century) must be produced to meet the worldwide demand. That task is enormous if we consider that a little bit than 100 billion t of crude oil has been produced since 1850 and the average production rate was about 0.7 billion t/y. As we will see in the next chapter, only 390 109 t crude oil may exist in proven and probable reservoirs. Namely, the converging opinion of different agencies1-7 is that the recovery rate of conventional hydrocarbons must be increased from 33−35% at present to 65−70%. Obviously, sophisticated recovery technologies must be routinely used at mostly matured oil fields in the future, however, a serious concern still exists whether that goal might be fulfilled or not.

Through the past two decades, the global economic growth and oil demand increased on average by 3.73% and 1.95%, respectively (Fig. 2). Consequently, as a short analysis made by Yergin8 a minimum 0.5% increase in oil production is needed to boost the world economy by 1%. Based on that prediction, the industrial oil demand will increase from 20 to 38 MBD (from 1.3 to 2.31 Gt/y) between 1980 and 2030; meanwhile the total oil production probably drops to less than 3 Gt/y by the end of that period1. Therefore, the sceptic opinions are supported by the facts that just the fuel consumption of transportation or hydrocarbon demand by industry alone will exceed the total crude oil production expected after 2040. It is no doubt, that additional hydrocarbon resources and industrial reserves are keenly necessary to maintain the rate of progress, otherwise the *"dwindling supplies of oil and gas, obsolete power net-works and new environmental regulations threaten the western word into a new energy crisis. Consequently, the mankind is becoming again vulnerable to shortage in hydrocarbons, price shock, supply interruptions, and in the worst case, political and military blackmail"* (Emerson T.: Newsweek, April 2002).

Aims & Research Methods: The paper deals with the availability of natural hydrocarbons until 2100. Starting point of the evaluation is that the global demand will not be met by production of conventional oil and gas. Basis of the discussion is the comparison of available resources and reserves, recovery factors and technologies. The analysis comprised oil shale, tar sand, gas shale, tight sand gas, coal bed methane and gas hydrates. Taking the data of competent organizations into account, obviously the global resources of unconventional oil and gas significantly exceed the availability of conventional natural hydrocarbons in spite of the fact that their recovery efficiency is extremely low.

Although the production cost (operation expenditure) of unconventional hydrocarbons is usually much higher than those of the conventional ones, industrial scale production of tar sand oil, tight sand gas and coal bed methane has started over two decades ago and their contribution to total oil and gas production is already substantial in several countries (US, Canada). The authors stated, however, that wider application of sophisticated technology to recover unconventional hydrocarbons needs more extensive and intensive R&D activity and further, new paradigms are necessary in education, research, production, field management, and governmental regulation.

Citation: Lynsay A.Bensman, CC Technologies, Inc. (A DNV Company); Corinne Byrnes, P.E., National Grid, 'Use of an Internal Corrosion Threat Assessment to Identify Locations to Conduct an Integrity Assessment' (Paper presented at CORROSION 2009, Atlanta, GA, March 22 - 26, 2009)

Topic Area: Threat assessment, internal corrosion, data integration, direct evidence, pipelines, indirect data

Jurisdiction: USA

Abstract: Internal corrosion threat assessment is a systemic, analytical process that can be used to determine the degree of the threat of internal corrosion for a pipeline or pipeline system. Corrosion is more likely to occur under certain pipeline design and operating conditions that promote specific internal corrosion threats. The nature of the conditions that promote these threats can be defined. Data can then be analysed to determine whether any of the potential threats exist in the present or existed in the past. Direct information from non-destructive examinations may be used to verify whether internal corrosion has occurred at representative locations, thereby verifying the threat. If direct information reveals that no corrosion has occurred due to a specific threat mechanism, and no corrosion is actively occurring at present, then it is unlikely that the specific threat has resulted in metal loss at similar locations. Where direct evidence verifies the presence of internal corrosion, an integrity assessment, is then required. The steps involved in the internal corrosion threat assessment process are: data collection, system segmentation, gap analysis, threat ranking, direct evidence verification, and integrity assessment method selection. This paper discusses the process by which an internal corrosion threat assessment is performed. A case study is then presented to illustrate the process on a natural gas pipeline system. The threat assessment was performed on thirty-one (31) pipelines within the system. As a result of the threat assessment process an integrity assessment was only performed on five (5) lines within the system (as opposed to all 31). Regulator acceptance of the methodology for performing the threat assessment detailed in this case study was obtained.

Aims & Research Methods: In the United States, federal regulations require that jurisdictional pipelines for which the threat of internal corrosion exists be assessed by in-line inspection (ILI), hydrostatic pressure testing, Internal Corrosion Direct Assessment (ICDA) or another method to assure their integrity. Removing the threat of internal corrosion can be justified if sufficient historical data on gas quality, monitoring, and/or inspection exists. A need therefore exists for a technically defensible and systematic process by which the internal corrosion threat can be determined. This paper describes a standard approach to organizing, integrating and analysing data to identify whether internal corrosion is a threat for a given pipeline segment. A case study illustrating the implementation of the approach is also provided.

Citation: J. Daniel Arthur, SPE, Brian Bohm, Bobbi Jo Coughlin, and Mark Layne, SPE, ALL Consulting, 'Evaluating the Environmental Implications of Hydraulic Fracturing in Shale Gas Reservoirs' (Paper presented at SPE Americas E&P Environmental and Safety Conference, San Antonio, Texas, 23-25 March 2009)

Topic Area: Waste Management, Produced Water Use, Discharge and Disposal and Environmental and Social Impact Assessments

Jurisdiction: USA

Abstract: Natural gas production from tight shale formations, known as "shale gas", is one of the most rapidly expanding trends in onshore, domestic natural gas exploration and production. In some areas, development of shale gas resources is bringing drilling and production to regions of the country that has previously seen little to no oil and gas development activity. In plays like the Barnett Shale of Texas, development is occurring in urban and suburban areas where both operators and regulators are adapting to this new environment. Shales are the most abundant sedimentary rock in the Earth's crust and are present across the U.S. (Figure 1).

Shales have been sources of natural gas in small but continuous volumes since the earliest years of gas development. The first producing gas well in the U.S. was completed in 1821 in Devonian-aged shale near the town of Fredonia, New York (Harper, 2008). Early sources of natural gas were shallow gas wells that were from dug wells and natural gas seeps (NY DEC, 1992). Shallow wells and seeps were capable of producing small amounts of natural gas which were used for illuminating city streets and households (Frantz and Jochen, 2005). These early gas wells played a key part in bringing illumination to the cities and towns of the eastern U.S. (Harper, 2008). In contrast, modern shale gas development has become a technological play, in which development is facilitated by the technological advances the oil and gas industry has made in hydraulic fracturing and horizontal drilling over the last two decades.

Aims & Research Methods: Exploration, drilling and production of shale gas plays such as the Barnett, Fayetteville, and Haynesville have transformed the unconventional gas industry. These and other existing and developing plays have had unimaginable economic impacts to many regions, created tens of thousands of jobs, and have generated royalty payments to a variety of state and local governments as well as many individuals. At the core of shale gas development are two key technologies: horizontal drilling and hydraulic fracturing. Techniques used to hydraulically fracture horizontal wells completed in shale reservoirs often require larger volumes of fracturing fluid than might be common for conventional, vertical well stimulations. The rapid development of shale gas across the country has created concerns on issues such as the use of infrastructure and environmental impacts. Specifically, the common practice of hydraulic fracturing of these shales has attracted critical interest regarding risks potentially posed to groundwater and surface water. This paper will present a summary and evaluation of the environmental implications of hydraulic fracturing in shale gas reservoirs, with examples from multiple basins.

Citation: S. Rana, M.S., M.Eng., P.E., 'Environmental Risks - Oil & Gas Operations Compliance and Cost Control Using Smart Technology' (Paper presented at Asia Pacific Health, Safety, Security and Environment Conference, Jakarta, Indonesia 4-6 August 2009)

Topic Area: Environmental risks facing Oil & Gas industry

Jurisdiction: Global

Abstract: To focus on general environmental risks, statistics of environmental incidences and preventions related to well drilling, pipelines incidents and spills/leaks are described. Guidelines and some economically feasible options based on technological advances to minimize risks to environment & human health are also listed.

However, the paper essentially emphasizes the importance of technological advances to reduce industry's operational and environmental compliance costs during all phases (exploration, drilling, production, transportation, and storage) of oil and gas exploration and production (E&P). An an example, using modern technology, a substantial cost reduction from $8M in 1980 to about $0.1M today is realized for a 50 sq-mile exploration survey. The U.S. Department of Energy (DOE) estimates that by 2020, the lower cost compliance technology programs could decrease cumulative industry environmental compliance costs by over $36 billion. The cost reduction coupled with better survey and monitoring data allows less intrusive methods with least impact on environment. Compliance cost reduction further provides opportunities for investing in continued research & development (R&D) towards achieving environmental protection goals. Therefore, special emphasis is to be given to applications of "smart technological solutions" in achieving essential goals of environmental protection, economic benefits and environmental sustainability.

Aims & Research Methods: The objective of the paper is to review the environmental risks facing Oil & Gas industry with the perspective of reducing pollution and environmental compliance costs by using innovative technological tools.

The environmental risks of industry operations are many but are commonly associated with; drilling fluids containing toxic materials (including oil/grease, heavy metals, & naturally occurring radioactive materials); produced waters posing threat of accidental release; potential emissions of hydrogen sulfide in natural gas deposits with its deadly effects on human health; and blowout of exploratory wells (statistically, in 0.5-1% cases) under pressurized contents of a geologic formation resulting in harmful emissions; and other accidents severely impacting environment and the project economics.

Citation: George Demian, BP Canada Energy Company, 'Unlocking the Potential of CBM: An Exploration of Alberta's Royalty Treatment of Unconventional Gas' (Paper presented at 19th World Petroleum Congress, Madrid, Spain, June 29 - July 3, 2008)

Topic Area: Royalty Regulation of Unconventional Gas

Jurisdiction: Canada

Aims & Research Methods: As conventional gas production in Alberta continues to decline, it is estimated by the Alberta Geological Survey that the province's coal bed methane (CBM) resource base could contain approximately 75 trillion cubic feet of natural gas. An estimated 60% of that gas is located in the Manville region of Alberta, which offers better gas concentration, pay thickness and permeability, yet represents a mere 8% of current CBM exploration activity due to the additional expense of disposing the associated saline water into deep water-injection wells.

Research CBM exploration and development carries a considerably higher risk profile than conventional gas due to its significant upfront research & development costs, more complex horizontal completions and longer payback periods. The resulting price-sensitive environment together with historically low natural gas prices and a lack of financial incentives has rendered many deep well projects uneconomic. An evaluation of financial data, stakeholder information and past royalty history focuses primarily on the following questions: Assuming that the Alberta government wants to encourage CBM development,

1. Based strictly on the development and production costs in dry and wet Alberta coals, should the Alberta government provide financial incentives for CBM development?

2. If it is determined that the Alberta government should provide such an incentive, what type of financial incentive would be most effective in stimulating CBM development? An economic comparison of shallow well versus deep well exploration examines the effects of saline water disposal on a host of economic indicators including NPV, IRR and Payback Period. A real options analysis examines the optimal conditions for exploration and development of CBM from the perspective of a junior natural gas producer. In addition, Alberta's ongoing royalty review presents a new set of parameters upon which sensitivity analyses are conducted in order to determine whether a government-sponsored financial incentive is appropriate. Finally, a comparison of CBM best practices is explored between Canada, the United States and India. Introduction Alberta is Canada's energy capital, leading

the nation in oil and natural gas production and contributing to its reputation as an innovative and responsible resource steward. Traditionally, the province's natural gas production has come from conventional shallow gas wells. In recent years, conventional gas production has declined and producers have begun to explore for new sources of natural gas. This search has led to the examination of coal bed methane (CBM) as a viable and economic energy source. According to a study by the Alberta Geological Survey, Alberta's coal seams could contain

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Citation: A.W. Gaudlip and L.O. Paugh, SPE, Range Resources Appalachia LLC, and T.D. Hayes, Gas Technology Institute, 'Marcellus Shale Water Management Challenges in Pennsylvania' (Paper presented at SPE Shale Gas Production Conference, Fort Worth, Texas, USA, 16-18 November 2008)

Topic Area: Produced Water Use, Discharge and Disposal

Jurisdiction: USA

Abstract: The Appalachian Shale Basin encompasses several large natural gas plays in the U.S. that geographically cover significant areas of five states in the Eastern U.S. including Pennsylvania, West Virginia, Ohio, New York and Kentucky, as shown in Figure A. As long as 10 year NYMEX strip prices for natural gas remain above $8/mmBtu, well drilling activity in the Appalachian Basin is expected to escalate throughout the next decade. Within this region, one of the major shale plays where development activity is greatest is the Marcellus Shale.

Many of the logistical problems associated with the development of shale gas stem from the large amounts of water associated with the completion and operation of shale gas wells that must be transported, stored and disposed of in a manner that is protective of human health and the environment. In the course of developing shale gas in the Appalachian Basin, thousands of wells will be drilled and completed. Hydraulic fracturing ("fracing") is a necessary step for the completion of each of these wells in order to achieve economic well performance in terms of natural gas production; this step requires between 1 and 4 million gallons (3,800 and 15,200 m^3) of water for successful completion of each well. Vertical wells (representing approximately 10% of the wells drilled in the Barnett Shale) require approximately 1 million gallons (3,800 m^3) and horizontal wells (representing the remaining 90% of Barnett wells) require 3-4 million gallons (11,400 to 15,200 m^3) according to a recent survey among Barnett Shale Producers (Galusky, 2007). Similar volumes of water per well will be required in the drilling and completion of Marcellus Shale gas wells.

The challenge ahead for Marcellus Shale gas developers is to identify techniques to deliver the water required for drilling and completion and to develop methods for the disposal of brines represented by flow back and produced water that comply with applicable environmental regulations. The purpose of this paper is to outline a number of considerations and potential alternatives associated with meeting this challenge in Pennsylvania.

Aims & Research Methods: The management of water resources poses considerable challenges to the Pennsylvania Oil and Gas Industry as it begins to expand the development of the Marcellus Shale. Although the play overlies a seemingly water-rich region the sourcing of fresh water for drilling and completions operations are far from straight forward due to regulatory restrictions. Development companies planning to operate in the state must seek to understand an evolving regulatory landscape that is struggling to create a framework specific to shale gas development. The current regulatory status limits conventional methods of surface water withdrawals from streams and rivers and forces industry to search out alternative water sources from groundwater wells, municipalities, private sources and recycled waters. In addition to the challenge of fresh water sourcing, operators are also limited in the options for disposing waste-waters generated during drilling, flow back and production. The current methodology of pre-treatment and discharge via NPDES permit has a finite capacity which is projected to be insufficient in a short time as the level of drilling activity increases. There is very limited potential for underground injection of fluids into permitted disposal wells and virtually no need for weighted brines for well control. Alternative disposal and recycling options which could potentially process the waste-waters into recycled fresh water and concentrated brine or salt cake are being actively studied by individual operating companies and the industry as a whole.

Citation: Pierre Goud, Stig Helland, Alexandre Goldszal, Ulf E. Moltu, and Laurence Pinturier, Total E&P Norge AS, 'Emerging issues in produced water management: Total EP Norge approach' (Paper presented at SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, Nice, France, 15-17 April 2008)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: EU (Norway)

Abstract: Produced Water Management is a worldwide concern with the growing number of mature fields and stringent discharge's regulations set in many countries. The discharge in the North Sea is regulated by the Convention for Protection of the Marine Environment of the North-East Atlantic (OSPAR) [1]. The purposes of the recommendations issued within OSPAR are, amongst others, to prevent and eliminate pollution by oil and other substances caused by discharge of produced water into the sea. The current legislation concerns only dispersed oil concentration where present limit is 30mg/l (was 40 mg/l until 1st of January 2007), but the long term objective is that by 2020 discharges shall present no harm to the marine environment.

Aims & Research Methods: The Norwegian Continental Shelf (NCS) is subject to stringent requirements regarding offshore discharges. Focus has previously been on dispersed oil concentration (OIW) in produced water (PW) discharge, but management tools like the calculation of the Environmental Impact Factor (EIF) have also shown the important contributions of naturally occurring dissolved components and production chemicals. Even if the legislation seeks a balance between technical feasibility and economic cost, it is believed that regulators may wish to move to requirements where dispersed oil concentration is not the only parameter to be considered.

Furthermore, recently developed water treatment technologies are currently being installed on the NCS. In relation with the various water management actors (operators, manufacturers, researchers, authorities), Total E&P Norge's R&D department is strongly involved in the issues related to installation and operation of these technologies. The work described in this study was performed in order to set guidelines to define strategy regarding R&D future directions within water management, foreseeing worldwide more restrictive legislation.

The paper presents a methodology, based upon experience from the NCS, to help to meet upcoming issues in produced water management. Efficiency and operating window of various produced water treatment technologies have been defined according to water inlet quality and field characteristics. The results are presented through a database to compare and rank performances and to set up a global vision of water treatment capabilities. The requirements of offshore facilities, operating criteria, etc. are also taken into consideration and are recorded in the database. By use of the database, combined with the EIF approach identifying, the most harmful compounds of a produced water discharge and quantifying the potential environmental benefits of PW management actions, the most appropriate technologies can be selected on a given field. Fewer field trials will have to be performed and new technologies will be installed more efficiently in the produced water treatment line. This methodology has been validated by Total E&P Norge on several cases on the NCS where new technologies have been implemented.

Citation: David C. DeGagne, Noise Solutions Inc., and Donald Burke, Energy Resources Conservation Board, 'Controlling Environmental Noise From Coalbed Methane Operations' (Paper presented at CIPC/SPE Gas Technology Symposium 2008 Joint Conference, Calgary, Alberta, Canada, 16-19 June 2008)

Topic Area: Health, Safety, Security, Environment and Social Responsibility and Sustainability/Social Responsibility

Jurisdiction: Canada

Abstract: A significant challenge for Coal Bed Methane producers is dealing with the impacts of high density development needed to effectively recover the natural gas resource. One such concern is the need to meet regulatory requirements for environmental noise as stated in the Energy Resources Conservation Board (ERCB) *Directive 038: Noise Control* (*ERCB Directive 038*) and Colorado Oil and Gas Conservation Commission (COGC) *Aesthetic& Noise Control Regulations, Series 800 (COGCC Noise Regulations)*. Anyone who has ever been involved in the process of complying with regulatory noise standards will agree that it is a complex and challenging task. Some regulated companies struggle through this process often dealing with unfamiliar considerations such as trying to predict facility noise levels before it is even built, or gambling on a best guess as to what is the right, least expensive amount of noise mitigation needed to meet regulatory requirements for environmental and occupational noise. Even the best of intentioned operators fail to hit the mark, sometimes by wide margins and end up with a situation that is potentially worse than when they started. No company wants to go through a process where in the end a lot of time, resources, and public confidence have been lost not to mention now being in a regulatory non-compliant status.

This paper will elucidate valuable lessons & experience learned and case histories for the successful approach to noise solutions accepted by regulatory agencies and industry clients. In addition to discussing the complexities of acoustical engineering practices this presentation will also cover the most significant points of *ERCB Directive 038* and *COGCC Noise Regulations*.

Aims & Research Methods: The energy needs of North America are continuing to grow nearly exponentially and the desire to have clean energy options makes natural gas an obvious contender. Considering the maturity of conventional gas reservoirs in the Western Canadian Sedimentary Basin (WCSB) and Western United States, the most significant new source of natural gas are unconventional deposits found primarily in coal or shale seams. In the first few years of the new millennium, the base price of natural gas had been very low on the belief that there was an oversupply in the marketplace and incentives were towards renewable energy sources (NEB 2003). Although crude oil prices were rising dramatically, natural gas was not tracking this increase leading to a decline in exploration and replacement of reserves.

Change started to occur slowly largely on the hypothesis that carbon dioxide (CO_2) from the burning of fossil fuels was the sole driver in climate change (IPCC, 2007) despite the steadily growing volume of peer reviewed scientific literature demonstrating that CO2 is an extremely minor forcing at best (2 – 37). Yet, this anthropogenic caused global warming view dominated in the media coverage and has for a time molded the development of government policy toward the reduction of CO_2 and indeed its reclassification as a pollutant.

Regardless, it is becoming increasingly clear that unless we intend to return to the dark ages, North America's energy must come from some non-renewable source given the limited production capabilities of the so called renewable options such as wind and solar. Deep conventional gas reservoirs can only deliver limited supplies and new pool finds that can satisfy the demand are not likely to be discovered in the continental basin. Hence the move to coal bed methane, a readily available source of clean natural gas that can go a long way to meeting the energy demands of North America. However, for coal bed methane to reach its potential operators must find innovative ways to overcome the growing concerns of nearby communities.

Citation: P.H. Stark, K. Chew, and Bob Fryklund, HIS, 'The Role of Unconventional Hydrocarbon Resources in Shaping the Energy Future' (Paper presented at International Petroleum Technology Conference, Dubai, U.A.E., 4-6 December 2007)

Topic Area: Research and Development Programs

Jurisdiction: Global

Abstract: Among the three pillars of future oil and gas supplies, the unconventional resource potential greatly exceeds that of the other two pillars - growth to known fields and yet to find fields. Estimated in-place resource of bitumen, extra-heavy oil and shale oil are about 7 times greater than the estimated recoverable conventional liquids from field growth and yet to find sources. Excluding gas hydrates, estimated in-place volumes of unconventional gas are estimated to be 4 to 5 times greater than estimated recoverable conventional gas from field growth and yet to find sources. In-place unconventional resources are huge but there are substantial challenges to transform these resources into supplies.

Unconventional hydrocarbons are found in tight, low permeability, low porosity, low recovery "difficult to produce" rock formations, such as tight sands, shales, chalks and coal seams. These rocks require distinctive completion, stimulation, and / or production techniques to recover the hydrocarbons. Fractures often are critical to establish economic recoveries and unconventional reservoirs may be over or under pressured and typically are not affected by hydrodynamic influences. Unconventional reservoirs often are described as

"resource plays". Many are pervasive throughout a wide area and also are referred to as "Continuous –type Deposits". Realistically, the boundaries between "conventional" and "unconventional" are gradational and change over time. For purposes of this report original definitions applied some 20 years ago to define U.S. tight gas reservoirs are used. Tight reservoirs were defined as having less than 0.1 millidarcy permeability and tight reservoirs typically have 13% or less porosity. Unconventional reservoirs also were characterized by low recovery factors – often less than 10% recovery on primary recovery. Conversion-sourced hydrocarbons such as gas to liquids and coal to liquids, fermentation of carbohydrates, non-fossil renewable resources and gas hydrates are not included in this report.

Aims & Research Methods: Unconventional resources have been identified throughout the world and contain enormous in-place volumes but tight and unfamiliar reservoirs challenge the transformation of these resources to supplies. The key issue is whether industry can grow production from unconventional reservoirs at a rate that will offset declines from older conventional reservoirs. E&P companies are attracted to such resources because they have low exploration risk, material production volumes, long-lasting production and exist near mature, stable markets. In addition, with the exception of Canadian bitumen production, current recovery factors are low so these accumulations have the potential for a substantial "technology dividend". At some 7.5 trillion barrels, estimates of the in-place resource of bitumen, extra-heavy oil and shale oil are over three times greater than the 2.25 trillion barrels of recoverable conventional oil estimated to have been discovered to date. Unconventional liquids production from Canada and Venezuela currently comprises about 2% of world liquids production. Current projections indicate these giant resources will add no more than about 400,000 barrels of annual new production. This is less than desired to offset global declines of 5 to 6 MMb/yr. Excluding gas hydrates, remaining recoverable resources of the three principal gas resource play types are estimated at over 1,000 trillion cubic feet and there is significant potential for growth in unconventional gas resources outside North America. Even though U.S. unconventional gas well completions have tripled the growth of gas from unconventional reservoirs has not offset declines in conventional gas production.

Citation: A. Merryman, The Frost National Bank, 'You Cannot Be Ethical if You Do Not Know the Rules' (Paper presented at SPE Annual Technical Conference and Exhibition, Dallas, Texas, 9-12 October 2005)

Topic Area: Ethics

Jurisdiction: USA

Abstract: Modern-day philosophers still grapple with questions of ethics that philosophers like Plato and Socrates discussed over 2500 years ago. While the passage of time has not eased the burden of ethical behaviour, it has provided some rules to guide those seeking to make ethical decisions. This paper addresses some of those rules and their application to evaluation of oil and gas reserves. Rules can be very comforting to those seeking direction and guidance. Unfortunately, the evaluation engineer often has so many rules that the rules themselves cause conflicts and confusion. This paper will help the reader recognize that different rules will lead to different results. Of course, following the rules will not necessarily lead to an ethical decision. However, only by knowing the rules and following the appropriate rules for the required purpose can evaluation engineers and managers obtain the information needed to make ethical decisions.

We need rules to guide us in following consistent procedures to reach our goals. If our goal is to make ethical decisions, we will find rules to evaluate actions that lead to "good" or "bad" outcomes. Our discipline for dealing with what is good and bad (and with moral duty and obligation) is often accepted as a definition of ethics. It follows that the process of making ethical decisions has at least two steps. The first step includes an evaluation of the facts involved to determine expected outcomes from different courses of action. The second step involves choosing the "good" outcome based on moral duty or obligation.

Aims & Research Methods: A supervisor is comparing a projection prepared following traditional department procedures to a significantly higher projection from a computer model. The traditional procedures include structure maps and isopach maps of net pay. The isopach maps incorporate "cut-offs" for porosity, water saturation, and shale; and recognize reservoir boundaries based on lease lines. The computer model was constructed by using available data for input and allowing the computer to predict recovery without artificial "cut-offs" and without an intermediate step to construct maps.

Before trying to select the "right" projection, the supervisor will want to review the rules. Rules from academic training might help validate each projection and perhaps resolve some of the differences. Rules based on experience and judgment might help. Finally, reflection on the purpose of the report, the intended use, and the intended audience will reveal other rules. For instance, projections to support development on a concession outside the United States should follow the rules of the host country and the terms of the concession agreement.

This paper is the result of discussion with friends that led to a survey of engineers working in producing companies, consulting firms, and universities. The most common responses suggested management can do a better job of disseminating and enforcing the rules.

This paper will demonstrate that many rules are involved, some will conflict with others, and some will change. Reflection on the rules reminds managers that there is a purpose for every evaluation, and potentially, a different “right” answer for each purpose. Only by disseminating and enforcing the rules can management know that ethical decisions are being made, based on projections of evaluation engineers.

Topics in this paper address only the first step by discussing the rules for evaluation. Exhibit 1 provides examples of conflicting rules that make this first step more challenging than it might appear. In the United States, a conflict between rules for preparing tax reports for the Internal Revenue Service and rules for preparing financial reports for the Securities and Exchange Commission can be easily resolved by knowing the purpose of the report and the appropriate rules. Conflicts caused by a middle manager suggesting rules that differ from the rules espoused by senior management are more difficult.

Citation: Barry Goldstein, Michael Malavazos, Alexandra Wickham, Michael Jarosz, Dominic Pepicelli, Mieka Webb, Dale Wenham, State Government of South Australia, ‘Regulatory Nirvana for Hydraulic Fracture Stimulation’ (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Hydraulic Fracture Stimulation

Jurisdiction: Australia (SA)

Aims & Research Methods: Government are challenged to deploy trustworthy regulation to enable profitable and environmentally sustainable unconventional petroleum projects. A key activity under scrutiny during the development of these projects is hydraulic fracture stimulation. Regulatory Nirvana for unconventional projects and conventional projects alike entails:

- Pragmatic licence tenure;
- Regulatory certainty and efficiency without taint of capture;
- Regulators and licensees with trustworthy competence and capacity;
- Effective stakeholder consultation well-ahead of land access;
- Public access to details of significant risks and reliable research to backup risk management strategies so the basis for regulation is contestable anytime, everywhere;
- Timely notice of entry with sufficient operational details to effectively inform stakeholders;
- Potentially affected people and organisations can object to land access - without support for vexatious objections;
- Fair and expeditious dispute resolution processes;
- Fair compensation to affected land-users;
- Risks are reduced to low or as low as reasonably practicable (ALARP) while also meeting community expectations for net outcomes;
- Licensees monitor and report on the efficacy of their risk management, and the regulator probes same;
- Regulator can prevent and stop operations, require restitution, levy fines and cancel licences; and
- Industry compliance records are public, so the efficacy of regulation is transparent.

These principles are deployed in South Australia where:

- 24 unconventional gas plays are being explored, each with giant gas potential;
- Hundreds of wells have been safely hydraulically fracture stimulated;

Since implementing South Australia's *Petroleum and Geothermal Energy Act 2000* [1] (PGEAct), more than 11,000 notices of entry for petroleum operations led to just one court action, and that was to establish a legal precedent that geophysical surveys can extend outside a licence to enable a complete understanding of the potential resources within a licence.

Citation: T. Anderson, C. Hooker, A. Uttecht, M. Boucher, N. Wagner, National Oilwell Varco, 'Dust Collection System for Personnel Health During Fracturing Operations' (Paper presented at 2013 SPE / IADC Drilling Conference and Exhibition, Amsterdam, The Netherlands, Mar 05 - 07, 2013 2013)

Topic Area: Silicosis, Hydraulic Fracturing, Dust, Proppant, Silica

Jurisdiction: USA

Abstract: Use of silica sand as a proppant has grown dramatically over the last decade with the rise in production of unconventional resources. Massive volumes of sand are transported to a well site and pneumatically conveyed into frac sanders. After formation fracture, sand is moved from the sanders across conveyers into the blender where it's mixed with fluid for transport down hole. During these operations, a significant amount of silica dust enters the air and onsite personnel are exposed. The dangers of inhaling dust and fine particles have been known for hundreds of years, yet many workers today are still not adequately protected. Silicosis, the most widespread industrial disease, results from exposure to crystalline silica and kills hundreds of workers every year and detrimentally affects the lives of untold more. Historically, many cases of silicosis have been associated with sand blasting, mining, and construction. There is now potential for connections to the hydraulic fracturing industry. Symptoms of silicosis can take 10-15 years to materialize, but once it develops the disease progresses incurably. According to a recent U.S. National Institute for Occupational Safety and Health (NIOSH) study, many frac sites exposure levels exceed, sometimes by a factor of 10, the NIOSH Recommended Exposure Limit (REL) to crystalline silica.

Aims & Research Methods: The rapid expansion of the hydraulic fracturing industry has in some places outpaced necessary regulations and equipment for worker safety, especially dust control. A dust collection system has been developed to target sand filling operations where sand particles are likely to be released into the air. With a system in place that aims to contribute to the U.S Occupational Safety and Health Administration (OSHA) permissible exposure levels (PELs), the threat of silicosis is significantly reduced from the hydraulic fracture process and unconventional development is made safer for everyone involved. This paper will discuss the dust collection equipment, its deployment and integration with existing equipment, as well as other activities to reduce worker exposure.

Citation: Amit D. Nakhwa, Boots & Coots, Ken Huggins, Halliburton, Ronald Sweatman, Consultant, 'Shale Gas Well Fracturing Technologies Help Address HSE Concerns' (Paper presented at Offshore Mediterranean Conference and Exhibition, , Ravenna, Italy, March 20 - 22, 2013)

Topic Area: Health, safety, and environmental concerns for hydraulic fracturing

Jurisdiction: Global

Aims & Research Methods: This paper discusses how applied science, historically safe operations, advancements in technology and standard processes are helping to address and reduce health, safety, and environmental (HSE) concerns for hydraulic fracturing in shale gas wells. The technologies presented include an improved method of removing total suspended solids in order for water recycling, UV light equipment used for bacteria control in fracturing fluids, fracturing fluids comprised of ingredients sourced from the food industry, aquifer protection using 3D fracture mapping and microseismic fracture monitoring and equipment footprints allowing for smaller well locations. This combination of scientifically-derived technologies and standards (a.k.a. best practices) is assisting in lowering the risk for HSE incidents and addressing misconceptions about hydraulic fracturing. To further address these HSE concerns, members of Oil & Gas (O&G) industry associations, including the American Petroleum Institute (API), Society of Petroleum Engineers (SPE), International Association of Drilling Contractors (IADC) and the International Association of Oil & Gas Producers (OGP) based in London and Brussels, continue to develop sound science and field-proven best practices in the form of industry standards, such as those referenced in this paper.

Technical publications by O&G service companies have provided numerous case histories highlighting these applicable technologies. These presented technologies and practices have helped to demonstrate the positive impacts for shale gas development projects.

Citation: S.T. Cham, P. Stone, Gas Industry Social and Environmental Research Alliance and CSIRO, 'How Can Understanding Community Concerns About Hydraulic Fracturing Help to Address Them?' (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Hydraulic Fracturing

Jurisdiction: Australia

Aims & Research Methods: Hydraulic fracturing has been the focal point of widespread and global public debate. While the resources sector typically sees hydraulic fracturing as a low-risk method for accessing the coal seam and shale gas reserves required to meet growing public demand for energy, some in the community perceive it as an unmanageable and unacceptable risk. Concerns about hydraulic fracturing and the coal seam gas (CSG) industry include the health impacts of chemicals used, contamination of water supplies from fugitive gas after hydraulic fracturing, equity of land and water access, long term impacts on groundwater, and the full life cycle emission of greenhouse gases from CSG compared to that of coal. This paper highlights the main psychological drivers behind some of these concerns and a possible approach to effectively address them.

Citation: Kimberly E. Carter, J. Alexandra Hakala, and Richard W. Hammack; National Energy Technology Laboratory, U.S. Department of Energy, 'Hydraulic Fracturing and Organic Compounds - Uses, Disposal and Challenges' (Paper presented at 2013 SPE Eastern Regional Meeting, Pittsburgh, Pennsylvania, USA, Aug 20 - 22 2013)

Topic Area: Waste Management, Waste Management, Reporting and Environmental and Social Impact Assessments

Jurisdiction: USA

Abstract: Hydraulic fracturing has allowed oil and natural gas producers in the U.S. to effectively tap reservoirs that would otherwise be unfeasible to produce. In recent years, the natural gas industry has experienced a boost in production through the increased use of hydraulic fracturing in shale and tight sand formations. Despite its production advantages, the hydraulic fracturing process is not without its concerns. Hydraulic fracturing utilizes large quantities of water which, together with a number of chemical additives known as the ‘fracturing fluid’, are injected into underground formations. After being injected, between 5 and 60 percent of this fluid mixture flows back to the surface as produced water carrying with it any remaining chemical additives and naturally occurring material from the formation. Due to the complicated cycling of water and organic compounds during hydraulic fracturing and produced water treatment, the ability to independently identify and quantify chemicals associated with fracturing activities at different stages of the shale gas water lifecycle remains challenging. The ability to identify and quantify organics may be relevant both for maximizing efficiency during fracturing and water treatment, and for environmental management.

Aims & Research Methods: Continued analyses of both the ‘hydraulic fracturing fluid’ and the produced water have shown that not all organic compounds that were injected into the well return to the surface. This suggests that adsorption/desorption and/or chemical transformation processes are taking place within the formation. Determination whether organic compounds detected in produced waters are synthetic or naturally-derived from the reservoir is complicated by the number of compounds that exist both naturally in the formation, and are injected with the hydraulic fracturing fluid. Depending on the fracturing job, roughly 4 – 10 different synthetic organic compounds are added to the hydraulic fracturing fluid at one time. A survey of 1000 API registered wells hydraulically fractured in Western Pennsylvania and West Virginia showed roughly 150 different organic compounds used as ingredients in the fracturing fluids. This makes identification and analysis of these compounds in produced waters difficult.

Further complications for evaluating organics in the shale gas water life cycle stem from the use of recycled produced waters. Analysis of samples from produced water treatment facilities showed the presence of organic compounds in the inlet and effluent of the treatment facility. The effluent of many treatment plants is reused bringing with it the organic compounds that are still present to the next hydraulic fracture job. This paper looks into the different organic compounds used in the hydraulic fracturing process, their possible life-cycle after the process, the difficulties encountered when analysing for these compounds, and possible challenges with site planning and environmental decision-making.

Citation: Marc Langford, SPE, and Brian Holland, SPE, Centrica; Christopher A. Green, SPE, G Frac Technologies; Bogdan Bocaneala, SPE and Mark Norris, SPE, Schlumberger, ‘Offshore Horizontal Well Fracturing: Operational Optimisation in the Southern North Sea’ (Paper presented at SPE Offshore Europe Conference & Exhibition 2013, Aberdeen, United Kingdom, Sep 03 - 06, 2013 2013)

Topic Area: Hydraulic Fracturing and Gravel Packing, Design and Optimization and Completion Planning, Design and Installation

Jurisdiction: UK

Abstract: Historically, cemented liners and “plug-and-perf” completions have been used for horizontal fracturing in the southern North Sea. Such operations often involve extensive coiled tubing interventions between fracturing stages. This introduces unnecessary technical and associated operational risks due to the extended, long horizontal well architectures that

are often used. An openhole, ball-activated multi-stage system, recently introduced into the North Sea, was applied in tandem with the application of a new environmentally-compliant seawater fracturing fluid. The use of the seawater-based system allowed sufficient fluid volume to be loaded and pumped for the placement of four hydraulic fracturing treatments on consecutive days, without the need for the vessel to disconnect and sail back to port to reload fresh water.

As a result of this dual development and correct application of the completion technologies, the requirement for coiled-tubing interventions between stages was eliminated, saving both vessel and rig time. Ultimately, such savings result in faster turnaround times for wells to be placed on production, thereby improving overall well economics. Following the success of the application of this technology the operator is actively pursuing similar new complimentary technologies. Such operational improvements will not only enhance well economics, but possibly define future North Sea fracturing operations.

Aims & Research Methods: Recently, there has been an increased interest in optimising horizontal multifrac completion technologies used to complete unconventional US onshore wells. The developing technologies and techniques are increasingly being used for offshore applications and have found widespread use in horizontal wells in areas such as the southern North Sea. This case history describes the application of two complementary technologies which have enabled the placement of 1.4 million pounds of proppant in four treatments within 4 consecutive days. Prior to this similar offshore completion operations have typically taken 12 to 25 days.

Citation: G. Steyl, Golder Associates Pty Limited and University of the Free State, G. J. van Tonder, University of the Free State, 'Hydrochemical and Hydrogeological Impact of Hydraulic Fracturing in the Karoo, South Africa' (Paper presented at ISRM International Conference for Effective and Sustainable Hydraulic Fracturing, Brisbane, Australia, May 20 - 22, 2013)

Topic Area: Hydraulic Fracturing

Jurisdiction: South Africa

Abstract: Hydraulic fracturing has become a prevalent public and regulatory issue in most countries developing shale gas. South Africa has only recently been exposed to terrestrial gas resource development and this has created unique regulatory issues which are currently being resolved. One of the key issues under debate is the protection of groundwater resources in rural areas, since most of South Africa's rural and some inland cities are dependent on groundwater for potable water supply. A second concern is the infrastructure requirements to handle the material movement processes during the development of each wellfield and subsequent processing of waste generated on site. Regarding the waste material production, a phased approach is required which considers the initial well development activities, production and subsequent well abandonment. Each phase has a unique risk associated with it and thus would require different management options. At the current stage most of the focus is on the initial stages of well development but the long term view has been neglected to some extent. Due to the unique geological structure of the Karoo, the presence of dolerite structures, a number of risk mitigation methods might be required to successfully develop hydraulically fractured wells. In all aspects the chemical and hydrogeological impacts related

to wellfield development cannot be ignored in the Karoo aquifer system, as it may directly influence human and environmental health.

Aims & Research Methods: This paper will present chemical perspective on the hydraulic fracturing perspective that will deal with the impact of hydraulic fracturing fluid and flow back water. Additionally, the interaction of wellfield development and hydrogeology of the Karoo area will be discussed and how it relates to future water quality issues.

Citation: Amit D. Nakhwa and Ken Huggins, Halliburton, Ronald Sweatman, Consultant, 'New Technologies in Fracturing for Shale Gas Wells are Addressing Environmental Issues' (Paper presented at 18th Middle East Oil & Gas Show and Conference (MEOS), Mar 10 - 13, 2013 2013, Manama, Bahrain, Bahrain International Exhibition Centre)

Topic Area: Hydraulic Fracturing

Jurisdiction: USA

Abstract: To further address these environmental issues, members of Oil & Gas (O&G) industry associations, including the American Petroleum Institute (API), Society of Petroleum Engineers (SPE), International Association of Drilling Contractors (IADC) and the International Association of Oil & Gas Producers (OGP) based in London and Brussels, continue to develop sound science and field-proven best practices in the form of industry standards, such as those referenced in this paper.

Technical publications by O&G service companies have provided numerous case histories highlighting these applicable technologies. These presented technologies and practices have helped to demonstrate the positive impacts for shale gas development projects.

Aims & Research Methods: This paper discusses how applied science, historically safe operations, advancements in technology and standard processes are helping to address and reduce environmental issues (EI) for hydraulic fracturing in shale gas wells. The technologies presented include equipment footprints allowing for a reduced risk for environmental effects, 3D fracture mapping, microseismic fracture mapping, "green" fracturing fluids, bacteria control through UV light technology and an improved method of water recycling. This combination of scientifically-derived technologies and best practices (a.k.a standards) is assisting in lowering the risk for EI and addressing misconceptions about hydraulic fracturing.

Citation: Martin Rylance, SPE, BP Exploration, 'Optimising Remote Unconventional Gas Exploration' (Paper presented at 2013 SPE Middle East Unconventional Gas Conference & Exhibition, Muscat, Sultanate of Oman, Jan 28 - 30, 2013 2013)

Topic Area: Completion Planning, Design and Installation and Horizontal/Multilateral Wells

Jurisdiction: USA

Abstract: Exploration and Appraisal of Unconventional gas, in remote areas, brings with it a variety of challenges; which are not normally encountered in established development areas such as North America. These challenges include, higher cost(s), logistical issues, lack of existing infra-structure, limited well numbers to name but a few. This paper will describe some of the important considerations, technology choices and approaches that can be considered in order to optimise such a remote Exploration and Appraisal programme.

There are a number of considerations, selections, choices and decisions to be made for an Exploration and Appraisal programme, which can significantly affect the results and outcome when performed in a remote environment. For example, vertical vs. horizontal wells, lower completion technology, stimulation approaches and data gathering choices. Due to a number of unique conditions in remote locations, the optimum decisions are not always obvious, nor always reflect typical practices in established areas and this paper will describe the rationale behind this and the appropriate considerations for various Drilling and Completion aspects.

The author will describe, options, considerations and decision making processes based on experience from recent case histories from a number of world-wide Exploration and Appraisal operations in unconventional gas.

Aims & Research Methods: The paper will attempt to indicate the relative importance and value associated with these decisions and their impact on the potential success of an Exploration and Appraisal programme.

Unconventional gas Exploration and Appraisal programmes can be challenging to progress in established areas; and this can be compounded by several orders of magnitude when operating in a remote environment. The requirements for establishing unconventional resource assessment can be somewhat different to conventional approaches and an Appraisal programme should take this into account. This paper summarises a number of key lessons learned from a worldwide selection of Unconventional operations and distils them into a philosophy that promotes and encourages success.

Citation: P.A. Parra, N. Rubio, C. Ramirez, B.D. Guerra, V.A. Exler, I.R. Campos, M.D. Trejo, J. Olguin, C.H. Vargas, R. Valbuena, D.F. Soler, M.I. Weimann, V. Lujan, P. Bonningue, Schlumberger; P.G. Reyes, R. Martinez, R. Muñoz, E. Rodriguez, M. Garcia, PEMEX, 'Unconventional Reservoir Development in Mexico: Lessons Learned From the First Exploratory Wells' (Paper presented at SPE Unconventional Resources Conference - USA, The Woodlands, TX, USA, Apr 10 - 12, 2013 2013)

Topic Area: Completion Planning, Design and Installation

Jurisdiction: USA

Abstract: Lately, the United States of America has experienced tremendous growth in shale plays development. To date, more than 5,000 wells have been drilled and completed in more than 20 fields. Worldwide, exploration and development of shale plays has also increased. Currently, due to low gas prices, operating companies are shifting resources to explore and develop condensate or oil producing shale plays. In 2010, exploration of gas-rich and possible liquid-rich shale reservoirs began in northern Mexico. The main challenges were to demonstrate the availability of reserves and set the foundation for future development of these plays, with the information gathered in a few exploratory wells. Wells were aimed at the upper cretaceous Eagle Ford formation and at the Jurassic Pimienta formation. As of July

2012, six horizontal exploratory wells were drilled and completed, implementing in four of them a two stage integrated workflow to achieve the objectives set.

The drilling stage used a petro physical and geomechanical static model to identify the most prospective interval in the reservoir, define the best drilling azimuth direction and landing point, and reduce drilling risk. Real-time geosteering was implemented to achieve the targeted navigation window. In the completion stage, a reservoir-centric completion and stimulation software, which integrates petro physical and geomechanical data, was used to optimize the completion and stimulation design. Results were evaluated using various techniques, including micro seismic monitoring, production history matching, and production logging and well testing.

Aims & Research Methods: This study presents the details of the workflow implemented and the lessons learned in each well. The main lessons learned were: 1. Proper well landing was key to achieving predicted production and booking of reserves; 2. Anisotropic geomechanical models were the most appropriate for simulating hydraulic fracturing treatments; 3. Conventional hydraulic fracturing models do not always represent the behaviour of fractures in the unconventional formations evaluated; 4. Production rates along the lateral of the well can vary significantly with single stages producing up to 20% of the total well production. The conclusions and lessons learned in this study have formed the bases and will be important to the subsequent development of the different shale plays in Mexico—and around the world.

Citation: A. Darishchev, SPE, E.N.S.G. de Nancy , Beicip-Franlab ; P. Lemouzy, SPE, and P. Rouvroy, Beicip-Franlab, France, 'On Simulation of Flow in Tight and Shale Gas Reservoirs' (Paper presented at 2013 SPE Middle East Unconventional Gas Conference & Exhibition, Muscat, Sultanate of Oman, Jan 28 - 30, 2013 2013)

Topic Area: Reservoir Engineering of Subsurface Storage, Unconventional Hydrocarbon Recovery, Management of Challenging Reservoirs, Risk Management and Decision-Making and Design and Optimization

Jurisdiction: Global

Abstract: Applicability of existing numerical simulation methodologies to unconventional reservoirs is questionable and requires investigation and research.

We have focused on gas flow simulation of a highly heterogeneous fractured reservoir with extremely low matrix permeability. First of all we have considered the key roadmap components, natural gas composition, rock properties, critical elements and the main features inherent in tight and shale gas reservoir engineering. Using field reference data and a reservoir simulator, different scenarios of gas production have been modelled.

Aims & Research Methods: This paper presents results from a sensitivity study of the dimension of hydraulic fracturing stimulated reservoir volume (SRV), matrix and propped fracture permeability which is spatially varied as one of the most realistic approaches, and of the bottom hole pressure. The approaches "dual porosity - single permeability", "dual porosity - dual permeability" and key reservoir properties have been reconsidered for specific geological and technological conditions in order to support decision making in unconventional reservoir management. Assuming pseudo-steady state gas flow, the simulation time step and gridblock size have been adjusted with a sector model represented by a logarithmically refined grid. In comparison with previous studies, it has been stated that the proposed approach of discrete fracture network modelling can be used in cases where the dual medium approach is questionable or inappropriate. The simulations of flow that have been performed, showed that the contribution of unstimulated reservoir volume (in the vicinity of the SRV) to gas production is non-negligible and can be a significant part of gas production to be taken into account in some field cases.

The results of this study can be used in unconventional reservoir modelling and flow simulation to identify development, stimulation, and completion strategies aimed at optimization of gas production, reservoir performance and gas recovery. The proposed approach also supports risk and uncertainty analysis, revenue estimation and economic performance evaluation.

Citation: Lucas Fontenelle, SPE, Melissa Weston, Paul Lord, and Johanna Haggstrom, Halliburton, 'Recycling Water: Case Studies in Designing Fracturing Fluids Using Flowback, Produced, and Non-traditional Water Sources' (Paper presented at 2013 SPE Latin-America Conference in Health, Safety, Environment & Social Responsibility Conference in the Oil and Gas Industry, Lima, Peru, Jun 26 - 27, 2013 2013)

Topic Area: Recycle water, produced water, flow back water

Jurisdiction: USA

Abstract: Well stimulation flow back water generally contains the chemicals and/or by-products of a hydraulic fracturing process used on a specific well. Produced water is a different category, which is naturally occurring formation brine that is produced along with the hydrocarbons from the well, and can contain large quantities of dissolved salts, dispersed hydrocarbons, and other materials. Both of these waters are considered waste by-products of oil and gas production and typically present logistical difficulties for operators. Some of the challenges include transportation of waste water over long distances as well as local government and environmental regulations related to the safe disposal of the water from oil fields.

The ability to recycle flow back and produced water provides great opportunities for service providers and producers to help reduce the total amount of fresh water that is used in their operations. By reducing the volumes of fresh water that are used in hydraulic fracturing and, at the same time, reducing the amount of flow back and produced water that has to be transported and disposed, operators are able to show their commitment to the community, the environment and can potentially minimize logistics. These benefits, however, can come with difficulty. For example, the cost of purifying flow back and produced water to near potable quality might not be financially feasible, while bypassing treatment entirely can pose difficulties in using the water effectively for fracturing fluids.

Aims & Research Methods: In this paper, new and customized fluid compositions that can be used effectively with recycled waters are discussed, as well as successful case studies.

Citation: Fa Dwan, Shell China E&P Co., J. Qiu, PetroChina SW ., M. Zhou, R.S. Yuan, Z. Zhang, L. Jin, Shell China E& P Co., S. Wang, X. Li, M. Lin, PetroChina SW., B. Liang, C. Deng, S. Liang, CCDC-SCGC, and L. Engelbrecht, R. Van Dok, L. Walter APEXHiPoint, 'Sichuan Shale Gas Microseismic Monitoring: Acquisition, Processing, and Integrated Analyses' (Paper presented at 6th International Petroleum Technology Conference, Beijing, China, Mar 26 - 28, 2013 2013)

Topic Area: Shale Gas, Monitoring (Pressure, Temperature, Sonic, Nuclear, Other) and Reservoir Geomechanics

Jurisdiction: Global

Abstract: The ability to estimate the stimulated reservoir volume and to enhance the effectiveness of hydraulic fracturing operation is fundamental in field development planning and critical to optimizing well completion in unconventional gas exploration and production. Microseismic Monitoring (MSM) survey provides essential observations study how induced rock volume responds seismically under field hydraulic fracture stimulation. Recent advanced microseismic technology with further development can provide real-time monitoring and interpretation which will improve hydraulic fracturing efficiency and better EUR, stop induced fracture development toward fault zones, and avoid connecting water-bearing layers. Advanced processing can enhance weaker microseismic signal, which provides a more complete Microseismically-Stimulated Reservoir Volume (M-SRV). M-SRV is essential to build the 3D understanding of the induced fracture network under various stimulation designs in volumes and in patterns from each fracturing stage.

Citation: Karin Ritter, Amy Emmert, and David Shin, American Petroleum Institute; G. Reid Smith, BP America Production Company; Miriam Lev-On, The LEVON Group, LLC; Terri Shires, URS Corporation, 'Characterization of Methane Emissions from Key Sources in the Natural Gas Production Sector' (Paper presented at SPE European HSE Conference and Exhibition - Health, Safety, Environment and Social Responsibility in the Oil &Gas Exploration, London, United Kingdom, Apr 16 - 18, 2013 2013)

Topic Area: Air Emissions and Environmental and Social Impact Assessments

Jurisdiction: USA

Abstract: Natural gas comprises almost one-fourth of all energy used in the U.S. with growing importance in the global energy mix. New production techniques, including those involving hydraulic fracturing, have enabled access to expanded energy resources and to increased natural gas based power generation, which has been credited with reducing greenhouse gas emissions in the U.S. However, in 2011, the U.S. Environmental Protection Agency introduced new calculation methods for gas wells - based on limited data - causing calculated emissions from natural gas systems to more than double in the U.S. national greenhouse gas inventories for 2009 and 2010 (submitted to the United Nations in 2011 and 2012 respectively).

To provide better data about natural gas systems, the American Petroleum Institute (API), in collaboration with America's Natural Gas Alliance (ANGA), undertook a survey of U.S. natural gas production companies resulting in a rich data base from over 90,000 natural gas wells widely distributed among different producing regions in the U.S.

Aims & Research Methods: This paper analyses key findings of the API/ANGA study regarding methane sources pivotal to EPA's assessment, including completions, workovers and gas well liquids unloading operations.

While the API/ANGA findings indicate significant potential overestimations in EPA's assessment, they also confirm the importance of understanding the key activities and conversion factors that impact the estimation of methane emissions from natural gas production. Although improving the greenhouse gas emission estimation methods may take time, a more nuanced analysis is essential for informing public debate and facilitating decisions on natural gas use and its role in mitigating overall greenhouse gas emissions.

Citation: Anthony Cortis, Gary Zheng, Martin Castle, Wang Jianghong, Guo Feizhou1. Karen Westley, 'Responsible Unconventional Gas Operating Principles in Practice, Sichuan, China' (Paper presented at 6th International Petroleum Technology Conference, Beijing, China, Mar 26 - 28, 2013 2013

Topic Area: Social Responsibility and Environmental and Social Impact Assessments

Jurisdiction: China

Abstract: Shell has published a set of five aspirational global onshore tight sand/shale oil and gas operating principles that provide a framework for protecting water, air, wildlife and the communities in which we operate. We design our activities using state-of-the-art technology and innovative approaches that make the most sense for local conditions.

Aims & Research Methods: This paper outlines Shell's implementation of these principles in the assessment and development of a Basin Centred Gas play in partnership with PetroChina in a block in Sichuan Basin, China. The 4,106 km2 block lies in the heart of the Sichuan basin, sometimes referred to as the "bread-basket" of China. The area is intensively farmed and is characterized by very hilly topography with problematic access. Population densities are 500-600 people per km2. The partners are executing a 3-year, 21-well appraisal program designed to evaluate the gas potential and commerciality of the block. A successful Development stemming from this appraisal would allow for an extended production period under the auspices of a PSC. Hundreds, if not thousands of wells, could ultimately be drilled. Operating presents unique challenges from a surface perspective because of the potential impact of our operations on local communities. In accordance with the onshore operating principles, Shell China has developed and implemented a number of operating methodologies that ensure we operate our wells and facilities safely, minimize the footprint of our operations, ensure water and air quality and properly engage with local communities. These methodologies, challenges, success factors and future plans to expand them and further mitigate impacts are discussed in detail.

Citation: Kushal Seth, SPE, Shawn Shipman, SPE, Morgan McCutchan, SPE, and Drew McConnell, SPE, Baker Hughes Incorporated, 'Maximizing Flowback Reuse and Reducing Freshwater Demand: Case Studies from the Challenging Marcellus Shale' (Paper presented at 2013 SPE Eastern Regional Meeting, Pittsburgh, Pennsylvania, USA, Aug 20 - 22 2013)

Topic Area: Produced Water Use, Discharge and Disposal

Jurisdiction: USA

Abstract: The Marcellus shale gas play lies in the Appalachian Basin in the eastern United States. It encompasses Maryland, Virginia, Ohio, New York, West Virginia, and Pennsylvania, which has the greatest area percentage at 35.35% (EIA, 2011). In April 2013, the Potential Gas Committee released a statement ranking the Atlantic area as “the country’s richest resource area with 33% of US traditional resources.” Production from the Appalachian Basin shales, consisting mainly of Marcellus, grew a staggering 147% in volumetric and percentage gains from 2010 to 2012, “proving abundant, recoverable natural gas resources exist within our borders” (Curtis, 2013).

Extracting gas from the Marcellus shale requires a large amount of water. Engineers use hydraulic fracturing to stimulate the reservoir to recover more natural gas at an effective production rate. Water and proppant, typically sand, are pumped into the solid rock at high rates, fracturing the hydrocarbon-bearing rock. The propping agent keeps the cracks open so the hydrocarbon can flow out of the reservoir and into the wellbore. A typical Marcellus hydraulic fracturing operation can use up to 3 to 8 million gallons of water. While most of the water remains underground, roughly about 10% of the volume flows back to the surface and is called “flow back water.” The amount of this flow back water can be 300,000 to 800,000 gallons per well (Penn State, 2011). In Pennsylvania, more than 37,740,000 bbl of flow back water have been produced during hydraulic fracturing operations (Rahm, Bates, Bertoia, Galford, Yoxtheimer, and Riha, 2013).

Aims & Research Methods: The rapid development of horizontal drilling and fracturing has greatly increased the access to shale gas deposits in the Marcellus shale play. Multifold increase in water consumption and subsequent disposal issues are prompting the operators to look for more economic and environmentally sustainable options for hydraulic fracturing.

Two major operators in Marcellus were interested in reusing their flow back water for hydraulic fracturing to reduce the cost of sourcing and disposal. A holistic approach was taken, resulting in a single-step, environmentally preferred water treatment technology to sufficiently clean the water to be used as a mix for hydraulic fracturing operations. To date, over 600,000 bbl of flow back water have been treated and successfully used in over 240 stages of stimulation for the two operators.

With the improvement in produced water quality, the operators were able to increase the mix ratio of treated water to fresh water. This paper will validate the viability and value of produced water reuse reducing the demand for fresh water, waste disposal, and truck traffic. A description of the operations from analysis, treatment, fluid testing, and reuse operation demonstrates the need for continual optimization of the treatment process to ensure the variability of produced water is addressed.

Citation: R. J. Kimball, and A. L. Locke, SPE, CDM Smith Inc, ‘Innovations in Sustainable Shale Gas Water Managment High Recovery Reverse Osmosis Case Study’ (Paper presented at SPE European HSE Conference and Exhibition, London, United Kingdom, 16-18 April 2013)

Topic Area: Water, Reuse, Treatment, Sourcing, Sustainable

Jurisdiction: USA and EU

Abstract: Natural gas production from low permeability shale formations (shale gas) has recently become economically viable due to technological advancements in horizontal drilling and hydraulic fracturing. Shale gas is present in numerous and large "basins" around the world, including across the United States, and has been largely untapped due to the very "tight" nature of shale rock. With horizontal drilling and hydraulic fracturing, previously inaccessible natural gas is made to flow through newly formed fractures in the shale to production wells.

As a result of this technology, natural gas is now one of the world's fastest growing energy sources. The development of unconventional sources, such as coal seam gas, will grow dramatically due to vast basins in the United States, and Europe. These reserves are being tapped with new techniques for detection, hydraulic stimulation and extraction.

Leveraging any natural resource requires responsible environmental management. Development includes many protective measures, with special concern for water resources and water quality. There is considerable debate about environmental concerns related to produced water. Our industry has a role to identify and apply robust, reliable and efficient scientific and engineering methods to help protect water supplies and the environment. Water management is one of the biggest operating issues for resource developers. While well development may require 4-5 million gallons of water per horizontal well, more liquid is produced throughout the gas well's lifecycle containing constituents at concentrations much higher than in surface water—all of which requires management through treatment and beneficial use. To protect fresh water resources and control treatment costs, resource developers are seeking innovative treatment and reuse options.

Aims & Research Methods: This paper provides detailed information and context from case studies including references of relevance to the gas field produced water characteristics of representative Europe and American gas fields.

Citation: M. Zimmerman, K. Patterson, H.R. Hedgcoxe, J. Houghton, K. Berger Environmental Resources Management, 'Groundwater Monitoring in the Eagle Ford: Evaluating Baseline Conditions in a Risk Management Context' (Paper presented at 2013 SPE Americas E&P Health, Safety, Security & Environmental Conference, Mar 18 - 20, Galveston, TX, USA, 2013 2013)

Topic Area: Environment and Sustainability/Social Responsibility

Jurisdiction: USA

Abstract: Unconventional Resource (UCR) development requires a robust understanding of baseline conditions and potential for environmental impacts due to its dependence on water and other shared resources, geographic overlap of target locations and the presence of potential receptors. While many operators have committed to monitor groundwater as part of their Environmental Management programs, the value of a monitoring program depends on having a coherent strategy for identifying critical data and implementing program elements in the correct stage of the project lifecycle. Increasingly, operators are also recognizing that

implementing a sound groundwater monitoring plan is a key component of their strategy to manage business risk in the rapidly developing shale plays.

Aims & Research Methods: Using the Eagle Ford shale as a case study, this paper evaluates the emerging industry standard of baseline and on-going groundwater monitoring to assess the potential for impacts to water resources from drilling and hydraulic fracturing. Data sources for this study include publicly-available state and federal agency data, interviews with major operators, and groundwater data collected as part of early lifecycle baseline assessments.

Water management programs in UCR development are complicated by factors such as population density, land use, depth and availability of potable or non-potable groundwater, and competition between water users. The challenge for operators has been to develop a monitoring program that is robust enough to manage current and potential future risk, while remaining efficient and flexible enough to accommodate changing development schedules. The monitoring program must be readily modified in response to new data.

Recent work in this area has been focused on using risk-based assessments to identify critical areas where monitoring will provide key information on the potential impacts of drilling and hydraulic fracturing operations. Major components of a water monitoring program include developing the risk basis for sample locations, agreeing on the suite of analyses to be monitored, and incorporating the program into the development schedule. This approach helps operators design a “fit-for-purpose” program based on local and regional hydrogeology, surrounding land use and potential sources of contamination, the presence of historical oil and gas operations, current groundwater use, and the presence of receptors. Such a program provides operators with the critical groundwater data and risk management information necessary to address stakeholder concerns, maintain schedule, transfer water resource infrastructure for future use later in the development lifecycle, and, ultimately, maintain this component of their social license to operate.

Citation: Y. Zhang, G.Q. Zhang, China University of Petroleum, Beijing, China, F.J. Sun, Q.Y. Bao, Langfang Branch of PetroChina Exploration and Development Research Institute,Langfang,China, ‘Application of U-Shaped Wells Technologies for Efficient Stimulation of CBM’ (Paper presented at 6th International Petroleum Technology Conference, , Beijing, China, Mar 26 - 28, 2013 2013)

Topic Area: Trajectory Design, Survey Calculation, Collision Checking, Horizontal/Multilateral Wells and Fundamental Research in Drilling & Completions

Jurisdiction: China

Abstract: The daily gas production of the pilot wellbeing in production for only 160 days and in control of the casing pressure kept at 0.7-0.8MPa to produce the gas in accordance with the producing rules of CBM wells has exceeded 2000m^3/d. It is still rising gradually and would come up to about 8000 to 10000m^3/d in a year’s production according to the numerical simulation results which exhibits the U-shaped well a promising application prospect.

Aims & Research Methods: Coal bed methane（CBM）development in China, especially in both Qin-shui Basin and East Ordos Basin has started at a large scale. There are more than

8500 CBM wells drilled in these two basins and most of which are stimulated with induced hydraulic fracturing and multi-lateral horizontal well technology. However, some of the CBM vertical wells are low productions due to the factors of geology, drilling or producing, while some of the horizontal wells have an appreciate production in the early stage but later drop down to a very low level dramatically due to the wall collapse. Thus, a new technology, namely U-shaped well technology, is researched and applied on site in Qinshui basin for enhancing the average gas productions of CBM wells.

An optimum scheme of drilling and completion of the U-shaped well is presented based on the comparison of the price, risk and feasibility of three different schemes in this paper and used as the pilot program. In order to decrease the comprehensive cost and period of the well, such factors as the access to fuel, water and land, the environmental regulations, i.e., water disposal, mud and drilling waste disposal, and so on, should be taken into account while choosing the well site. The reservoir characteristics and physical parameters, the upper formation lithology and the technology requirements of drilling, cementing and completion should be researched in detail before doing the well design which is the basis of the success of the U-shaped well. Besides, drilling along the coal seams and connecting to the vertical well are two key steps in yielding a successful U-shaped well, therefore, it is important to monitor and adjust the well path in time based on the logging response characteristics, measurement parameters of EMWD, and the drilling and mud logging parameters. With the slotted screen completion in the horizontal well, the U-shaped well can still provide a good flow path for the water and gas even though there is a wall collapse in the horizontal well while producing. In addition, the well bores can also be cleaned up by injecting water from the vertical well and circulating out of the horizontal well when the slotted screen is block by the coal dusts. As a result, the U-shaped well technology can solve such problems as production decreasing and cycle shortening of the multilateral horizontal wells due to the wall collapse while producing.

Citation: X. Ye, N. Tonmukayakul, P. Lord, and R. LeBas, Halliburton, 'Effects of Total Suspended Solids on Permeability of Proppant Pack' (Paper presented at 10th SPE International Conference and Exhibition on European Formation Damage, Noordwijk, The Netherlands, Jun 05 - 07, 2013 2013)

Topic Area: Produced Water Management and Control

Jurisdiction: EU

Abstract: Within the worldwide oil and gas industry, hydraulic fracturing is a commonly used stimulation method. The fluids pumped are often water-based, introducing millions of gallons of water into the formation. Water sources can vary from lakes and rivers, to municipal water, to produced formation water. Fresh water has long been the preferred type of base liquid used in fracturing fluids. However, fresh water is becoming increasingly difficult to source because of droughts, increasing regulations, increasing municipal demand, etc. In some cases, the transportation of fresh water from the source to the well site is extremely costly. As such, operators are exploring the possibility of using produced formation water. The use of produced water comes with its own set of challenges, such as high levels of both TSS and total dissolved solids (TDS). Often, it is recommended that the produced water is treated before reuse in reservoir stimulation. Removal of TSS is critical. The solids are generated from a wide range of sources, such as formation fines and clays,

sand, and corrosion products from the injection/production lines. Clogging or bridging of the pore space in the formation by these suspended solids can be rapid and severe if these particles are not removed before use.

There are two technologies commonly used in the filtration of the colloid fine particle in porous media (i.e., absorption and straining). Absorption is a physicochemical mechanism governed by chemical, electrostatic, and van der Waals forces. Coagulation occurs when the particles attract and stick to the sand particles. Straining, however, is a geometric mechanism, where the particles to be captured are larger than the pores in the filter media. Hall (1957) suggested that straining rate scales with the size of the strained particles, d, as (d/D)1.42. Similar scales have been reported by other researchers (Sharma and Yortsos 1987; Bradford et al. 2003; Rodriguez and Bryant 2007). In addition to those traditional filtration techniques, EC is a novel technology that uses electricity to process coagulation in the water. Typically, the coagulant is generated in situ by electrolytic oxidation of an appropriate anode material, and the cathode is subjected to passivation (Lai and Lin 2003).

Aims & Research Methods: Recently, interest in using produced water for hydraulic stimulation processes has greatly increased within the oilfield services industry. However, successful hydraulic fracturing operations using produced water have yet to reach their full potential. This is largely because of wide variance in water quality from such sources as bacterial content, suspended solids, scale, and precipitate potential. Among these, suspended solids are a major issue. Their presence can create severe problems by plugging the proppant's pore space. In this paper, the effects of total suspended solids (TSS) on proppant permeability using a novel benchtop device (Ye et al. 2009) are discussed. This apparatus imposes a controlled strain on the proppant pack while continually measuring its permeability up to a compressive stress of 7,100 psi. Another unique feature of this apparatus is the direct visualization of the proppant pack through a polycarbonate window. Images taken have been analysed, which provides quantitative information about the relationship between relative permeability and fine particles invasion. Results using produced water samples revealed that electrocoagulation (EC) treatment would increase the permeability up to 40%, depending on the proppant and produced water source. Extensive data analyses and flow visualizations are presented, demonstrating the effects of TSS on the permeability of proppant packs.

Citation: Dina Kuykendall, SPE, Baker Hughes; Brad Snow, PE, PG, Snow Environmental Solutions; Edward Gatliff, PhD, Applied Natural Sciences, 'Phytoremediation of Chlorinated Solvents in Fractured Rock' (Paper presented at 2013 SPE Americas E&P Health, Safety, Security & Environmental Conference, Galveston, TX, USA, Mar 18 - 20, 2013 2013)

Topic Area: Remediation

Jurisdiction: USA

Abstract: Over a 21 year period, several remediation methods were used for the clean-up of chlorinated solvents dissolved in groundwater at an oilfield pump manufacturing facility in Claremore, Oklahoma. These methods included soil excavation and off-site disposal, air sparging/soil vapor extraction, groundwater circulation wells, high vacuum multiphase extraction, carbohydrate injection and throughout the project's history, the current pump-and-treat system. The primary chemicals of concern (COCs) include trichloroethene (TCE); 1,1,1 trichloroethane (TCA); and associated degradation products. Due to challenging hydrogeological conditions and the nature of the contaminants, only a modest improvement in groundwater quality has been achieved. Even with the significant historical remediation efforts and considerable expenditures, there was no foreseeable end point. The company objective is to reduce the contaminant concentrations and to assure that no off-site contaminant migration can occur which might impact sensitive receptors. The company sought a sustainable solution that would not involve continued expensive remediation system operations and maintenance.

The remediation strategy was evaluated and revised to include engineered phytoremediation as a primary component. In March 2012, 52 trees were installed within large diameter boreholes for groundwater hydraulic control and in situ treatment.

Aims & Research Methods: This paper presents the challenges and solutions for drilling and completing the tree installations in highly variable fractured shale and sandstone within the constraints of tight spaces at a busy operating plant. Preliminary data concerning tree health, growth and hydrologic effects are presented. This evaluation includes the varying mortality of bare root versus potted trees and the importance of staking the trees in the strong Oklahoma winds. During the first growing season, the tree roots reached and began using groundwater, enabling them to survive an unusually hot and dry summer.

Once the trees are more fully established, phytoremediation is expected to provide a sustainable and cost effective remedial alternative to the long-term groundwater pump-and-treat system. Its successful application at this site opens up the possibility for using phytoremediation at other challenging fractured rock sites.

Citation: Nolan Lerner, SPE, Brent Schaab, SPE, Juan Garcia, SPE, Dan Bianco, SPE, Scott Thomas, SPE, Jason Thompson, PennWest Exploration; Jeremy Hollan, SPE, Packers Plus Energy Services, 'Evolution of Drilling and Completions in the Slave Point to Optimize Economics' (Paper presented at 2013 SPE Hydraulic Fracturing Technology Conference, The Woodlands, TX, USA, Feb 04 - 06, 2013 2013)

Topic Area: Wellbore Design/Construction and Production Enhancement

Jurisdiction: USA

Abstract: The Slave Point has a greater thickness and is less permeable than other tight rock plays in Alberta such as the Cardium and Viking. It produces high-quality, light oil with low water and solution gas production rates. Despite high estimates of original oil in place of approximately 3 to 10 MMbbl per section, horizontal well rates are still challenged due to lower permeability through the pay section. In this regard, the continued deployment of innovation and technology has been critical in improving well production performance, compressing project costs, and ultimately optimizing project economics. The focus of this paper is solely upon one of the major Slave Point operators who has drilled 49 horizontal wells accounting for 200,000 m (656,000 ft) drilled and 1,350 fracture stages in the Evi and Otter Slave Point fields since 2008. This operator has continually deployed advancing technologies to improve project economics. The information will be presented in terms of the influence of technology on well design, the optimization and deployment of the various technologies, and the demonstrated improvement on productivity and reserve recovery. The discussion will focus on three development phases outlined below, which highlight the progression from vertical to horizontal technology.

- Vertical Appraisal
- Single Lateral Development
- Dual Lateral Development

The case studies presented will clearly demonstrate the production impact upon the utilization and application of these technologies. The methods and lessons learned through the use of dual laterals, open hole junctures and open hole multistage systems can be applied to other unconventional formations.

Aims & Research Methods: This paper will detail the technological evolution of drilling and completion practices utilized to optimize economic development of the Slave Point carbonate platform specifically in the Evi and Otter fields in northern Alberta. The Slave Point platform was initially targeted for conventional production via vertical wells in the early 1980s. Success was marginal due to the unpredictability of localized porosity development. As a result, full scale commercial development of this resource was deemed uneconomic due to poor reservoir quality. More recently, however, horizontal drilling and multistage fracturing technology has allowed operators to open up lower porosity horizons to improve flow capacity, improve recoveries, and allow for commercial development from zones previously deemed as uneconomic.

Citation: Katherine Gardner, ERM, SPE, Maximo Hernandez, ERM, SPE, 'Unconventional Technology Performance: Bridging the Technical to the Nontechnical' (Paper presented at 2013 SPE Americas E&P Health, Safety, Security & Environmental Conference, Galveston, TX, USA, Mar 18 - 20, 2013 2013)

Topic Area: Integrating HSE into the Business and Social Responsibility

Jurisdiction: USA

Abstract: As the need for energy independence broadens hydrocarbon exploration to new geographies and involves new and improved techniques, new lifecycle success factors are continuously introduced to unconventional projects which are required to achieve production objectives on schedule and budget. These factors differ somewhat from the ones a traditional drilling and production field development exposes to the view of those beyond the industry, thus generating new challenges. Traditionally perceived technical issues are typically cantered on well control, hydraulic fracturing fluid composition and other technical discipline improvements on a well by well basis. However a set of new challenges have developed as a range of social, economic and environmental stakeholder issues. These can significantly support or affect the ultimate outcome of an investment. The following analysis exposes the authors' views on performance to the technical limit and factors that contribute to the end result which are beyond the technical limit.

Citation: Robert McGrath, Noble Drilling; Sara Davila, SPE, and Natalie Wagner, SPE, National Oilwell Varco; Mark Miller, Terresolve Technologies, 'Lessons Learned Regarding

Offshore Oilfield Applications and Hydraulic Fluids' (Paper presented at SPE European HSE Conference and Exhibition - Health, Safety, Environment and Social Responsibility in the Oil &Gas Exploration, London, United Kingdom, Apr 16 - 18, 2013 2013)

Topic Area: Oil and Chemical Spills, Drilling Equipment and Operations and Waste Management

Jurisdiction: UK

Abstract: As interest and demand increase for reduced liability and exposure related to offshore hydraulic applications, equipment and fluid manufacturers are starting to work together. Over the years, many drilling contractors have learned by trial and error with significant equipment and maintenance costs as a result. One drilling contractor's goal to reduce the exposure to risk, from purchase to disposal, has led years of experience in the area. As decisions based on a paper review of datasheets can be problematic, understanding the application is vital to ensure performance. As such, there is a need for a better understanding of fluid dynamics and the related tests in a holistic perspective. Specific lessons learned about fluid testing standards and methods, in relation to both performance and environmental parameters, are shared. Topics include case studies on types of environmentally friendly hydraulic (HE) fluids and the associated engineering and compatibility concerns.

Citation: J.A. Veil, SPE, Veil Environmental; P. Jehn, Ground Water Protection Council; M.J. Fine, Colorado Oil and Gas Conservation Commission; B.G.Griffith, Sr., Oklahoma Corporation Commission, 'Unique System for Managing Data From Oil and Gas Operations' (Paper presented at 2013 SPE Americas E&P Health, Safety, Security & Environmental Conference, Galveston, TX, USA, Mar 18 - 20, 2013 2013)

Topic Area: Information Systems and Data Use

Jurisdiction: USA

Abstract: State agencies have the primary responsibility for overseeing and regulating oil and gas operations. Those operations generate a large amount of data. Managing the data in an effective and coordinated way presents challenges to federal, state, and local agencies and to other interested users. In 1992, the U.S. Department of Energy (DOE) provided initial funding to the Ground Water Protection Council (GWPC), a national association of state agencies, to develop the Risk Based Data Management System (RBDMS), a family of software applications that allows management of data associated with oil and gas operations.

Aims & Research Methods: The RBDMS software is used for a variety of purposes including: managing operator and bonding information; the permitting processes; tracking well locations and construction details; tracking production data; assessing the impacts of injection wells on underground sources of drinking water; and tracking inspections, compliance, and other enforcement activities. Since its inception, RBDMS has relied on a combination of DOE's financial support and matching funds and feedback from the 21 states that use the system to keep it updated and to incorporate new features. RBDMS has recently added a variety of new features that are discussed in the full paper. The paper and presentation will show many of the features and capabilities of RBDMS that can be useful to oil and gas companies, researchers, and other interested persons.

Citation: Arvind Patel, Joyce Hui Zhang, Mingjie Ke, and Balakrishnan Panamarathupalayam, M-I SWACO, 'Lubricants and Drag Reducers for Oilfield Applications - Chemistry, Performance, and Environmental Impact' (Paper presented at 2013 SPE International Symposium on Oilfield Chemistry, , The Woodlands, TX, USA, Apr 08 - 10, 2013)

Topic Area: Production Enhancement

Jurisdiction: USA

Abstract: Drilling fluids, whether for drilling a well bore (drilling fluid, mud) or drilling a reservoir (reservoir drilling fluid, RDF) have many functions, including transport cuttings from the well bore and separate them at the surface, maintain the well bore stability by depositing a thinner impermeable filter cake, clean and cool the drill bit to increase the drilling efficiency of drill bit, and reduce the friction between the drill pipe and the well bore. As drilling in directional and extended-reach wells continues to increase, high torque and drag become critical issues. This is particularly true for water-based mud's (WBM), since they (WBM) have high coefficient of friction (COF) between the drill string and well bore compared to that of oil-based muds (OBM). The typical COF for OBM is less than 0.1 when measured between metal to metal surfaces in laboratory, while that of WBM is typically from 0.2 to as high as 0.6. In recent years, innovations in drilling equipment, drilling fluids, and fluid additives have taken drilling performance to the edge and allowed extended reach wells to be drilled to and beyond limits that were unachievable earlier. Drilling fluids and fluid additives play an important role in reducing the torque and drag in those drilling operations.

For many years the oil and gas industry has used brines for well completions and workovers. Included in commonly used brines are seawater, formate brines, monovalent and divalent halide brines, as well as their combinations. The operations employing these brines include, among others, running production tubular/screens, wellbore clean-up, and coiled tubing operations. As extended-reach, high-angle and deepwater wells are drilled, high friction is one of the major problems that need to be addressed. Additives can be applied to the brines to reduce the friction.

Many drilling fluid additives (lubricants and drag reducers) have been developed and evaluated to continuously improve their performance and environmental impact in oil field operation. The choice of the lubricant for water-based drilling fluid, reservoir drilling fluid and clear brine completion fluids is primarily driven by their performance criteria and environmental requirements. The performance criteria include: reduction in Coefficient of Friction (C.O.F); torque and drag reduction (reduction in pump pressure); compatibility with fluids and other fluid additives; and formation damage issues. The environmental criteria include toxicity, biodegradability and other human health related issues. The development and choice of correct chemistry can have great impact on performance of lubricants and drag reducers, on environmental related issues, and ultimately on their success in the field.

Aims & Research Methods: Lubricants are often added to drilling, completion and work over fluids to reduce the coefficient of friction between tubular equipment and tubular and wellbore wall. For coiled tubing (CT) operations, however, drag reducers are added to the fluids to reduce or minimize the pressure loss caused by high pumping rates. From the perspective of molecular structure and chemical properties, this paper illustrates the differences between lubricants and hydraulic drag/friction reducers. The subject matter will be illustrated using a newly developed phospho-lipid derived and modified ethoxylated castor oil-based chemistry as very effective and environmentally acceptable lubricants for clear brines and drilling fluid applications. Also included are drag reducers derived from high-molecular-weight sulphonated polyacrylamide polymer that effectively reduce the hydraulic friction of completion fluids including both low and high density monovalent and divalent brines. The paper will also include the chemistry and performance of several other newly developed environmentally safe lubricants and synthetic drag reducers for applications in various wellbore fluids.

Citation: Guangzhi Han, SPE, Wilfredo A. Davila, SPE, Eric C. Magnuson, Azar A. Azizov, SPE, all Baker Hughes, 'Practical Directional Drilling Techniques and MWD Technology in Bakken and Upper Three Forks Formation in Williston Basin North Dakota to Improve Efficiency of Drilling and Well Productivity' (Paper presented at 2013 SPE Middle East Unconventional Gas Conference & Exhibition, Muscat, Sultanate of Oman, Jan 28 - 30, 2013 2013)

Topic Area: Site Operations, Drilling Project Management and Horizontal/Multilateral Wells

Jurisdiction: Global

Abstract: he Upper Devonian-Lower Mississippian Bakken petroleum system, including the Bakken, Lower Lodgepole, and Upper Three Forks formations, is a widespread unit within the central and deeper portions of the Williston Basin in Montana, North Dakota, and the Canadian provinces of Saskatchewan and Manitoba. The USGS estimated that the U.S. portion of the Bakken Formation contains between 3 and 4.3 billion barrels of undiscovered, recoverable oil, 1.85 Tcf of associated/dissolved natural gas and 148 million barrels of natural gas liquid; the Upper Three Forks Formation is estimated to contain 20 billion barrels of oil, with approximately 2 billion barrels of recoverable oil.

There are extensive horizontal drilling and multi-stage hydraulic fracturing activities targeting these two formations. Those horizontal wells typically have 10,000 ft lateral sections in pay zones and multi-stage hydraulic fracturing with 24 to 36 stages. The extensive well paths bring numerous challenges, including precisely landing the curve, enhancing drilling rig operating conditions to obtain measuring while drilling (MWD) system optimal performance, and avoiding drilling into undesirable formations. Overlooking some or all of these conditions could lead to unnecessary high dogleg severity (DLS), poor rate of penetration (ROP), unnecessary trips and sidetracks to name a few. All these conditions could ultimately add additional time and cost to the drilling and completion program of the well and in the worst-case lower future production rates to the operator.

Aims & Research Methods: Several practical field techniques and technology applications are presented as solutions to help optimize ROP, reduce non-productive rig time and chances of sidetracks. Several field examples were analysed. The techniques gained are valuable for developing optimal drilling practice procedures, and improving drilling operations and future well production.

Citation: Ramin Lakani, SPE, and Daniel Brown, SPE, Baker Hughes, 'An Integrated Approach to Managing Risks and Uncertainties: Combining Technical and Commercial

Analysis' (Paper presented at 2013 North Africa Technical Conference & Exhibition, Cairo, Egypt, Apr 15 - 17, 2013 2013, InterContinental Citystar)

Topic Area: Gas to Liquids, Unconventional Resources and Energy Economics

Jurisdiction: North Africa

Abstract: As engineers and scientists, we are very familiar with analysing technical risks, developing mitigation plans and implementing the plans that are safe and technically feasible. At the same time, dealing with subsurface projects has made us adept at analysing and understanding technical uncertainties. Furthermore, because of the large investments involved in upstream projects we are regularly exposed to commercial issues. However, the optimum situation is when the technical and commercial risks and uncertainties are evaluated in an integrated fashion.

Although many organisations combine technical and commercial evaluations, there are many examples that such integration is either superficial or is done in a series. Often the economic evaluation is performed at the end of the process, by which time it may be too late to influence the decisions or the changes may be too expensive to implement.

Techno-economic integration becomes absolutely essential when our industry faces "game-changing" technologies, for example:

- Unconventional resource developments: Shale gas/oil
- Isolated gas monetisation: Gas to Liquid (GtL), Floating Liquefied Natural Gas (FLNG)
- Heavy oil developments: In-situ combustion, Steam Assisted Gravity Drainage (SAGD), Cold Heavy Oil Production with Sand(CHOPS)

Examples will be given to demonstrate the successes and failures of game changing technologies, where the failures are generally less advertised. It is important to discuss the 'lessons learnt' from these important events in our recent history: How can we apply techno-economic evaluation in an integrated fashion (and at an earlier stage) to better evaluate risks and uncertainties associated with implementing game-changing technologies? How can we influence the outcome of these projects?

Aims & Research Methods: This discussion is particularly relevant to the North Africa region as governments, National Oil Companies (NOCs) and International Oil Companies (IOCs) try to harness unconventional resources and seek alternative ways to monetise their gas resources.

Citation: Phaneendra Kondapi, FMC Technologies, Houston, Texas, USA, Randi Moe, FMC Technologies, Asker, Norway, **'**Today's Top 30 Flow Assurance Technologies: Where Do They Stand?' (Paper presented at 2013 Offshore Technology Conference, Houston, TX, USA, May 06 - 09, 2013 2013)

Topic Area: Flow Assurance, Production Monitoring and Control, Oilfield Chemistry, Technology Valuation and Subsea Processing

Jurisdiction: Global

Aims & Research Methods: The purpose of this paper is to provide conclusions from an extensive evaluation of all known state-of-the art flow assurance methodologies. The various technologies were assessed by maturity level (i.e. embryonic, emerging, matured or aging), applicability, solution type and their affectivity. Affectivity is a function of ease of application, probability of success and cost effectiveness. Within this study, the solutions were classified into thermal, chemical, hardware, operating and software technologies. Thirty different existing and developing flow assurance technologies were considered for this study with the aim to summarize the current state of technology and identify potential areas for improvement. The selected technologies are regarded as major enhancers and perceived to have a great impact on both cost effectiveness and production.

Citation: Flavio Dias De Moraes, Petrobras; Oswaldo Moreira, Petrobras America Inc.; Ziad Haddad, FOI Technologies; Scott Ogier, and Jonathan Shipley, SPE, Cherokee Offshore Engineering; Mauricio Rebelo, Petrobras, Fernando Gama, Petrobras America Inc., 'Drilling and Completing Cascade and Chinook Wells: A Design and Execution Case History' (Paper presented at 2013 Offshore Technology Conference, , Houston, TX, USA**,** May 06 - 09, 2013)

Topic Area: Wellbore Design/Construction and Completion Planning, Design and Installation

Jurisdiction: USA

Abstract: The technical contributions of the work presented in this paper are as follows: pushing the technical limits of Single-Trip Multi-Zone frac-pack systems to depths over 27,000 ft using high (>30 bpm) fracture rates and high strength proppants; enhancing the knowledge gained from ultra-high pressure (>20,000 psi) tubing conveyed perforating systems; and presenting a well design criteria suitable for high drawdown (>12,000 psi) production operations.

The Cascade and Chinook (C&C) development plan in the Gulf of Mexico is one of the most technologically challenging and complex projects implemented by Petrobras. This project uses the first Floating Production Storage and Offloading vessel (FPSO) in operation in U.S. waters, at a water depth of 8200 ft. The C&C subsea infrastructure considers the use of subsea manifolds, rigid flowlines, pipe-in-pipe pipelines, and Free Standing Hybrid Risers (FSHR). Details about the subsea infrastructure and the FPSO are discussed in greater detail by Porciuncula et al. (2010) and Corte et al. (2010).

Aims & Research Methods: The paper is based on work performed during the design, implementation and operation of the Cascade and Chinook Field Development Project in ultra-deep water in the Gulf of Mexico. It describes the basis of design for the drilling and completion of the wells, new technology selection criteria, risk and cost mitigation plans applied during the well operations, ultra-high pressure perforating of an interval longer than 700 ft, application of the first Single-Trip Multi-Zone Frac Pack System (3 zones) in wells deeper than 27,000 ft MD, and the unique fracturing design approach used to deliver multiple fractures across 1200 ft of reservoir thickness. This case history paper will describe the pre-qualification work done with all critical systems and details of the well construction operations during the drilling and completion of the wells. The information provided will be useful for Operators to identify the technologies that are most suited for application in deep wells. It will also serve as a starting point for the design and construction of wells for other operators developing projects in the Lower Tertiary play, which is a key exploratory frontier in the U.S. Gulf of Mexico (USGoM). More than 12 discoveries have been made in the Lower Tertiary, with potential recoverable reserves of several billion barrels of oil. The results and conclusions presented in this paper are related to the feasibility and benefits of using new technology and prototype equipment in the Lower Tertiary environment. Field data from critical well operations will be included.

Citation: Lydia Brantley, Jennifer Kent, Natalie Wagner, SPE, National Oilwell Varco, 'Performance and Cost Benefits of Environmental Drilling Technologies: A Business Case for Environmental Solutions' (Paper presented at 2013 SPE / IADC Drilling Conference and Exhibition, , Amsterdam, The Netherlands, Mar 05 - 07, 2013 2013)

Topic Area: Environment, Waste Management, Integrating HSE into the Business and Partnership and Communication

Jurisdiction: EU

Abstract: Environmental impact has become business critical as we have been unable to crack certain issues to the degree expected for our industry. It is the central challenge for the continued development of shale markets, as it has been offshore. In a customer survey completed in the first quarter of 2012, a diverse group of operators, drilling contractors, and service companies identified their top three challenges for shale development: pricing, inexperienced personnel, and—of paramount importance—environmental impact. The industry recognizes the need for reduced environmental impact, but what do we need to achieve it?

In the aforementioned survey, many operators and drilling contractors expressed looking to oilfield service and supply companies for continued innovation with the expectation that they continue to be to be forward-thinking and present ideas that provide value. The industry has two primary means for reducing environmental impact of its operations: processes (operator and contractor-driven) and equipment (service and supply-driven). This paper proposes that the two must work hand-in-hand. It explores the opportunity to take this further: identifying critical steps such as process design for reduced environmental impact with lower-impact technology and industrial engineering. The dual approach is needed to affect large-scale change.

Aims & Research Methods: This paper will examine the positive impact of the implementation of select environmental technology can have on oilfield economics from the perspective of an oilfield equipment, technology, and services provider. It aims to: -Demonstrate a case for environmental solutions

- Establish the importance of improved environmental performance for market access

-Identify areas in which operators evaluate environmental impact

-Discuss the technology opportunities available to operators

- Recognize and quantify the performance and cost benefits of aforementioned technologies.

Citation: Calvin Holt, Nilesh Lahoti, and Vince Fortier, SPE, Tesco Corporation, 'Dynamic Cementation: A Solution to Well Integrity Problems' (Paper presented at 2013 SPE / IADC Drilling Conference and Exhibition, Amsterdam, The Netherlands, Mar 05 - 07, 2013 2013)

Topic Area: Downhole Operations (Casing, Cementing, Coring, Geosteering, Fishing)

Jurisdiction: EU

Abstract: Whether operators are drilling extended reach wells in prolific shale plays or offshore HPHT wells, well integrity remains the critical concern. Effective zonal isolation using cementing techniques is essential to mitigate risks and non-productive time associated with leaks, corrosion and contamination.

Although well researched and considered a mature discipline, effecting cement placement in the annulus still has a significant degree of uncertainty. As global regulatory agencies respond to public concerns with drilling operations either in deepwater or unconventional plays, the industry is reviewing well construction best practices to reduce risk. The discipline of cementing has been given renewed focus. In spite of the industry's detailed understanding of the advantages of reciprocating and rotating casing during cementing operations it is applied to less than 10% on wells globally. This mechanical method, although proven to be the most cost effective remains the least applied. Why?

A proven emerging technology, drilling with casing (DwC), developed the modern casing running tool (CRT). Using tools and drilling engineering methods developed from over 4,000,000 feet of drilling with casing; rotating casing to ream and while cementing is now a low risk activity.

Employing the CRT on conventional casing running jobs delivers a measurably higher degree of probability that casing while reach bottom and effective zonal isolation by cement has been achieved.

A new method of dynamic cementation, where pipe movement is maintained until cement begins to set maximizes the mud-cement displacement process. It can achieve a high quality completion using a combination of modern cementing software, real-time rig instrumentation and casing rotation/reciprocation with a CRT monitored to planned torque and weight levels while cement is pumped in the annulus.

Aims & Research Methods: In this paper, barriers to change, a new methodology with its classification of dynamic cementation levels and field examples are presented. It investigates the positive effect of casing movement during cementing and reviewing cement bond logs.

Citation: Gina Vega Riveros, SPE, Reservoir Consultant, 'Exploitation and Production of Gas Condensate Reservoirs' (Paper presented at 2013 Offshore Technology Conference, Houston, TX, USA, May 06 - 09, 2013 2013)

Topic Area: Operations Management, Fundamental Research in Production and Operations, Operations Management

Jurisdiction: South America

Abstract: Latin America countries have shown a great interest for increasing the reserves of gas and gas condensate reservoirs in mature fields. However, the production per well in some cases is very low with an elevated cost of production. It has pushed in some countries to adopt a long work strategy to handle multi-research studies oriented the enhancement of the field production in pre-selected mature fields.

In the Eastern Venezuela, gas reserves are concentrated in Anaco area, Anzoategui State. Anaco has been one of the most important operational districts and it has a high number of gas condensate reservoirs. However, a good portion of the remaining reserves are still trapped due to inefficient drainage and low production. Due to the importance of exploitation in these fields, it is fundamental the development of new technologies that allow their exploitation and production.

Aims & Research Methods: This paper presents an analysis method to accelerate production, as well as, recover additional reserves based in the detection of connected pay sands known as hydraulic units. The integration of the geology, seismic, petrophysic, geochemical study, fluids and reservoir properties identified the existence of hydraulic units through both areal and vertical communication. The reserves were evaluated using analytical methods, volumetric analysis, empirical correlations, P/Z material balance and probabilistic analysis. From static model, well correlations identified stratigraphic coalescence between G and H sands. The dynamic model detected that the four reservoirs are hydraulically connected showing an increase of gas condensate in place GCIP of 231.99 BCF in comparison official data. Based on the analysis of well spacing, there was a good opportunity to increase the daily production rate via adopting infill drilling.

The development strategy proposes the exploitation of several sands by hydraulic units, fracturing, pumps, workovers, infill drilling, well highly inclined and horizontal well in order to contact higher reservoir volumes and accelerate the operational process. A compositional simulation study was recommended to evaluate the factibility of injection EOR fluids, recycling gas and water-flooding as a secondary recovery project. This will increase the recovery factor and help to maintain the reservoir pressure.

Citation: H.L Read, P.E., D.D. Bradley III, P.E., Environmental Resources Management, 'Keeping Up With Rapid Change: Performance Assurance for Operating Assets in Shale Development Areas' (Paper presented at 2013 SPE Americas E&P Health, Safety, Security & Environmental Conference, Galveston, TX, USA, Mar 18 - 20, 2013 2013)

Topic Area: Audit and Certification

Jurisdiction: USA

Abstract: Unconventional development projects follow a general life cycle. Each step in the life cycle has a number of common activities that can have important environmental and

social impacts. Managing those activities to reduce/control the impacts can reduce the project's business risks and improve the overall success of the development program.

Operations in many shale plays are rapidly shifting from exploration into the longer-term production step of the life cycle. The pace of change presents significant challenges to maintaining compliance with federal and state environmental, health and safety (EHS) requirements.

To reduce the risk that significant noncompliance could result in regulatory issues that could slow or halt development activities, many operators are conducting independent reviews of their assets. Such reviews, which can be conducted in accordance with the Texas Environmental Health and Safety Audit Privilege Act, provide management and owners with an appraisal of potential environmental liabilities and recommendations for managing compliance risk. EPA has also developed a specific audit policy for new owners of assets who want to make a "clean start" at newly acquired facility by addressing environmental compliance prior to or early in the stages of ownership.

These types of audits focus on key questions to identify areas for improve performance and thereby enhance shareholder value:

- Do the locations have the necessary permits, authorization and plans?
- Do the permits, authorization and plans represent current operations?
- Can the operations expand?
- What capital will be necessary to come into compliance with regulatory permits and requirements?
- What is the compliance culture? Is there a sufficient management of change program to identify and adjust to different compliance requirements?

ERM's experience has shown that the most frequent findings from these audits include storm water contamination issues, lack of air permitting or under-permitting emissions sources, failure to use adequate control devices, and problems with spill containment and spill plan implementation. Through the audit privilege process, disclosed civil and administrative violations can be corrected without incurring monetary penalties, in addition to a prescribed time frame to implement corrective actions. An environmental audit can be a beneficial tool for new or experienced owners or operators looking to enhance their asset value and manage non-technical risk at their sites.

Citation: S. Austin, A.N. Martin, A. Glennie, J. Martinez and S. Bradford, Baker Hughes, 'Design Considerations For The Next-Generation Stimulation Vessel In Europe' (Paper presented at Offshore Mediterranean Conference and Exhibition, Ravenna, Italy, March 20 - 22, 2013)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: EU

Abstract: The operating envelope and environmental demands for hydraulic fracturing and stimulation treatments in the North Sea and Mediterranean are increasingly larger and more complex. As a result, a new vessel is being fabricated specifically to meet these European requirements.

The strategy for the new vessel is to provide state-of-the-art technology and built-in flexibility to meet the needs of the North Sea and Mediterranean oil and gas industries for the next 30 years, through to 2043. As such, it must be designed to provide cost-effective stimulation treatments with proppant and acid with the highest QHSE standards. The flexible stimulation plant should also be able to perform chemical washes. Automation, remote controls and reliable, robust instrumentation should be incorporated to reduce exposure hours, improve safety and increase efficiency. The use of modern work practices will be promoted with the latest IT in communications and the option of a high level technical and operational support.

Aims & Research Methods: The design characteristics of the new vessel can be split into five categories: (i) stimulation plant (ii) marine systems (iii) environmental protection (iv) welfare of the crew and (v) regulatory compliance. All five categories are critically important to achieving the stated goals for the new vessel, and all require implementation of cutting-edge technology and new, forward-thinking design concepts that enable technical evolution over the lifetime of the vessel. This presentation describes the design issues in each category and the solutions chosen for a new vessel that will be ready for operation in August 2013.

Citation: Arne Handal, Sondre Øie, DNV, 'Safety Barrier Analysis and Hazard Identification of Blowout Using Managed Pressure Drilling Compared With Conventional Drilling' (Paper presented at 2013 IADC/SPE Managed Pressure Drilling & Underbalanced Operations Conference & Exhibition, San Antonio, TX, USA, Apr 17 - 18, 2013 2013)

Topic Area: Safety

Jurisdiction: USA

Abstract: Safety barrier analysis and structured hazard identification of critical managed pressure drilling equipment related to well control have been performed. Well-known risk identification methods have been used to analyse common aspects related to Managed Pressure Drilling. Hopefully the analysis introduced in this paper will help the industry to decide when critical drilling equipment should be regarded as well barrier elements or not. The results indicate that while managed pressure drilling systems have significant advantages both in terms of safety and productivity, risks related to implementation of safety critical equipment need to be managed through reliable and efficient control systems.

Aims & Research Methods: The majority of overbalanced drilling operations are still performed using conventional drilling. The trend indicates that managed pressure drilling systems are increasingly being introduced in regions where the operational pressure window of formations is restricted. DNV has during the last years noticed a considerable demand for third party evaluation of new upcoming managed pressure drilling systems. This paper discusses some of the challenges and advantages for managed pressure drilling compared with conventional drilling.

Many managed pressure drilling systems introduce critical equipment with the intention to enhance operational effectiveness and safety. At the same time the respective equipment is used to adapt the hydraulic pressure profile throughout the wellbore to manage the annular bottom-hole pressure within the formation pressure limits. A general description of the connection between safety critical equipment and the well barriers is discussed in this paper.

Citation: Alec Tang, Kristina Ringwood, Environmental Resources Management (ERM), 'Water Sustainability Risk Assessments: Lessons From Water Sensitive Industries' (Paper presented at 2013 Offshore Technology Conference, Houston, TX, USA, May 06 - 09, 2013)

Topic Area: Integrating HSE into the Business, Produced Water Use, Discharge and Disposal, Environment and Environmental and Social Impact Assessments

Jurisdiction: USA

Abstract: Water has become an increasingly important consideration within the design, operation, and decommissioning of a broad range of industrial activities across the globe. Identifying and characterizing water-related risks is an activity that requires the review of environmental and ecological impacts alongside community and societal concerns, legal and regulatory requirements as well as broader supply chain, reputational and operational aspects. A range of methodologies and techniques to frame these 'water sustainability risk assessments' and allow the assessment of impacts across these different risk categories continue to be developed and refined. Methods that ensure consistency across multi-jurisdiction operational portfolios are also increasingly sought such that the most material risks are identified and addressed.

Aims & Research Methods: This paper highlights the diversity of water sustainability risk assessment methodologies that have been implemented across a range of water sensitive industries. These industries include mining, petrochemical production, pharmaceutical and health product manufacturing and food and beverage. Key lessons for the offshore industries and opportunities to draw across best practices from these examples will also be explored. The critical importance of both undertaking these assessments and ensuring the relevance of outputs will also be reviewed along with the value of integrating broader sustainability and non-technical risks within large capital projects.

Citation: Cesar L. Palagi, Orlando J. S. Ribeiro, Deborah M. Mattos, Salvador da Matta Jr, Petrobras, 'Development and Production of Cascade and Chinook Fields in the Gulf of Mexico: An Overview' (Paper presented at 2013 Offshore Technology Conference, Houston, TX, USA, May 06 - 09, 2013 2013)

Topic Area: Offshore Construction Management

Jurisdiction: USA

Abstract: The initial phase of development, already implemented, consists of two subsea wells in Cascade and one in Chinook tied back, through a field-specific subsea system, to a Floating, Production, Storage and Offloading (FPSO) platform. Oil is transported from the FPSO in shuttle vessels to terminals of opportunity along the USGoM and gas is exported through pipeline. Wells started-up production in 2012. Future phases of development will depend on the performance of the wells.

Aims & Research Methods: This paper is based on the work performed during the design, implementation and operation of the Cascade and Chinook fields, located offshore the United States Gulf of Mexico (USGoM) – the first deployment of an FPSO in the region. It presents an overview of the reservoir rock and fluid properties, the design and construction of wells, the design and installation of the subsea system and FPSO BW Pioneer, the oil export system through shuttle tankers, the gas export through pipelines and the regulatory framework of the project. It also presents operational information about the first wells on stream in each field.

The information provided in this paper is a useful reference for petroleum field operators when designing development concepts for ultra-deep water discoveries, not only in the USGoM but also worldwide. It is especially useful for the design of field development and early production systems located far from pipeline infrastructure. It is useful for contractors to identify the technologies which are most suited for application on deep wells and ultra-deep water subsea systems and production platforms.

Citation: Don Hannegan, P.E., SPE, Weatherford, 'Operational Reliability Assessment of Conventional Drilling vs. MPD on Challenging Offshore Wells' (Paper presented at 2013 SPE / IADC Drilling Conference and Exhibition, Amsterdam, The Netherlands, Mar 05 - 07, 2013)

Topic Area: Pressure Management (MPD, Underbalanced Drilling)

Jurisdiction: Global

Abstract: Value-added efforts towards determining the optimum approach to drilling challenging offshore prospects include applications of reliability cantered strategy early in the planning process. The objective would be to determine the drilling method with highest probability of enabling a safe, on-time and on-budget drilling program that reaches total depth objective with large enough hole for viable production.

Reliability assessments focus on probability of successful functioning; fit for a purpose, resistance to failure, ability to perform a required function for a definitive period of time, and ability to fail well. The reliable performance of the hydraulics of the circulating fluids system itself, even if the encountered pressure environment is not within the predicted drilling margin of error, is critical for operational success.

Aims & Research Methods: This presentation applies Reliability Engineering skills to a HPHT prospect whose water depth and formation pressure map suggests risk of kick-loss scenarios, differential sticking, cementing challenges and TD with too small a hole. An offset well's actual experience with conventional drilling methods will be compared with an operational reliability assessment of applying some applicable variation of managed pressure drilling (MPD) on the proposed well.

Reliability theory became a creditable science during the early days of sail ships to inform investors of the reliability of a vessel to return safe & sound.1 The author proposes that operational reliability concepts remain valuable in marine environments and are uniquely applicable for the purpose of choosing the optimum drilling and well construction methods for drilling challenging offshore drilling programs.

Citation: Md. Amanullah SPE, Saudi Aramco, 'Dendrimers and Dendritic Polymers - Application for Superior and Intelligent Fluid Development for Oil and Gas Field Applications' (Paper presented at 18th Middle East Oil & Gas Show and Conference (MEOS), Mar 10 - 13, 2013 2013, Manama, Bahrain, Bahrain International Exhibition Centre)

Topic Area: Fluids Characterization

Jurisdiction: Global

Abstract: Application of dendrimers and dendritic polymers in oil and gas field fluid formulation can revolutionise the fluid properties due to the unique physical, chemical and biological characteristics of these materials. The ability to synthesize tailor made dendrimer products with desirable functional behaviour also highlights the potential application of dendrimers in smart and intelligent fluid design for oil and gas field application. The large number of monomer units associated with dendrimer core has the potential to add several functional groups of same ionic nature or different ionic natures to fulfil certain technical tasks for a particular application. Custom made dendrimer-based additives that are insensitive to temperature, salinity, pH, solids concentration, cement and lime contamination may lead to the development of a multiple contaminant tolerant drilling mud system for trouble free drilling operation in variable borehole environments. Due to superior physical, chemical, electrical and mechanical properties of dendrimers and dendritic polymers, and also the synthesis of dendrimers that are capable to respond intelligently according to down hole conditions can provide instantaneous solution to various drilling problems.

The internal cavities within the dendrimer structures can be used to store desirable chemicals, enzymes, surfactants, etc. to trigger appropriate interactions on-demand at bottom hole condition to negate, neutralize or reduce the unwanted changes in drilling, drill-in, completion, cleaning, stimulation, fracturing, etc. fluids. The three dimensional spherical configurations of nano-sized dendrimers with high specific surface area can also allow the attachment of multiple functional groups at the terminals to accomplish different functional tasks. Dendrimers with the ability to trigger on-demand interaction by releasing stored chemicals, enzymes or surfactant stored in the cavities can play a pivotal role in developing an intelligent drilling fluid system to provide instantaneous solution to down hole problems. Due to nano-scale dimension, dendrimers may provide effective external and internal inhibition to reactive shale surfaces leading to long-term stabilization of reactive shales. The tiny size and high surface area of dendritic materials will also provide superior fluid properties at a drastically reduced additive concentration.

Dendrimers and dendritic polymers with high thermal stability and affinity to acid gases such as H2S and CO2 will help overcome the technical challenges of geothermal and sour gas drilling operations for a safe, risk-free and economic drilling operation.

Aims & Research Methods: This paper describes some applications of emerging dendrimers and dendritic polymer-based additives in the development of high performance drilling and drill-in, completion, stimulation, etc. fluids for trouble-free drilling, completion and production operations in challenging environments

Citation: Kemal Farid, Merrick; Kashif Bhatti, Merrick; Clara Fuge, Merrick; Sharon McLaughlin, J-W Operating Company; Dana Nichols, Cimarex Energy Co.; Janet Dassinger, Kodiak Oil & Gas, 'Information Technology and Field Data Required to Successfully Manage Shale Production Operations' (Paper presented at 2013 SPE Digital Energy Conference and Exhibition, The Woodlands, TX, USA, Mar 05 - 07, 2013 2013)

Topic Area: Operations Management, Produced Water Use, Discharge and Disposal, Air Emissions, Information Systems and Data Use and Unconventional Hydrocarbon Recovery

Jurisdiction: USA

Abstract: Maintaining the quality of the information gathered is a constant concern. Poor data leads to costly results, from un-optimized production to fines for inaccurate reporting. Incorporating validation checks and approvals into the field systems promotes consistency and accuracy as data is being gathered. Asset specific variances, alerts and visualization can immediately identify operational issues. Access to production targets via mobile devices keeps the field team aligned with corporate goals.

Once gathered, raw production measurements collected in the field are processed to produce allocated production volumes at each well and zone. Consumed by different departments across the company, the allocated volumes are used for planning, forecasting, operations management, revenue accounting, marketing, regulatory and partner reporting. Operators must have an effective production data management system to provide the resulting information to a variety of users at the time, place and in the format they require.

Field information is at the heart of operations management for any operator. The issues around collecting, analysing and sharing it will be examined along with the technologies employed to provide the best solutions appropriate for shale plays.

Aims & Research Methods: This paper will review the unique challenges of field data management and the technologies used to meet them in unconventional resource operations. Examining the lifecycle of field data, we will look closely at issues of data quality, analytics, enterprise data availability, integration, and regulatory compliance from the perspective of shale operators.

Responding to the high decline rates of wells, factory drilling in unconventional plays results in high-paced operations and a large number of wells. With these come massive volumes of field data that must be captured, processed and turned into actionable information for surveillance, operational accounting and HSEQ compliance.

Field teams collect fluid volumes and operating conditions at the well site along with run tickets, tank battery inventories, sales volumes, equipment status, and chemical use. Increased sensitivity to environmental issues around shale plays require operators to closely manage water, emissions and other environmentally impactful measurements that must be collected, monitored and reported. To accommodate these requirements, shale operators need IT systems flexible enough to capture any information that might be needed. Mobility solutions are increasingly being implemented as an enabling technology for capturing the data in the field and communicating it to the systems and users who must process and act upon the resulting information. The use of mobile devices helps eliminate paper, saves time spent on data entry and improves the quality of data flowing into ERP and technical systems.

Citation: L.Nicholas, W.Lozier, Environmental Resources Mangement (ERM), 'Case Studies Demonstrating Sustainability and Risk Evaluations in Environmental Due Diligence for Upstream Oil and Gas Transactions in Alberta' (Paper presented at 2013 SPE Americas E&P Health, Safety, Security & Environmental Conference, Galveston, TX, USA, Mar 18 - 20, 2013)

Topic Area: HSSE & SR Management, Environment and Sustainability/Social Responsibility

Jurisdiction: Canada

Abstract: Recent advances in the unconventional oil & gas plays have resulted in increased investment activities in the upstream space aimed at monetizing large acreage lease holdings as well as cash management to fund exploration and development of new plays. Often these transactions involve the global investment community at both the private and government owned company level. Coupled with these transactions, Global corporations are moving from a narrow view of environmental health and safety (EHS) management to a holistic Corporate and Social Governance (CSG) approach that includes EHS as just one component of managing a sustainable and profitable business. To compete successfully, it is critical that investors understand the implications of CSG risk management strategies and their impact on sustainable business growth plans.

Traditional due diligence activities have focused on quantifying and minimizing EHS impairment liabilities, at best considering a snap shot of current conditions and regulatory operating status. This is due to the fact that the cash flows of established operations are well understood. However, for upstream oil and gas plays with little to no operational assets, the most significant risks are not environmental impairment but rather are the environmental and sustainability risks that could affect asset development. Further, most oil and gas investments involve vast amounts of land and leaseholds, often at various stages within the project life cycle, for which traditional ASTM type due diligence methodologies are not practical.

Aims & Research Methods: This paper uses case studies involving due diligence for acquisitions in the Alberta oil reserves to illustrate a forward-looking assessment methodology for evaluating key non-technical risks such as community relations, water availability and management, sustainable risk management strategies, and reclamation planning. The case studies demonstrate how the results of the due diligence activities were incorporated into the financial models for the investment, allowing the investors to more fully understand the potential risks and opportunities associated with the acquisitions and asset development and incorporate these into their financial models.

The approaches used in these case studies represent a significant and important shift in thought processes around risk evaluation and prioritization during due diligence.

Citation: Andre J. Cantrell, SPE, Cherokee Offshore Engineering, and Mingqin Duan, SPE, Chevron, 'Casing Design for Dual Gradient Wells' (Paper presented at 2013 SPE / IADC Drilling Conference and Exhibition, Amsterdam, The Netherlands, Mar 05 - 07, 2013 2013)

Topic Area: Wellbore Design/Construction and Pressure Management (MPD, Underbalanced Drilling)

Jurisdiction: EU

Abstract: When planning dual gradient wells, it is important to understand the details of dual gradient drilling (DGD) operations and the resulting loads exerted on the casing strings in the wellbore. Standard casing design loads for conventionally drilled wells must be modified so that they apply to dual gradient drilling, and there are additional load cases specific to DGD that must be considered.

Aims & Research Methods: This paper outlines those factors that should be accounted for in dual gradient casing design as compared to conventional deepwater casing design, including:

- Internal and external pressure profiles for typical deepwater casing design load cases for drilling and production strings.
- Additional load cases that should be considered for dual gradient drilling, such as running/cementing casing with an air gap in the string and tension/collapse combined loading when running in the hole.
- Application of dual gradient pressure profiles to worst-case discharge load cases.
- Annular pressure build-up analysis for dual gradient wells.
- Negative test magnitudes and procedures.

While the dual gradient casing design loads are generally less severe than the corresponding load cases considered in conventional deepwater casing design, there are instances in which this does not hold true. Additionally, the collapse loads can be much greater than conventional due to the u-tube that exists during dual gradient operations. A thorough understanding of dual gradient operations is required to conduct a proper, diligent casing design that ensures a safe and efficient well plan and execution.

Citation: Wei Liu, Lin Shi, Yingcao Zhou, Ying Wang, Hongwei Jiang, CNPC Drilling Research Institute, 'Development and Application of Pressure Control Drilling System (PCDS) for Drilling Complex Problem' (Paper presented at 6th International Petroleum Technology Conference, Beijing, China, Mar 26 - 28, 2013)

Topic Area: Intelligent Completions

Jurisdiction: China

Abstract: In the complex geological condition, drilling operation often encounters the stratum whose fracturing pressure and formation pressure is very near. It is easy to cause drilling complex problems such as well kick and well loss. In order to solve the problems, a pressure control drilling system (PCDS) was developed, including automatic manifold system, back-pump system and auto-control system, which can control the pressure distribution in the entire borehole annular precisely through closed-loop automatic control system. The kernel of PCDS is auto-control system which has three significant characteristic, including an advanced real-time hydraulic method, simple and effective control system, self-adaptive control strategies. The auto-control system configuration composes of field-bus device,

controller and workstation which form three levels. Level Ⅰ is measure and on-site diagnosis level. Level Ⅱ is monitor and control level. Level Ⅲ is optimized control level.

From 2011 to now, the PCDS has successfully finished six field services in China which can provides additional flow-rate and back pressure to compensate for the reduction or increment of bottom hole pressure while making a connection, reduction in rig pump rate, change in mud weight or drill pipe movement and so on. The underbalanced-pressure control technology is also developed which is different from the conventional PCDS technology because the controlled bottom-hole pressure is lower than pore pressure of formation and the gas or fluid can be allowed to come out from formation at a controlled rate which is benefit to protect reservoir and improve ROP.

Aims & Research Methods: The applications prove that the PCDS equipment can control the bottom-hole pressure in an exact range and the precise pressure control technology of underbalanced drilling is feasible. So the PCDS equipment can easily adapt to do over-balanced, near-balanced and under-balanced drilling operation and will be more successful in the oil or gas well with safety and fast drilling in the future.

Citation: Luciana Bava, Amir Mahmoudkhani,SPE, Robert Wilson and Leanne Levy, KEMIRA, 'New Generation of "Green" Defoamers for Challenging Drilling and Cementing Applications' (Paper presented at 2013 SPE Production and Operations Symposium, Oklahoma City, Oklahoma, USA, Mar 23 - 26, 2013 2013)

Topic Area: Materials Selection (Casing, Fluids, Cement), Oilfield Chemistry, Drilling Fluids, Handling, Processing and Treatment and Downhole Operations (Casing, Cementing, Coring, Geosteering, Fishing)

Jurisdiction: Global

Abstract: Increased environmental regulations in the North Sea, US and Canada offshores (OSPAR, US EPA, etc.) call for the use of less toxic and biodegradable chemicals in upstream oilfield applications. Compliance with international and domestic protocols governing use and discharge of oilfield chemicals is a crucial factor in the development of new, environmentally benign additives. To create competitive products, service companies need to re-evaluate their existing product lines and re-formulate with chemistries that must meet not only the standards for the ecotoxicity footprint but also, the technological challenges in oilfields. With increasing offshore production activities, the need to develop efficient technological solutions generates a substantial market for "green" chemical substances.

In drilling and cementing applications, the reliable administration of defoaming chemistries is a key step in preventing excessive foaming and avoiding operational difficulties due to entrained air. Traditional products that are used in common operating conditions, often pose a risk to the environment. A new generation of "greener" chemistries is needed either in liquid or solid forms. Solid defoamers represent a particularly attractive alternative, as they are characterized by long term stability and ease of handling under severe climatic conditions.

This paper presents the development of "green" technologies that show superior performance when compared to traditional defoamers. Formulated products in liquid and solid forms are

evaluated using an advanced analytical approach to optimized performance during simulated field conditions.

Aims & Research Methods: Based on widely used risk assessment models, these new alternatives offer safe and reliable solutions for slurry design and chemical control of foaming in offshore applications. Examples of severe foaming cases in slurries containing diverse additives are presented and demonstrate the advantage of this "green" technology.

The oilfield industry is presently facing several challenges both from stricter environmental restrictions and also from specific field application requirements. The focus on finding suitable replacement additives for cementing and drilling systems without compromising the properties of completion fluids is a priority for many oil service companies. The studied "green" defoamers are less toxic and easily biodegradable thus providing new environmentally responsible and cost-effective additives.

Citation: C. Coll, BG, S. Elliott, BG, 'Probabilistic and Deterministic methods: Applicability in unconventional reservoirs' (Paper presented at 75th EAGE Conference & Exhibition incorporating SPE EUROPEC , London, United Kingdom , June 10 - 13, 2013 2013)

Topic Area: Unconventional Hydrocarbon Recovery

Jurisdiction: EU

Abstract: Unconventional resources are pervasive throughout large areas and are not affected by hydrodynamic forces. In contrast with conventional reservoirs, the discovery risk is typically low with reservoir boundaries typically extending beyond the limits of the acreage holding. When estimating reserves and resources, the major uncertainty in unconventional reservoirs tends to be around the local reservoir properties that control well production potential and ultimate recovery. Very high areal variability of factors such as permeability, well deliverability, saturation state, rock mechanical properties exists. Accordingly, field appraisal is continuous as the field is developed to help understanding reservoir heterogeneity dictates the initial production from the wells and decline rates. Technological advances help optimizing the mechanical efficiency of well operations improving the economic viability of these resources through increases in well rates and ultimate recoverable volumes accessed by each well as demonstrated by the successful implementation of new fraccing technologies in shale gas reservoirs.

The new SEC[1] rules adopted in 2009 allow the application of probabilistic methods for reserves and resources estimations. In unconventional reservoirs different stages of maturity exist as described by SPE PRMS[2], COGEH[3] and SPEE[4] Monograph 3 guidelines. The COGEH guidelines are based on deterministic methods whereas SPEE Monograph 3 guidelines are mainly focused on probabilistic methodologies to use for reporting reserves in resource plays (CSG, Shale, Tight Gas/Oil and Basin- cantered Gas Systems) particularly how to estimate proved undeveloped reserves in areas where enough drilling and production exist. COGEH[3] (volume 3) provides valuable guidance on deterministic estimation of reserves and resources for coal bed methane **(**CBM) and Bitumen/SAGD consistent with the definitions provided in COGEH Volumes 1 and 2. In November 2011 the new Guidelines for Application of the Petroleum Resources Management System were published by the SPE[5]. These new guidelines used the 2001 original guidelines as the starting point updating

significantly two new areas: "Estimation of Petroleum Resources Using Deterministic Procedures" and Unconventional Resources. The 2011 SPE guidelines cover more extensively unconventional reservoirs describing the reservoir characteristics, extraction and processing methods, assessment methods, commercial and classification issues for heavy oil, bitumen, tight gas formations, coal bed methane, shale gas, oil shale and gas hydrates.

Aims & Research Methods: This paper provides some guidance on best practices on the applicability of deterministic and probabilistic methods to estimate reserves and resources for unconventional reservoirs based on the maturity of the resource play and existing industry guidelines.

Citation: Deborah Shields, Colorado State University and Politecnico di Torino, Francesca Verga, SPE, and Gian Andrea Blengini, Politecnico di Torino, 'Sustainability Versus Sustainable Development: The Case of Shale Gas' (Paper presented at 75th EAGE Conference & Exhibition incorporating SPE EUROPEC , London, United Kingdom, June 10 - 13, 2013 2013)

Topic Area: Sustainability/Social Responsibility

Jurisdiction: EU

Abstract: The term sustainability is applied to energy resources in multiple ways. One thread of discourse focuses on the sustainability of oil and gas production, the need for exploration, and the consequences of resource depletion. It is widely believed that conventional oil and gas production have already or will peak in the foreseeable future, and will then enter a long term decline. Maggio and Cacciola (2012) predict that conventional oil will peak between 2009 and 2021 and conventional natural gas between 2024 and 2046. They also suggest that coal will peak between 2042 and 2062. The exact peak dates are less important than is the reality of eventual depletion because energy is essential for virtually every sector of every economy. Much of that needed energy is currently generated by burning fossil fuels. Given that alternative energy technologies, such as nuclear and renewables, will be unable to fully meet society's needs in the short to medium terms, concerns about the availability of oil, gas, and coal are wholly appropriate.

Fortunately, we will not run out of fossil fuels soon; due to scientific and technological advances, extraction of unconventional forms of oil and gas are now feasible. Conventional oil and gas deposits consist of porous reservoirs in geologic formations, capped by an impervious rock 'trap' within which migrating fluids such as oil, natural gas and water accumulate. The distribution of oil or natural gas throughout a geologic formation over a wide area, but not in a dicrete reservoir, is called an unconventional deposit (Whitney, et al. 2010). These resources, which include oil sands, oil shale, coal bed methane, and shale gas, may be very large, but their recovery is complex and often expensive. In this paper we focus on shale gas, an unconventional deposit type in which natural gas is distributed throughout low-permeability shale formations. Gas occurrences of this type require special production techniques that often involve horizontal drilling into the gas-bearing formation, followed by hydraulic fracturing of the rock to release the gas from the rock.

Aims & Research Methods: There is an ongoing dialogue in society about the place of energy resources in sustainability. One aspect of that discussion focuses on resource sustainability, the ability of governments and industry to ensure continued supply of needed resources. A related topic centres on the economic benefits and costs of fossil fuel production. Concerns about negative impacts on environmental social sustainability drive other parts of this conversation, and often lead to opposition to fossil fuel production and use. This paper uses the example of shale gas to argue that concentration on single sustainability aspects is inappropriate. Rather, development and production of these resources needs to be considered in the context of sustainable development, which necessitates integrating environmental and development strategies so as to satisfy current and future human needs. Integrated Sustainability Assessment (ISA) is proposed as a way to analyse the net contributions of a shale gas play to economic, environmental, social and resource sustainability. The latter topic is considered and variables that could be used in an ISA are proposed. Understanding, quantifying and communicating the nature and magnitude of the net contribution of shale gas to society will be a challenging, but essential, task in the process of responding to opposition in an open and constructive manner, one which ISAs can support.

Citation: L.K. Cheng, M. Boering, and R. Braal, TNO, 'Toward the Next Fiber Optic Revolution and Decision Making in the Oil and Gas Industry' (Paper presented at 2013 Offshore Technology Conference, Houston, TX, USA, May 06 - 09, 2013)

Topic Area: Production Monitoring and Control, Steam-Assisted Gravity Drainage (SAGD), Monitoring and Control, Production Enhancement and Reservoir Engineering of Subsurface Storage

Jurisdiction: USA

Abstract: Increasing energy demand combined with scarcity means that oil must be produced from new and often more complex reservoirs. These reservoirs may consist of many sections separated by geological faults or the oil may be very viscous, making production more difficult or economically impossible with current technology. This implies that well and production strategies are becoming increasingly complex and require accurate and reliable input for decision making.

Maturing assets develop complex 'time critical' process dynamics such as production decline, liquid loading and salt precipitation creating the need for real-time monitoring and control. This measurement and control technology must give a more accurate understanding of the key processes involved. It should also improve asset diagnostics to lead to improved production control and recovery strategies without compromising reliability or safety. Furthermore the industry has to deal with increasingly complex environmental and safety regulations and an increasing shortage of expert personnel.

We believe that innovations in fiber optic sensing technology have the potential to help better understand the key processes behind decision-making in the oil and gas industry. This insight is based on many projects both inside and outside the oil and gas industry related to monitoring, process modelling and data processing. These new insights are essential to control and optimize the 'new' Oil & Gas industry when one considers the challenges that lie ahead. Before we focus on these upcoming fiber optic technologies for the oil and gas industry, we would like to illustrate the versatility and potential of fiber optic technology based on applications from other industries and their applicability to the oil and gas industry. Fiber optic technology is a proven technology but needs to be adapted and modified to the restricting and demanding applications of the oil and gas industry. These applications also give rise to innovations as will be discussed later.

Aims & Research Methods: Fiber optic data transmission has caused revolutionary developments in the current information society. It was also an eye opener for the Oil & Gas industry when fiber optic-based Distributed Temperature Sensing was introduced in the nineties. Temperature profiles over the entire length of the wellbore could suddenly be monitored in real-time to deliver data that is used for troubleshooting and production optimization. Ongoing research in fiber optic sensing technology for applications with extreme operational conditions (such as aerospace or nuclear fusion) will further boost the development of fiber optic multi-parameter sensing systems. Innovations like these will particularly benefit the Oil & Gas industry in situations where conventional electronic sensors are not technically feasible or cost efficient.

In multi-parameter sensing systems of the future, different types of fiber optic sensors (e.g. flow, pressure, acoustic, chemical, vibration, gravity) can be manufactured and read out via one single optical fiber. Data from the different types of sensors will be merged and processed via special data-mining algorithms to generate unambiguous information for faster and better decision making. Judging on the speed of developments witnessed today, we believe there will be a second fiber optic sensing revolution in the Oil & Gas industry in the near future. In this paper, we will give some in-house examples of fiber optic innovations from both in and outside the Oil & Gas industry to demonstrate the versatility and potential of fiber optic technology.

Citation: Jan Reier Huse, Scandpower; Inge A. Alme, Scandpower, 'BOP Reliability monitored Real Time' (Paper presented at SPE European HSE Conference and Exhibition - Health, Safety, Environment and Social Responsibility in the Oil &Gas Exploration, London, United Kingdom, Apr 16 - 18, 2013)

Topic Area: Operational Safety, Risk, Uncertainty, and Risk Assessment and Decision-Making Processes

Jurisdiction: EU

Abstract: The BOP is a complex construction with multiple parts and systems integrated. Any single failure will affect the overall functionality of the BOP. A key question will always be whether a particular failure has such an adverse effect on the overall functionality that the BOP needs to be pulled for repair and hence drilling halted. The presentation will outline how a BOP is broken down into a detailed fault tree. The fault tree is modelled in the software tool RiskSpectrum® originally developed for assessing process safety of nuclear power plants. Once a failure of any part in the BOP assembly is detected, the information is fed into the model, and the effect on the overall availability of the BOP is evaluated through a predefined methodology. The results are displayed to the crew on board through any easy to understand mimic. The operating crew on board an offshore drilling unit can then continuously monitor the availability of the BOP and make decision on their further actions based on real time facts on BOP status.

Aims & Research Methods: The BOP model has been developed under a contract with and funding from a major drilling operator and Lloyd's Register, with BOP manufacturers being directly involved. US Authorities has been kept informed on the development. A joint industry panel with representative from Mobile Drilling Unit Owners, BOP manufacturers and Operating Companies has been overseeing the work.

The model has been launched and training of the operators has been carried out. Results from the implementation will be available at the presentation at the conference.

Citation: James Slutz, SPE, Global Energy Strategies; Jeffrey Anderson, SPE, Select Energy Services; Richard Broderick, Fountain Quail Water Management; Patrick Horner, SPE, Aqua-Pure Ventures, 'Key Shale Gas Water Management Strategies: An Economic Assessment' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Australia

Abstract: "When the well is dry, we know the worth of water." – Benjamin Franklin. Water management typically make up between 5% and 15% of overall shale gas drilling and completion costs. When we understand the short and long term considerations that contribute to overall costs, we know the worth of shale gas water management. Understanding the variables that influence flow back quality and quantity are a key foundation to establishing an overall strategy. Cost components, such as fresh water, transportation, storage, treatment options, and disposal, are highly dependent on the nature of the flow back, and both regional geography and regulations. There are three basic shale gas water management strategies: disposal of flow back, re-use of flow back, and recycling of flow back. A simple economic model can be used to determine the most cost-effective strategy, depending on the specifics of a particular scenario. A proactive shale gas water management strategy can both reduce costs and enable long-term production by addressing and balancing the needs of industry, the regional regulators, the environment, and the community.

Aims & Research Methods: As a result of recent innovations in horizontal drilling and hydraulic fracturing, shale gas has become an important global energy supply. However, water consumption and disposal issues associated with shale gas development, coupled with industry growth, are creating a need for sophisticated water management strategies. Current shale gas water management strategies fall into three key categories: disposal, re-use, and recycling. Disposal strategies involve sourcing fresh water for hydraulic fracturing and transporting all frac flow back and produced water to an injection well for disposal. Re-use strategies involve primary treatment of frac flow back, so it can be blended with make-up water for re-use as frac fluid. Recycling strategies involve treating the flow back to fresh water quality, either for re-use in hydraulic fracturing or for environmental discharge. This paper will analyse the total life cycle water management costs per frac by comparing the options and costs of water supply; water transportation; cost and options for disposal, re-use, and recycling; impact of water quality on frac chemical costs; the impact of water quality on frac performance and long-term well performance. This paper will also identify other impacts, including safety, public perception, community impact, and environmental liability.

Citation: O. Hausberger, SPE, L. A. Högn, SPE, K. Soliman, SPE, Mining University of Leoben, 'Management Decision Matrix for Shale Gas Projects in Europe' (Paper presented at SPE Hydrocarbon Economics and Evaluation Symposium, , Calgary, Alberta, Canada**,** 24-25 September 2012)

Topic Area: Strategic Planning and Management and Social Responsibility

Jurisdiction: Global

Abstract: The world energy demand is increasing gradually and E&P companies are forced to increase their resources. In the last few years a worldwide increase in shale gas projects could be recognized, especially in the US. This hype of shale gas is coming over to Europe. The situation in Europe is mainly different than that in the US. Consequential an adaptation of the project management has to be done, to fit into the European requirements.

To achieve a general overview on shale gas projects, an understanding of the relevant techniques and geological issues need to be established. The authors intend to highlight the difference in project management between conventional and unconventional projects, particularly for shale gas projects. Furthermore the difference of social, ecological, technical and economic issues is presented in the 3D matrix. The developed matrix acts as a decision tool for the project management level and should help to implement the shale gas project in a more sustainable way. To guaranty the transformation of the three columns of sustainability the matrix covers the main tasks of an E&P project for the particular project phase. The matrix should act as an impulse for discussions in the E&P business. It is important to notice that this matrix is based on interviews with University Professors as well as engineers from different petroleum companies in Europe, which are currently realizing shale gas projects.

Aims & Research Methods: On the today's global market it is an important issue to have an adapted management system, due to the fast change of beliefs in social communities and politics. In the last few years a significant change in E&P business could be recognized from conventional sources to unconventional ones. With this extensive change the degree of resistance and possible problems for E&P companies increase, especially in Europe.

To realize an unconventional project in Europe, like shale gas, it is very important to adjust the project management to the given situation. There is a lot of resistance and fear from the population in Europe against shale gas projects, which is somehow unfounded.

To maintain a high acceptance of the communities and governments, the emphasis lies on the adaption of this operation.

The projects have to be operated in a more sustainable way. Observation of economic and technical issues is important, but the management has to look further beyond. To account for the overall sustainability, two further levels have to be considered, especially in shale gas projects. Ecological and social aspects for unconventional projects have to be introduced and interconnected in a higher degree compared to conventional projects in the oil and gas industry.

This paper introduces a 3D matrix, where the three major points of sustainability are imbedded into a workflow chart of a shale gas project. The matrix should act as a sort of subsidiary to the management of a shale gas project in Europe.

Citation: Roberto F. Aguilera and Ronald D. Ripple, Centre for Research in Energy and Mineral Economics (CREME), Curtin University; Roberto Aguilera, Schulich School of Engineering, University of Calgary, 'Link between Rocks, Hydraulic Fracturing, Economics, Environment, and the Global Gas Portfolio' (Paper presented at SPE Canadian Unconventional Resources Conference, Calgary, Alberta, Canada, 30 October-1 November 2012)

Topic Area: Economic Analysis Guidelines

Jurisdiction: Canada

Abstract: Figure 1 is a pentagon showing the link between rocks, hydraulic fracturing, economics, environment, and the global gas portfolio. Our view is that there must be an equilibrium in the pentagon to provide a win-win situation for society at large. All corners in the pentagon are interrelated and there is no need to sacrifice one for benefit another. It has been shown that there is a significant gas endowment in conventional reservoirs. However, we have to also unlock natural gas stored in unconventional formations to ensure that gas plays an important role in satisfying future energy consumption. We cannot produce it economically without hydraulically fracturing the unconventional formations. At the same time, we cannot sacrifice the environment solely for economic gain and nothing but the highest environmental standards are acceptable. All stakeholders must act responsibly to generate the win-win situations.

Aims & Research Methods: This paper presents a methodology for connecting geology, hydraulic fracturing, economics, environment and the global natural gas endowment in conventional, tight, shale and coal bed methane (CBM) reservoirs. The volumetric estimates are generated by a variable shape distribution model (VSD). The VSD has been shown in the past to be useful for the evaluation of conventional and tight gas reservoirs. However, this is the first paper in which the method is used to also include shale gas and CBM formations.. Results indicate a total gas endowment of 70000 tcf, split between 15000 tcf in conventional reservoirs, 15000 tcf in tight gas, 30000 tcf in shale gas and 10000 tcf in CBM reservoirs. Thus, natural gas formations have potential to provide a significant contribution to global energy demand estimated at approximately 790 quads by 2035.

A common thread between unconventional formations is that nearly all of them must be hydraulically fractured to attain commercial production. A significant volume of data indicates that the probabilities of hydraulic fracturing (fracking) fluids and/or methane contaminating ground water through the hydraulically-created fractures are very low. Since fracking has also raised questions about the economic viability of producing unconventional gas in some parts of the world, supply cost curves are estimated in this paper for the global gas portfolio. The curves show that, in some cases, the costs of producing gas from unconventional reservoirs are comparable to those of conventional gas. The conclusion is that there is enough natural gas to supply the energy market for nearly 400 years at current rates of consumption and 110 years with a growth rate in production of 2% per year. With appropriate regulation, this may be done safely, commercially, and in a manner that is more benign to the environment as compared with other fossil fuels.

Citation: George E. King, Apache Corporation, 'Hydraulic Fracturing 101: What Every Representative, Environmentalist, Regulator, Reporter, Investor, University Researcher, Neighbor and Engineer Should Know About Estimating Frac Risk and Improving Frac Performance in Unconventional Gas and Oil Wells' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 6-8 February 2012)

Topic Area: Production and Operations, Hydraulic Fracturing and Gravel Packing, Wellbore Design/Construction, Risk Management and Decision-Making and Chemical Tracers

Jurisdiction: USA

Abstract: Identification of risk, the potential for occurrence of an event and impact of that event, is the first step in improving a process by ranking risk elements and controlling potential harm from occurrence of a detrimental event. Hydraulic Fracturing has become a hot environmental discussion topic and a target of media articles and University studies during development of gas shales near populated areas. The furor over fracturing and frac waste disposal was largely driven by lack of chemical disclosure and the pre-2008 laws of some states.

The spectacular increase in North American natural gas reserves created by shale gas development makes shale gas a disruptive technology, threatening profitability and continued development of other energy sources. Introduction of such a disruptive force as shale gas will invariably draw resistance, both monetary and political, to attack the disruptive source, or its enabler; hydraulic fracturing.

Some "anti-frack" charges in media articles and university studies are based in fact and require a state-by-state focused improvement of well design specific for geology of the area and oversight of overall well development. Other articles have demonstrated either a severe misunderstanding or an intentional misstatement of well development processes, apparently to attack the disruptive source.

Aims & Research Methods: Transparency requires cooperation from all sides in the debate. To enable more transparency on the oil and gas side, both to assist in the understanding of oil and gas activities and to set a foundation for rational discussion of fracturing risks, a detailed explanation of well development activities is offered in this paper, from well construction to production, written at a level of general public understanding, along with an initial estimation of frac risk and alternatives to reduce the risk, documented by literature and case histories. This discussion is a starting point for the well development descriptions and risk evaluation discussions, not an ending point.

Citation: C.E. Cooke, Jr., SPE, Cooke Law Firm; J.T. Watters, SPE and L.T. Watters, SPE, CSI Technologies, LLC; S.R. Wann, Danimer Scientific, LLC; D. Zhu, SPE and Y.S. Hwang, SPE, Texas A&M University, 'Eco-Friendly Creation of Propped Hydraulic Fractures' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA , 6-8 February 2012)

Topic Area: Drilling and Completions, Fundamental Research in Drilling & Completions and Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: USA

Abstract: Near wellbore damage to wells prevents new wells from producing at the expected rate or causes wells on production to lose productivity with time. The problem has been addressed by applying small-volume hydraulic fracturing and by acidizing or solvent treatments to decrease damage to flow capacity near a wellbore. When well tests are performed to determine reservoir and near-wellbore flow capacity, it has been found that a substantial fraction of the benefit from a larger fracturing treatment comes from near-wellbore damage removal, particularly in higher permeability reservoirs. There has long been a need for an environmentally-friendly, cheaper and more effective process to remove the effects of near-wellbore damage to the flow capacity of a well. This paper describes such a process.

The U. S. land market for small, accurately placed fracture treatments to bypass near-wellbore damage is significant and largely untouched by current technology developers. A recent estimate of small fracture treatments performed in the U. S., focused primarily in Texas, Oklahoma, and Louisiana, came to 26,000 jobs/year. Market revenue was estimated at around $1 billion per year, with small independent operators and independent service companies representing the majority of consumers and suppliers.

A process has been developed and is ready for field testing that can create a wide, propped fracture for a limited distance, in the range of tens of feet, and that extends all the way to the wellbore. The process uses an environmentally-friendly polymer that is introduced into the wellbore in the form of solid pellets containing proppant. The polymer degrades in the presence of water to form a very viscous, proppant-laden gel fluid in the wellbore. Before the polymer degrades enough to allow prop-pant particles to settle, the proppant-containing gel is squeezed into the formation above fracturing pressure. The polymer continues to degrade to a clear aqueous solution, leaving no damage in the fracture. The polymer degrades to an acid, which can be effective to create fracture conductivity without proppant in carbonate formations.

The benefits of this process include:

- Creation of wide, high-conductivity fracture near wellbore
- Use of much less water
- No damage to proppant pack or formation face from polymer residue
- Less horsepower and fewer surface units
- Polymer synthesized from renewable resources that degrade to environmentally benign end products

Aims & Research Methods: A novel method for creating short, highly conductive fractures in wells to bypass formation damage has been developed. The method uses relatively small material volumes, low horsepower and pump rate, produces minimal environment effect, and leaves the formation face and proppant pack residue free. Function and application of the method present significant varia-tions in treatment design and execution compared to traditional hydraulic fracturing past damage. This paper presents results of development work to confirm the method’s applicability and to provide sufficient performance data to design initial field applications.

Citation: V.P. Stenin, S.V. Delia, Lukoil, V.S. Levchenko, Lukoil Engineering; S. Vereschagin, SPE, K.K. Butula, SPE, P. Enkababian, SPE, Schlumberger, 'First Hydraulic Fracturing from a Supply Vessel in the Caspian Sea Offshore Russia' (Paper presented at SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition, Moscow, Russia, 16-18 October 2012)

Topic Area: Production and Operations

Jurisdiction: Russia

Abstract: Rakushechnoe-8 is one of the exploration wells drilled in the Northern Caspian Sea. The understanding of the geometry and performance of the propped fracture completion in the Apt formation was considered critical for the economic development of this offshore oilfield. Because of this, and the potential risk of fracture breaking into the water zone below, no resources were spared and robust engineering methods were applied for the first time in Russian offshore operations to determine the formation productivity without and with a hydraulic fracture completion in place. This case history will detail how a planned joint engineered approach provided critical information for the reservoir and production teams to determine the formations potentials, ensuring at the same time reliable and safe offshore operations.

Aims & Research Methods: After a detailed feasibility and engineering study, a local supply vessel was converted into a stimulation vessel to meet the maritime regulation requirements and projected needs of the Russian Federation. As part of the Project Readiness Assessment, the 4000-HHP strong frac equipment was mock-assembled on the dock, tested, and all the hazards evaluated before sailing. The joint engineering team prepared a rigorous plan for multi-source data collection before, during, and after treatment operations. The plan included running dipole cased hole acoustic measurements before and after the frac treatment, bottomhole pressure gauges, a complete mini-frac test, multiple post mini-frac temperature logging runs, production logging runs, and well testing and sampling operations before and after the frac. Finally, a novel vertical seismic profile and micro-seismic measurement was employed to further understand the hydraulic fracture behaviour in the Apt formation.

The data analysed before the main fracture treatment enabled safe placement of all 49 tons of 16/20 mesh Intermediate Strength Proppant (ISP) through the drillstem test string obtaining a C_{fd} = 2.7 deemed optimal for the formation.

Post frac measurements and semi numerical modelling indicated that the mechanical model created before the mini frac required some additional modifications and that the propped fracture remained within the target zone. The acoustic and microseismic post frac measurements and well-test results correlated with the expected fracture effective half-lengths and conductivity, confirming that the preparation and execution involved with attaining accurate measurements provided significant value.

Citation: Bilu V. Cherian, SPE, Schlumberger, Edwin S. Stacey, SPE and Stephen Bressler, Petro-Hunt, LLC., Fabian O. Iwere, SPE, Robin Noel Heim, SPE, Shannon Higgins-Borchardt, SPE, Schlumberger, 'Evaluating Horizontal Well Completion Effectiveness in a Field Development Program' (Paper presented at SPE Hydraulic Fracturing Technology, The Woodlands, Texas, USA, Conference, 6-8 February 2012)

Topic Area: Hydraulic Fracturing and Gravel Packing, Construction of Static Models and Well Candidate Recognition

Jurisdiction: USA

Abstract: The Bakken Formation is a widespread unit in the central and deeper portions of the Williston Basin in the states of Montana and North Dakota, in the United States, and the provinces of Saskatchewan and Manitoba in Canada (Figure 1). The formation is comprised of an Upper Shale Member, a Middle Siltstone Member and a Lower Shale Member (Figure 2). The Upper and Lower Bakken shales are organic rich and are the petroleum source rocks for both the Bakken and Three Forks Formations. Porosity in the middle member of the Bakken formation is in the range of 4% to 9%, and water saturation ranges between 25% and 50%, depending upon the county where wells are located. In the Williston Basin the Upper Bakken Shale is overlain by the Lodgepole Formation which consists of dense, dark gray to brownish gray limestone and gray calcareous shale. Below the Lower Bakken Shale is the Three Forks formation. The Three Forks is composed of thinly interbedded greenish gray and reddish brown shales, light brown to yellow gray dolostone, gray to brown siltstone, quartzose sandstone and minor occurrences of anhydrite (Kume, 1963). The contact between the Bakken and Three Forks appears conformable in the deeper portions of the basin and unconformable on the basin flanks. The Three Forks has an average of 30.5 ft pay thickness, 65% oil saturation and 6.9% porosity. The Nisku (or Birdbear Formation) is conformably overlain by the Three Forks Group.

Aims & Research Methods: In field development programs where large variations in reservoir and completion parameters exist, the evaluation of reservoir performance to determine the optimal completion strategy can be a challenging task. This paper presents findings from a recent integrated cross-discipline analysis of a pilot program performed in the Bakken and Three Forks Formations (Williston Basin, North Dakota) to evaluate the impact of petro physical and geomechanical properties on hydraulic fracture lengths, reservoir connectivity, well performance and well spacing.

Microseismic, geological, geomechanical, completions, engineering and production data were integrated in single and multi-well modelling approaches to provide an objective method to evaluate and compare well performance. Results and conclusions from various disciplines were validated by integrating operational observations with the modelling. The application of the proposed workflow allows one to (1) understand and evaluate the effect of fracturing parameters (length/conductivity) on well performance, (2) characterize reservoir and fracture properties using hydraulic fracture pressure and production history matching techniques (3) relate fracture parameters to reservoir, geology and mechanical properties and, (4) provide a methodology to understand key drivers controlling the development strategy of an asset.

Citation: Geert M. van der Kraan, The Dow Chemical Company, Philip A. Keene, The Dow Chemical Company, Malcolm James, The Dow Chemical Company, Bei Yin, The Dow Chemical Company, Terry M. Williams, The Dow Chemical Company, Otto P.J. van Ruiten, The Dow Chemical Company and Donald J. Love, The Dow Chemical Company, 'Water Management and Microbial Control Programs in the Exploitation of Unconventional Hydrocarbons' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, , Vienna, Austria**,** 20-22 March 2012)

Topic Area: Produced Water Use, Discharge and Disposal, Chemical Treatments, Standards, Regulations and Codes and H2S Management

Jurisdiction: Global

Abstract: Worldwide, the production of natural gas and now oil from shale basins (source rock) has been embraced as a commercially viable way of producing unconventional energy resources leading to a revolution in gas production in the US. Developments to invest in and tap into this alternative way of gas production are taking off in Europe and Asia. Hydraulic fracturing is a proven technology, used for many years to develop hydrocarbon resources. Successful strategies with hydraulic fracturing include the safe and effective use of chemical additives, proper well casing and robust water management programs. During the exploitation of hydrocarbons from shales, chemical additives such as corrosion inhibitors, gelling agents, biocides etc., have to be used in the fracturing of wells. Sustainable chemistries and effective product stewardship programs are required to minimize environmental and human exposure hazards. The addition of water with organic molecules to the actual fractured wells makes these environments subject to unwanted growth of microorganisms and biofilm development, which has detrimental effects on hydrocarbon flow and leads to pipeline/equipment corrosion. Often the presence of sulphate reducing microorganisms leads to unwanted H2S production and subsequently souring. Due to this, water cycle management and properly designed microbial control programs for all water sources including injected water or produced water, are required. Because the microbial challenges and environmental parameters of these water sources vary, different microbial control strategies and treatments are required for each source.

Aims & Research Methods: New formulations of biocides and control programs aimed at the needs of the gas and oil industry have been developed, e.g. improved heat stability and the reduction in biocide levels to achieve the same level of microbial control. These newly developed microbial control technologies will be presented in this paper, and the related regulatory and product stewardship support will be shortly addressed.

Citation: Robert L. Kennedy, SPE, William N. Knecht, SPE, and Daniel T. Georgi, SPE, Baker Hughes, 'Comparisons and Contrasts of Shale Gas and Tight Gas Developments, North American Experience and Trends' (Paper presented at SPE Saudi Arabia Section Technical Symposium and Exhibition, Al-Khobar, Saudi Arabia, 8-11 April 2012)

Topic Area: Unconventional shale and tight gas development

Jurisdiction: USA

Abstract: Unconventional shale and tight gas development in the US was sparked by the 1980 introduction of The Alternative Fuel Production Credit of the Internal Revenue Code (an income tax credit). "The 1980 WPT (windfall profit tax) included a \$3.00 (in 1979 dollars) production tax credit to stimulate the supply of selected unconventional fuels: oil from shale or tar sands, gas produced from geo-pressurized brine, Devonian shale, tight formations, or coal bed methane, gas from biomass, and synthetic fuels from coal. In current dollars this credit, which is still in effect for certain types of fuels, was \$6.56 per barrel of liquid fuels and about \$1.16 per thousand cubic feet (mcf) of gas in 2004" (Lazzari 2006). Initially, the credit was set to run until 1989; however, it was extended twice until the end of 1992 (Martin and Eid 2011).

Higher gas price was another reason for the continued development of tight gas and especially shale gas. Figure 1 shows Henry Hub spot prices from 2000 until January of 2012. The “spot price” represents the price for natural gas sales contracted for next day or weekend delivery and transfer at a given trading location. Henry Hub is the primary trading location, centralized point, for natural gas trading in the United States, and is often a representative measure for wellhead prices. Higher prices are reflected by the six year (2003-2009) run of gas prices over $6 per MMBtu after generally hovering around $2 per MMBtu for the prior twenty-year period, 1980 to 2000. During this time, two significant peaks in gas prices occurred. In the summer of 2005, hurricanes along the U.S. Gulf Coast caused more than 800 billion cubic feet (Bcf) of natural gas production to be shut in between August 2005 and June 2006. As a result of these disruptions, natural gas spot prices at times exceeded $15 per million Btu (MMBtu) in many spot market locations and fluctuated significantly over the subsequent months, reflecting the uncertainty over supplies (Mastrangelo 2007). In 2008, due to physical and financial market factors, spot prices broke from the $6-$8 per MMBtu range of the two previous years and peaked at $13.32 per MMBtu, but ended the year at $5.63 per MMBtu. This was the beginning of the current fall in gas prices.

Aims & Research Methods: All Shale Gas reservoirs are not the same. There are no typical Tight Gas reservoirs. These two statements can be found numerous times in the literature on shale gas and tight gas reservoirs. The one common aspect of developing these unconventional resources is that wells in both must be ‘hydraulically fractured’ in order to produce commercial amounts of gas. Operator challenges and objectives to be accomplished during each phase of the Asset Life Cycle (Exploration, Appraisal, Development, Production, and Rejuvenation) of both shale gas and tight gas are similar. Drilling, well design, completion methods and hydraulic fracturing are somewhat similar; but formation evaluation, reservoir analysis, and some of the production techniques are quite different.

Much of the experience in shale and tight gas has been developed in the US and in Canada, to a lesser extent; and most of the technologies that have been developed by operators and service companies are transferable to other parts of the world. However, the infrastructure, including equipment and service company availability, governmental regulations, logistics, processing, environmental considerations, and pricing are not the same as in the US. This may impact the rate of the technology transfer as well as the selection of some of the technology. This paper is focused on operations challenges, technologies, and experience associated with shale and tight gas projects. It is likely that environmental concerns and the drive to reduce development costs of tight and shale gas reservoirs will drive new approaches to the development of these reservoirs in China, Latin America, Middle East, North Africa, and other parts of the world.

Citation: Scott D. Reed, Zeeco, Inc., ‘Best Practices for Using Flares to Meet Proposed EPA Emissions Regulations for Hydraulically Fractured Natural Gas or Oil Wells’ (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Air Emissions

Jurisdiction: USA

Abstract: On April 17, 2012, the US Environmental Protection Agency (EPA) released final environmental regulations to reduce air pollution from the oil and gas industries. The final ruling, the result of an eight-year review of the EPA's Clean Air Act, includes the first federal air standards for oil and natural gas production. After final comments were received, a New Source Performance Standards (NSPS) for VOC and SO_2 reduction at the well site, and a National Emissions Standards for Hazardous Air Pollutants (NESHAP) for oil and gas production facilities were developed. The final ruling provides well owners and operators increased compliance flexibility while enhancing transparency and accountability. The new regulations will also help well operators avoid unnecessary spending of state and private resources and maintain comparable environmental benefits.

One of the key components of the new ruling is reducing the potent greenhouse gases that result from natural gas production. Forty percent of all greenhouse gas emissions occur from oil and gas production and processing; gas production and processing is one of the single largest methane sources.[1] Reducing the VOC emissions from production equipment and well sites will help reduce ground-level ozone. This final ruling is "expected to yield a nearly 95% reduction in methane and VOCs emitted from more than 11,000 new hydraulically fractured gas wells each year.[1]" VOCs in the presence of sunlight promote the formation of smog (ground level ozone), a known irritant with potential health and environmental impacts near oil and gas production sites. Crude oil and gas production as well as natural gas onshore processing are targeted segments for VOC and SO_2 reduction. Other emissions, including benzene and other known potential air toxins, are also defined.

40 CFR Part 63 subpart HH directly impacts the oil and gas production industry. Subpart HHH of regulation 40 CFR Part 63 specifically affects the natural gas transmission and storage market segment. In previous rulings, Startup, Shutdown, and Malfunction (SSM) activities were exempted from meeting performance standards during these specific periods of operation. In the new regulations, SSM is not exempt and is required to meet the noted performance standards. This is a departure from previous regulations and should be a consideration in the design of control devices.

Aims & Research Methods: The new 2012 EPA Oil and Natural Gas Air pollution standards, enacted April 17, 2012, are designed to reduce harmful emissions of VOCs from hydraulically fractured wells. VOCs in the presence of sunlight promote the formation of smog (grade-level ozone) near areas where oil and gas production occurs. The four-targeted areas of VOC reduction in oil and gas production will affect some 25,000 wells per year as well as storage tanks and other processing equipment. Flare systems are proposed as one of the preferred control devices to meet these new regulations.

Complicating the hydraulic fracturing production picture further, the industry expects new EPA flare regulations to be proposed shortly. These regulations are currently under review with public comment underway via the TCEQ and EPA Flare Stakeholder Task Force.

This paper will address specifics of both new regulations and provide guidance for cost-efficient and effective flare system designs.

Citation: Steve Szymczak, SPE, Dong Shen, SPE, Rocky Higgins, SPE, and D.V. Satya Gupta, SPE, Baker Hughes, 'Minimizing Environmental and Economic Risks with a

Proppant-Sized Solid Scale Inhibitor Additive in the Bakken Formation' (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Hydraulic Fracturing and Gravel Packing and Production Enhancement

Jurisdiction: USA

Abstract: Several methods are known in the art for introducing scale inhibitors into producing wells. For instance, a liquid inhibitor may be pumped into a water-producing zone of the subterranean formation by application of hydraulic pressure from the surface, which forces the inhibitor into the target zone. In most cases, such treatments are performed at down hole injection pressures below that of the formation fracture pressure. However, this scale squeeze operation is a non-selective process that leads to uncertainties in the extent of coverage of water-producing zones during hydraulic fracture operations. Thus as the liquid scale inhibitor is injected into the fracture, the liquid tends to be lost into the formation before penetrating any appreciable distance along the propped fracture (Norris et al., 2001). Alternatively, a liquid scale inhibitor can be incorporated into the fracturing fluid to provide initial protection against scale. However, there is little control over the release rate as measured through subsequent inhibitor residual testing.

Rather than use a liquid chemical inhibitor, the wells can be treated with a solid inhibitor. For example, a chemical inhibitor can be adsorbed onto an inert, proppant-sized, solid particle, which can be applied with a fracture stimulation operation that combines two treatments, saving the operator time and possibly expense (Gupta et al., 2010; and Brown et al., 2011). In this strategy, the solid inhibitor is placed in the created fracture, far enough from the wellbore, and distributed evenly throughout the fracture. When production begins, the inhibitor slowly desorbs into the fluids contained in the formation before such fluids enter the wellbore. More than 15,000 wells have been treated with the proppant-sized solid inhibitor during the hydraulic fracture process since 2004.

Aims & Research Methods: Within the past decade, hydraulic fracturing has been proven to improve the efficiency and economics of recovering oil and natural gas from shale formations. In a previous paper (SPE 134414), a summary of treatment results of placing a solid scale inhibitor into formations via the fracturing process for over five years and in over 1500 wells was fully discussed. The practice of hydraulic fracturing has come under scrutiny due to concerns about the environmental impact, health and safety. Therefore, a novel biodegradable solid scale inhibitor with an excellent ecotoxicity profile for fresh water incorporated into a solid matrix was recently developed and deployed in North Dakota. For one operator in this area with 150 Bakken-producing wells, 22 of the wells have experienced at least one event of severe mineral scaling in the pump and production tubing, leading to well failure, whereas the results from over 140 Bakken wells now fractured with the new solid inhibitor additives indicate no reported scale failures to date.

This paper provides a detailed description of the first deployment of this environmentally preferred proppant-sized solid scale inhibitor additive under severe scaling conditions in the field. In addition, an analytical method developed to track the residual of this additive in the produced fluid containing polysaccharide contaminants is also discussed.

Citation: Harold D. Brannon, Daniel J. Daulton, Matthew A. Post, Harold G. Hudson, and Andrew K. Jordan, Baker Hughes, 'The Quest to Exclusive Use of Environmentally Responsible Fracturing Products and Systems' (Paper presented at PE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 6-8 February 2012)

Topic Area: Hydraulic Fracturing and Gravel Packing

Jurisdiction: USA

Aims & Research Methods: Hydraulic fracturing processes have recently been the subject of increasing scrutiny with particular concern directed towards protection of water resources. Operators and fracturing services companies in the United States have been targeted by both federal and state legislators and the EPA with audits, inquiries, and regulations requiring disclosure of the chemicals pumped in fracturing treatments and banning the use of certain chemistries, such as diesel oil. Much effort has been expended to identify alternative, more environmentally acceptable products which maintain the needed material performance characteristics and cost basis.

A new quantitative process based upon the Globally Harmonized System for Classification and Labelling of Chemicals (GHS) has been employed to evaluate and rank the hazards posed by various treating fluid additives and potential alternatives. The GHS is a process is which has been adopted by the United Nations to standardize information regarding the hazards and toxicities of chemicals. Once the respective material hazards have been quantified, they may be ranked for comparison with like purposed additives for their anticipated safety, health, and environmental impact. The best candidates by that measure may then be assessed for performance and cost. The process has become a valuable tool to guide fracturing R&D and oilfield chemical suppliers toward development of more environmentally acceptable products and systems.

The progress towards the objective of full implementation of environmentally acceptable chemistries in fracturing applications is documented. Working examples of the more acceptable chemical additive selections resulting from the applications of the hazard assessment process are provided. Furthermore, the migration to more environmentally responsible fracturing processes through quantification of hazardous risk "removed" from applications by replacement with more favourable alternatives is discussed.

The fruits of the process will be discussed in this endeavour, providing working examples of the chemical additive selection. Furthermore, the progress to more environmentally responsible fracturing processes through quantification of hazardous risk 'removed' from applications, i.e. amount of hazardous material removed by replacement with more favourable alternatives.

Citation: Jason E. Bryant, Johanna Haggstrom, SPE, Halliburton, 'An Environmental Solution to Help Reduce Freshwater Demands and Minimize Chemical Use' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Production Enhancement and Hydraulic Fracturing and Gravel Packing

Jurisdiction: Global

Abstract: New technologies to reduce chemical exposure to personnel and the environment during fracturing operations are at the forefront of research and development efforts. Unconventional reservoir developments require large amounts of fresh water, sometimes up to 5 million gal to complete a well, leading to difficulty in water sourcing in remote locations or regions where droughts are persistent. Several new areas currently under consideration for shale exploration are in environmentally sensitive locations, making the water sourcing for fracturing operations even more critical. Freshwater use needs to be minimized, and a careful examination of current practices should be undertaken to reduce, eliminate, and recycle chemicals wherever possible. Furthermore, fracturing fluids essential for successful stimulation treatment should be comprised of chemicals adhering to environmentally acceptable standards.

Recent developments have allowed one operator to minimize freshwater usage through recycling of their flow back and produced water using electrocoagulation (EC) technology. EC is a water-treatment process that removes colloidal solids through methods of coagulation, electroflotation, and settling. Unlike conventional water-treatment practices, such as reverse osmosis or distillation, EC generates relatively small quantities of waste, while leaving dissolved solids in the water. To ensure enough water was available for fracturing stimulation treatment, fresh make-up water was also used. This freshwater source was treated for bacteria using an ultraviolet (UV) trailer, which minimized the need for biocide on location. In addition, dry-blending technology was used to hydrate the gel without the aid of mineral oils. All of these processes were used to reduce the environmental impact on location.

With increasing public scrutiny and concern over the practice of hydraulic fracturing in environmentally sensitive locations, fluid systems need to follow strict environmental guidelines. A new fluid system was developed with components from the US Code of Federal Regulations Title 21 (CFR 21), or the Generally Recognized as Safe (GRAS) affirmation process. While setting a high precedence by adhering to this environmental benchmark, the fluid performance was not compromised.

Citation: Susan Stuver, Jesse Alonzo, Stephen Holditch, Skip Mills, Texas A&M University System, 'Getting Ahead Of The Regulators By Building Your Own Emissions Profile' (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Air Emissions

Jurisdiction: USA

Abstract: Development of improved air emissions management through better emissions estimation methodologies and best available estimation techniques for hydraulic fracturing phases.

Federal and State regulators are developing air emissions regulations that will have an impact on the oil and gas industry. In the near future, regulatory requirements will be put in place that entail the measurement and reporting of such air emissions as NOx, VOCs, Greenhouse gases (such as methane), NO2, SO2 and more. Historically, air emissions studies have been conducted using methods that sample off site, ambient air. Much of the data gathered in this fashion falls short because this collection method fails to consider emissions transport from

other industry such as power generation, waste water treatment, or even emissions that blow in from other countries. It also falls short of being helpful to the industry since the operators and service providers are left questioning which pieces of equipment are producing these emissions if any.

If properly characterized, these sources may be eliminated from regulatory compliance requirements by simply identifying and demonstrating their minimal contributions as de minimis sources. The research team travelled to a hydraulic fracturing site on the Eagle Ford Shale Play and collected real time activity data from equipment that has the potential to release large amounts of air pollutants. Actual run times and load factors of the engines were measured. The activity data was then compared to data collected in the traditional manner of conservative off-site emission assumptions. Regulators performing offsite estimates will typically default to the conservative assumption that engines are operating at 100% load and 24 hours a day, and every day that the operation occurs.

The emissions factors that the regulators typically use are the US EPA AP-42 Standards that were created in 1974 and updated in 1996. Unless provided data to the contrary, it is likely that regulators will continue to use AP-42 for emissions calculations as the basis for potential regulatory development. These emission factors assume the worst possible emissions output. Meaning that emissions are calculated with the assumption that engines are uncontrolled – or no emissions reduction controls on them whatsoever.

Aims & Research Methods: This study will show that the hydraulic fracture pump engines are in fact the newer tiered engines – many of which have significant emissions controls on them. The results indicate that the Tier II fracture pump engines are emitting 539 pounds per hour less emissions than the AP-42 estimation would assume. Additionally, using tiered engine emissions factors are acceptable to Federal and State regulators.

Citation: Aaron Padilla, PhD; Chevron, 'Social Responsibility & Management Systems: Elevating Performance for Shale Gas Development' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: USA and EU

Aims & Research Methods: This paper presents findings on the effectiveness of management systems to elevate social performance, illustrated by two case studies of shale gas development in the United States and Europe. This paper provides practical insights to the upstream oil and gas industry on (a) using management systems to drive a higher level of social performance for shale gas development and (b) generally integrating social performance even more effectively into management systems. The case studies illustrate several benefits driven by management systems: increased organizational focus and identification of resourcing needs through deliberate planning, performance innovations to meet stakeholder expectations and concerns, an ability to meet the challenge of community-level engagement with underlying confidence in processes. The company's experience in these case studies also illustrated a difference between the environment, health and safety (EHS) function and the external affairs function in the extent that the management system governed performance. Practioners also noted a seeming trade-off in employing a management systems approach: that better performance in the short- and long-term requires reconciliation with initially slower decision making and operational expansion. Finally, this paper presents several practical tips on social responsibility and shale gas across the key dimensions of a management system, with three concluding considerations around the importance of adequate resourcing, sharpening functional responsibility and accountability for social performance and the role of company-wide requirements.

Citation: Christopher Burns (Gaffney, Cline & Associates), Adrian Topham SPE (Baker Hughes), Ramin Lakani SPE (Gaffney, Cline & Associates), 'The Challenges of Shale Gas Exploration and Appraisal in Europe and North Africa' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Reservoir Description and Dynamics, Exploration, Development, Structural Geology, Petrology and Well Logging

Jurisdiction: Global

Abstract: The shale gas revolution on North America has created an incentive for the rest of the world to chase this challenging hydrocarbon resource. Currently around 44% of the 20.6 tcf annual gas production in the US occurs from unconventional resources, with this forecast to rise to 65% by 2020. The pitfalls and challenges faced by North American development projects provide a wealth of experience, which can be used to understand how we can apply technology more effectively in Europe and North Africa. However, there are differences in both operating environments and gas markets between North America and Europe and North Africa, and we aim to highlight these differences as well as the similarities. Unconventional oil and gas projects in Europe and North Africa are currently at an early stage of their life cycle, exploration and appraisal.

Aims & Research Methods: We identify the following key challenges for the European region:

• The potential spread of the North American unconventional gas revolution to Europe and North Africa could create competition and depress gas prices. Reduced gas prices and increased costs will considerably reduce the margin for error in exploring for unconventional gas. Therefore there is a need to apply technology effectively, to avoid having to learn "by the drill bit".

• A lack of infrastructure and specialised equipment, particularly in North Africa, leading to a higher cost base for developing the region's unconventional resources.

• The regulatory environment in Europe is not presently conducive to development of shale gas resources together with the negative public perception of the environmental risk associated with shale gas development.

Aside from these medium to long term challenges, Europe at present is facing a more critical short term challenge: the need to prove the concept by completing and producing the first economic shale gas wells.

Citation: Olivier Peyret, Julian Drew, Mark Mack, Keith Brook, Shawn Maxwell, Craig Cipolla, 'Subsurface To Surface Microseismic Monitoring for Hydraulic Fracturing' (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Hydraulic Fracturing and Gravel Packing, Monitoring and Control, Seismic Processing and Interpretation and Permanent Downhole Sensors

Jurisdiction: USA

Abstract: Microseismic Monitoring has gained widespread acceptance as a tool for optimizing well stimulation. Led by the extraordinary boom of shale hydraulic fracturing activity in North America, it is now rapidly expanding to the rest of the world. This spectacular expansion is first and foremost related to the nature of microseismic monitoring, which is still the only technique to help determine the 3D geometry of the fracture network created hundreds of feet away from the borehole by hydraulic fractures.

Although microseismic monitoring is still mostly used as a tool for visualization of the fracture geometry, it is extremely valuable because it has the potential to optimize the many billions of dollars spent each year fracturing formations. In its simplest form, the half-length of the fracture network (*x*) is a key input to the well spacing, the width (or complexity) of the fracture network (*y*) is a key input to optimizing the number and geometry of stages in a given well and its vertical extent (*z*) is critical for understanding fracture containment, both up and down. When a relationship can be established between *x*, *y* and *z* and the pumping parameters then all ingredients are present to optimize completion operations. Of course, as our industry continues to learn more about the technique and its interpretation, we will extract even more information from the data and will therefore create more value.

Aims & Research Methods: The options for acquiring microseismic data to evaluate hydraulic fracture treatments have expanded in recent years to include surface and near-surface monitoring. However, there has been an absence of detailed and comprehensive validation and comparison of the various monitoring techniques, leading to misconceptions and uncertainties concerning the different alternatives. Traditional down hole monitoring is constrained by the requirement for adequately located deep monitor wells, which limits application in exploration and appraisal and other areas without suitable monitor wells. Surface monitoring provides a means to gathering important microseismic data without the need for observation wells, although the validity of the results is sometimes questioned.

This paper presents detailed "side-by-side" comparisons of surface and near-surface monitoring techniques and provides guidelines for the application of the various monitoring options. This multi-year journey was undertaken by comparing several surface/near-surface data sets with their down hole counterparts in a series of concurrent surveys in US shale plays. These comparisons answer the following questions concerning sensitivity, attenuation, and location uncertainty of surface monitoring options:

- How do the microseismic events detected and located at the surface or near-surface compare with those detected and located down hole?

- What is the best surface or near-surface design and what parameters are key to optimizing it?
- How does the processing and analysis of surface data compare with that of down hole data?

The paper includes a rare dataset from a field laboratory in the Fayetteville shale that was instrumented with a 4000 geophone surface microseismic array, a 5 Shallow Hole Grid, and traditional down hole microseismic arrays located in both vertical and horizontal observation wells. In addition, a 71-level geophone array was deployed from TD to surface in a vertical observation well. This multifaceted monitoring provided an unparalleled dataset to compare the various microseismic monitoring options.

The paper documents how and when the surface or near-surface technique provides a meaningful alternative to down hole monitoring both technically and economically, presents candidate selection criteria and provides a comprehensive comparison of the relative technical and economic merits of each monitoring option.

Citation: Freeman Hill, SPE, Steve Monroe, SPE, and Reshmy Mohanan, SPE, Baker Hughes, 'Water Management-An Increasing Trend in the Oil and Gas Industry' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Projects, Facilities and Construction

Jurisdiction: Global

Abstract: Excess water production has many direct and indirect costs. In 2011, it has been estimated that the oil industry spent more than $50 billion on handling produced water. These costs include discharge, trucking, reinjection and treatment of produced waters. The trend of water production and associated costs is illustrated in Figure 1. Not captured is the related indirect cost such as the production that is delayed or lost due to:

- hydrostatic losses
- preferential flow
- lack of facility capacity
- fines migration
- mechanical-related issues
- bypassed hydrocarbons that lead to less than optimal (hydrocarbon) production
- shut-ins and abandonments

The total costs due to water production are also sometimes difficult to track due to the compartmentalization of responsibilities. Some companies have increased their efforts in this area.

Aims & Research Methods: Water plays an essential role in the recovery of oil and gas. Managing subsurface water conformance can maximize hydrocarbon production and reduce operating costs. However, unchecked water can decrease hydrocarbon production, reduce oil and gas recovery, increase costs substantially, and lead to possible well abandonment.

In the life of a well it is natural that water will eventually enter into the production stream. It is important to identify the water's source and reason for the intrusion, and how it is interacting with the wellbore. This knowledge can be used to create an integrated customized solution that fits the needs of the well. An in depth understanding of the reservoir can avoid water problem areas in new infield drilling by the use of advanced navigation and directional systems.

Water management is essential to maximizing returns on investment and in controlling costs. There are a variety of technologies available for near-wellbore control and reservoir water conformance. Understanding of the water mechanism followed by proper application is key to reducing excess water production.

Citation: N. Modeland, Halliburton; I. Tomova, El Paso; D. Loveless, J. Lowry, J. Holtsclaw, and V. Yeager, Halliburton, 'Using Enhanced Fracturing-Fluid Cleanup and Conductivity in the Hosston/Travis Peak Formation for Improved Production' (Paper presented at SPE Hydraulic Fracturing Technology Conference, The Woodlands, Texas, USA, 6–8 February 2012)

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: USA

Abstract: The Travis Peak/Hosston is one of the commonly hydraulic-fracture-stimulated tight-gas sand reservoirs in East Texas. Often, the formation is stimulated as a recompletion for wells drilled for Cotton Valley targets and could potentially hold a strong future as a secondary completion for thousands of the recently drilled Haynesville Shale horizontal wells once their shale-gas production has been exhausted. The structure of the formation has several pay lenses that can be targeted; thus, it often requires multiple treatment stages to develop its total potential (gross target pays often spanning over 1,000 ft). Through the years, several types of stimulation treatments and fluid systems have been used in the Travis Peak/Hosston formation, and because the variance still continues, it is apparent that the optimal treatment methodology is not readily agreed on by the region's operators.

Aims & Research Methods: For many years, the Travis Peak/Hosston formation of East Texas and North Louisiana has been hydraulically fractured with various treatment designs, ranging from low-viscosity water fracs using only linear gel or polyacrylamide friction reducers to cross-linked gels typically sourced from guar polymers or guar derivatives. While lower-viscosity fluids can minimize gel damage to the formation, the result is often that less fracture conductivity is achieved because of the inability to transport larger proppant concentrations and maintain width. In late 2010, a new milestone occurred for the East Texas/North Louisiana region as a newly developed cross-linked gel system, sauced entirely from the food industry, was incorporated into the Travis Peak/Hosston fracture designs. The fluid system demonstrates both better proppant-transport capabilities and better conductivity-performance numbers than friction-reducer polyacrylamide systems and typical guar fluids. In addition to enhanced clean-up and proppant transport, all of the fluid system's components, having been sourced from the food industry, demonstrate a health, safety, and environmental (HSE) quality that surpass the previously used fluid systems. This paper will show laboratory test results for retained conductivity and proppant transport for the sourced-from-the-food-industry (SFI) fluid system in comparison to other fracturing gels, both of which should aid in flow back and production of a tight-gas sandstone formation.

Case histories for the Landon No. 6 well (a single-stage Travis Peak and Pettet completion in Rusk County, Texas) and the Shadowen 3-2 well (a four-stage Hosston completion of DeSoto Parish, Louisianna) will be examined. These two wells were the early pioneers for this SFI fluid system and have both shown benefits from its improved fluid clean-up and conductivity capabilities. Nearby offset comparisons of the production well show these wells to outperform wells with similarly completed frac stages using different fluid systems. Use of this SFI fluid in the tight-gas sandstones of East Texas and North Louisiana not only exemplifies the environmental stewardship of the oil-and-gas industry, but can also lead to improved estimated ultimate recovery (EUR) of the wells.

Citation: T. McLean, SPE, E. Dalrymple, SPE, M. Muellner, S. Garcia-Swofford, SPE, Nalco, an Ecolab Company, 'A Method for Improving Chemical Product Risk Profiles as Part of Product Development' (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility and Integrating HSE into the Business

Jurisdiction: USA

Abstract: A robust chemical product comparative scoring process (CSP) has been developed that facilitates continuous improvement in human and environmental hazard reduction. The method is simple and quick enough to use during development of new products, is adaptable to changing needs and visually communicates the hazard profile improvements of new products.

The CSP is used during product development. Human and environmental hazard profiles of developmental products are compared to current products used for similar purposes. Since the CSP requires little additional time, it allows hazard profiles to be determined during project development and identifies areas of potential improvement to the hazard profile. The CSP uses specified categories of concern for which public databases exist. For substances that have no database information, US EPA computer models are used. Using the CSP method, hazard profiles of formulations may be improved during the development phase of the project and the results are reported in a visual, qualitative, comparative format.

The CSP has been used to improve the human and environmental hazard profiles of several types of chemical products.

Aims & Research Methods: This paper will outline how the CSP is used for hazard profile improvement as a part of a development project, reducing delays due to testing or reformulating. The unique visual presentation format of the CSP allows hazard profile improvements over existing products to be easily identified by, and communicated to customers and other concerned parties. The CSP yields the most valid comparisons when data is available for the existing and proposed substances. Computer models are effective if used by personnel trained to use them. The process must include communication with (and validation by) regulatory and toxicology specialists.

Citation: Lydia Brantley, National Oilwell Varco; Thomas Major, National Oilwell Varco, 'Equipment Design and Technology for Global Shale Markets' (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Production and Operations

Jurisdiction: USA

Abstract: Last year when the Energy Information Administration (EIA) released its review of the international shale gas resources, which identified 5,760 trillion cubic feet (Tcf) of technically recoverable shale gas resources outside the U.S., it generated a critical question: will the shale gas revolution be a global phenomenon? [Figure 1]. With an estimated 862 Tcf of technically recoverable shale gas resources, the U.S. represents less than one sixth of the world's estimated shale gas resource potential; however, it continues to represent upwards of 75% of shale gas exploration and production (E&P) activity. The U.S. began exploring large-scale shale gas production in 1981 after George Mitchell introduced hydraulic fracturing into Central Texas's Barnett shale; meanwhile, decades later, most international markets remain in the nascent stages unconventional development. Notable differences in market conditions, geological characteristics, surface environment, and socio-political milieu will shape different shale development models worldwide.

Aims & Research Methods: Shale gas is widely considered to be revolutionizing the industry in the U.S. Various countries have begun shale exploration, but none have begun pursuing it with the aggressive growth characteristic of the North American experience. While the price of natural gas in some regions can be three to five times higher than in the U.S., the nature of lease agreements, geological characteristics, and political and societal factors all shape different emerging shale development models.

In North America, variations in shale gas plays have resulted in differences in technology and equipment design. The Horn River, for example, is located in a flat environment with very cold winters, while the Marcellus is located in a population-dense area with small local roads. These examples result in differences to field, well, and equipment design. This will be exaggerated as we move to international locations. In Europe, for example, road regulations restrict weight and dimensions, requiring rigs to break into smaller modules, and limiting the horsepower on a single fracture pumping unit. Novel fracture methods, such as pin-point fracturing, may be given different considerations internationally, potentially reducing horsepower requirements. Additionally, as international markets move into commercial development of resources, the truck traffic, emissions reduction, and need for smaller overall surface footprint will likely drive the market toward more wells per pad. This will cause rig design to follow closely the development seen in Canada's multi-well pad design with load limits and equipment designed more like the Marcellus.

This paper investigates the impact of varying emerging global markets on the future of technology and innovation in shale and tight gas reservoirs. The influences such as geological, political, and infrastructure on equipment design for varying gas reservoirs will be discussed.

Citation: Mark A. Miller, SPE, Cuadrilla Resources Ltd., Eric Vaughan, SPE, Cuadrilla Resources Ltd., 'European Shale Gas, Getting Buy-in From The Public and Stakeholders' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Management and Information

Jurisdiction: Global

Abstract: During the past 10 years shale gas development projects have proven to be highly successful in a number of North American basins, and have become a game changer for the energy supply there. Because of these successes, shale gas exploration and development technologies are being deployed around the globe, including Europe. But while there appears to be vast shale gas resources across Europe, many industry analysts express concerns about the probability of repeating the North American successes in Europe. These concerns are based on the denser population in Europe, different safety and environmental regulations, and the doubts of many European residents about the overall safety of shale gas development. Moreover, unlike North America where landowners often are entitled to significant lease payments and royalties for their mineral rights, the mineral rights throughout most of Europe are owned by the governments, rather than the landowners. The combination of these factors adds to the difficulty of building public support for a shale gas program.

This paper provides a discussion of a shale gas exploration program currently being conducted by Cuadrilla Resources in England. It examines the concerns of the local residents, and how these have affected media coverage, and support (or opposition) from politicians. It discusses the strategy and approach used by Cuadrilla for addressing questions and concerns from the local residents, various UK regulatory bodies, politicians and the media. While this paper focuses on a UK shale gas case, the conclusions and recommendations are applicable to any shale gas program in Europe or elsewhere.

Aims & Research Methods: Obtaining public acceptance for a European shale gas program requires that we address a wide variety of issues and public concerns. Topping the list of concerns are potential for chemical contamination of aquifers, natural gas migration to shallow water wells, and small earthquakes induced during hydraulic fracturing operations. Additional concerns include disposal of post-frac flow back fluids, large consumption of fresh water resources during the hydraulic fracturing process, excessive road traffic during the drilling and completion phases, industrial noise, and property devaluation.

In the UK, these concerns were largely escalated when shale gas opponents launched the movie, "GasLand", in early 2011. Since then, getting buy-in from the stakeholders and public requires tackling a number of complex issues and questions. But the complexity can be managed if the issues are broadly grouped into the following three simple questions that are in the minds of the public.

• Can we trust them? (the other oil/gas company)

• Is it safe? (with regard to the operations and technologies to be used)

•What's in it for us? (both at the personal and community levels)

Understanding how to wrap the list of public concerns into one of these simple questions is the beginning of a successful public relations program, which ultimately results in public acceptance for the shale gas program. The discussions here focus specifically on shale gas, firstly because that's what Cuadrilla is currently working on, and secondly, because of the worldwide attention that shale gas programs are receiving. Additionally while we will be working in more than one European country, we are focusing our discussions primarily on UK examples, as that is where we have developed a work history. Many of the discussions and recommendations given in this paper are applicable to any oil and gas exploration or development program, regardless of the reservoir type, or location in Europe or elsewhere in the world.

Citation: Cornelia Cretiu Vasiliu, Dale Pierce, Kelly Bertrand, 'Water Recycling and Produced Water Treatment present complex problems' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia 11-13 September 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Global

Abstract: Water is a precious commodity that is needed in all human activity and for life in general. The Oil & Gas industry uses and generates large quantities of this commodity (Produced Water Volume Report). On average, for every barrel of oil produced there are eight barrels of associated wastewater. Increasing the efficiency of water usage and improving its management is both a high priority among E&P companies and a subject of intense scrutiny for the communities in which they operate.

The availability of suitable water for hydraulic fracturing and the means for environmentally responsible water recycling and disposal are critical for sustainable unconventional development. Produced water that comes to the surface during oil and gas recovery presents a challenge for Marcellus drillers because of the scarcity of injection wells in the Appalachian region. Other areas, like West Texas (Permian Basin or Eagle Ford Shale) do not lack for disposal options but do suffer due to the arid climate and depletion of ground water resources.

Aims & Research Methods: From the point-of-view of a solutions provider the wastewater treatment should be straight forward: once given the composition of the feed and the required composition of the effluent, today's technology allows formulating a set of solutions which best meets the operator's and the regulatory criteria.

The problem with wastewater in the unconventional gas exploration and production operations is that there are large volumes to be handled and treated. To add complexity, composition varies for the same well in time and varies even more from area to area of development. Also, the requirements for the cleaned fluid vary from operator to operator and by region. Moreover, management of the water based fluids is under the pressure and scrutiny of various regulating agencies: public, privately, or governmentally run. All these constraints make the vetting of treatment methods and technologies to be a very dynamic and intensive process.

Our findings during the process of formulating a set of solutions shows that a deep understanding of the problems, combined with close collaboration with the operators and regulators along with solid basic engineering practices are the key to success.

Our experience would benefit the new developments in other unconventional exploration and production area in Asia by showing the steps that were undertaken to insure solutions are up to the highest standards.

The process of finding and testing various waste water treatment technologies to formulate a flexible comprehensive set of methods will be described. Laboratory results of various samples of water will be presented as well as the challenges that were overcome for obtaining consistent, reliable analytical data. The oilfield tough requirement presented to new technologies translates as: rugged, flexible, mobile, and low cost.

Citation: S. Lindsay, C. Ables, SPE, D. Flores, Halliburton, 'Downhole Mixing Fracturing Method Using Coiled Tubing Efficiently; Executed in the Eagle Ford Shale' (Paper presented at SPE/ICoTA Coiled Tubing & Well Intervention Conference and Exhibition, The Woodlands, Texas, USA, 27-28 March 2012)

Topic Area: Drilling and Completions

Jurisdiction: USA

Abstract: The down hole mixing process (DMP) allows multiple-interval fracturing treatments in horizontal laterals in a single trip. DMP enables the fracturing treatment to be manipulated in real-time. This allows the altering of bottomhole conditions to increase net pressure, resulting in increased complexity and more SRV versus conventional casing fracturing treatments. The DMP fracturing method is a management of two flow paths, versus just one for conventional treatments.

Using this method, multiple treatments can be performed in a time-effective manner with less hydraulic horsepower (HHP) on location. This is a result of the higher rate per interval that is pumped into the formation. On a typical 100-bbl/min treatment with four perforation intervals, each interval only receives at a 25-bbl/min fracturing rate. This, of course, is assuming that all the intervals are of a homogeneous rock type, have the same fracture initiation and extension pressures, and are all receiving fluid.

With DMP, each interval is fractured individually, helping ensure that all fluid enters the desired area of the formation at the desired pumping rate. This results in a reduction in required HHP; for example, only 25 bbl/min must be pumped to achieve the desired 25-bbl/min fracturing rate in that interval. An example of this process is illustrated in Fig. 1.

Aims & Research Methods: The increased demand for natural gas from shale plays in the US has forced the industry to be more efficient and develop innovative methods for fracture-stimulation optimization. Pinpoint-fracturing methods represent a divergence from the conventional methods with minimal optimization needed to help maximize reservoir volume. Multiple-interval completions can be performed efficiently so that all intervals receive the designed proppant volumes, one interval at a time. To accomplish this efficiency, coiled tubing (CT) is used to hydrajet perforate intervals for individual fracturing treatments at predesigned depths. Using various methods, CT depths can be corrected to actual depths, resulting in the precise placement of the perforations. Proppant plugs are used not only for isolating previously stimulated intervals, but also for maximizing the near-wellbore (NWB) conductivity necessary for long-term production performance. These fracturing methods do not require removing the CT from the well between treatments, and contingencies for early screen out can be remediated immediately with minimal impact to overall completion costs. Treating intervals individually substantially reduces the amount of hydraulic horsepower required onsite.

The latest pinpoint-fracturing technique provides maximum engineering flexibility in the execution of these treatments by allowing down hole control of the proppant schedule; this can be used to optimize the stimulated reservoir volume (SRV) on-the-fly, in real-time, and with down hole control. The process also incorporates large-OD CT. A recent 25-interval completion in the Eagle Ford shale demonstrated the process and is discussed in this paper.

Citation: Dirk Nuyens, SPE, Walter Heinz, SPE, & Dieter Hiller, SPE, Environmental Resources Management, 'License To Operate: Nontechnical Risks and Shale Gas Development in Europe' (Paper presented at SPE Hydrocarbon Economics and Evaluation Symposium, Calgary, Alberta, Canada, 24-25 September 2012)

Topic Area: Social Licence to Operate

Jurisdiction: EU

Abstract: Initial experience in Europe has shown that the non-technical challenges have initially been underestimated, and that huge efforts are necessary to gain public acceptance and political support. A lot of efforts have already been put on stakeholder engagement, public information on technical processes, disclosure of chemicals and initial promotion campaigns, but the acceptance in most parts of Europe – Poland being the only exception - remains challenging. Besides technical and regulatory requirements, obtaining a "social license to operate" is thus of increasing importance for the success of a project.

Aims & Research Methods: This paper discusses how non-technical risks are impacting shale gas developments in Europe and how challenging it is to obtain the Social License to Operate. Although still at the early exploration phase, most European developments are already significantly hit by stakeholder concerns, lack of public acceptance and often lack of government support. Some European countries have even halted early exploration – at least temporarily - by political decision. Most of the public concerns are of environmental nature, especially linked to the use of chemical additives in the hydraulic fracturing process and related concerns about potential groundwater impacts, but hardly any is based on real events in Europe. Most concerns have developed on the back of perception and experiences in the US. This paper also takes a critical look at the discrepancy between public environmental concerns and real environmental risks.

Citation: Xiude Lu, Dengsheng Ye, Juhui Zhu, Dan Song, Congbin Yin, Bin Guan, and Guigang Wang, CNPC Chuanqing Drilling Engineering Company Limited, 'Applications of New Coiled Tubing Multi-staged Fracturing Technology' (Paper presented at IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition, Tianjin, China, 9-11 July 2012)

Topic Area: Production Enhancement and Workovers

Jurisdiction: China

Abstract: With oil and gas exploration and development in low permeability reservoir located in Sichuan Basin, it becomes vital to employ a multistage fracturing technique to achieve multiple-zone stimulation. In the past, a variety of historical fracture methods attempted to stimulate multiple pay zones in vertical, such as targeting best pay-zone fracturing, commingled fracture stimulation of multiple intervals and multiple-zone stimulate partially with packer, the reservoirs with multiple-zones achieved stimulation to some extent [1]. For reservoir with multiple zones in vertical, two problems potentially arose: (1) Failure to achieve targeted stimulation of each interval; (2) No optimized fracture parameters matched for treated zones. The previous methods were generally costly and time-consuming without significantly increasing production. Therefore, the new multi-staged fracturing technique with bottom annular packer on CT has been developed to stimulate multi-zone reservoirs.

Aims & Research Methods: Multiple new technologies of stimulations have been successfully developed and used in domestic low permeability reservoirs over the last few years. A new staged fracturing technique with bottom annular packer on coiled tubing (CT) has been extensively used in the fields of Sichuan. This process employs a new bottomhole tool assembly (BHA) on the CT, which offers the opportunity to achieve hydro-jet perforating, annular packing and fracturing multiple pay zones with a single entry of the CT string. This technique has proven effective in stimulating thin interbedded reservoirs individually to open pay zones and improve gas production optimally. Following the final CT stimulating stage, the well is cleaned out and for subsequent production. This paper describes the unique features of the coiled tubing staged fracturing technology with bottom annular packer. Case studies of seven well are presented on this paper. The key procedure controls and surface process enhancements during the applications of the new CT stimulation technique will also be analysed and summarized.

Citation: Piers Touzel, SPE, Environmental Resources Management, 'Managing Environmental and Social Risks in China' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Sustainability/Social Responsibility

Jurisdiction: China

Abstract: China has the largest reserves of unconventional gas in the world. Led by Chinese National Oil Companies (NOCs), and with participation from International Oil Companies (IOCs), exploration and appraisal activities for unconventional gas, in particular shale gas, have ramped up significantly since 2009. Eager to exploit domestic gas reserves and reduce its reliance on imports, the Chinese Government has implemented policies to support the industry and has announced ambitious plans for the development of the country's shale gas reserves to 6.5 billion cubic meters (bcm) per annum by 2015, rising to 60-100 bcm by 2020.

China's unconventional gas reserves are concentrated in four areas: the Ordos Basin on China's northern plain, the Tarim and Junggar Basins in western Xinjiang and the densely populated Sichuan Basin in the south. Each of these areas faces significant environmental and social constraints, including availability of water for hydraulic fracturing and its subsequent

disposal, land access and resettlement, and community relations (including those with indigenous peoples in some areas).

While China has adopted policies to support the development of unconventional gas resources, technical and administrative standards are yet to be released. Outside of the oil and gas companies and their service providers, there is little understanding of the potential environmental and social impacts associated with unconventional gas development.

Chinese officials are concerned with maintaining social stability in rural farming communities and are keenly aware that environmental issues are today a leading cause of community protests. Sensitive to issues that may affect farmland or the groundwater required to sustain the livelihoods of China's rural residents (and the potential for ensuing social unrest) Chinese regulators are beginning to scrutinize more closely activities associated with the exploration and development of unconventional resources. Similarly, local communities are concerned about the environmental impacts from exploration and development activities and are becoming more vocal in their demands that they too are beneficiaries of upstream activities.

Demonstrating to regulators and to the community that unconventional resources can be developed in an environmentally and socially responsible manner will be critical to the future success of the industry.

Aims & Research Methods: The paper concludes that the current round of exploration, appraisal and pilot testing activities being undertaken for unconventional gas in China represents a window of opportunity for this to be demonstrated at a small scale prior to scaling up future field developments.

Citation: C.Smith, SPE, S.Caldwell, D. Graves, SPE and J.Galvan, SPE, Schlumberger, 'Chemical Regulatory Changes Are We Managing Them Effectively?' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Global

Abstract: The health, safety, environmental and regulatory aspects of a resource and risk intensive industry, such as exploration and production (E&P), is in constant evolution. Regardless of size and devoted manpower, organizations have an increased responsibility of ensuring compliance within their supply chain. They also have the added responsibility of communicating their adherence of the regulations to their stakeholders.

As the global market expands and competiveness for market share increases within the chemical supply industry, so also does the introduction of multilateral regulations. As such, the need to comply with new or changing regulations is becoming so important that it is often linked to organizational structure, product profiles, market demographics and finance allocation. Regulation change is slowly becoming a major determinant for business decisions.

The expansion of business into global markets ultimately drives chemical regulations into new regions. The recent introduction of regulations globally, such as hydraulic fracturing disclosure requirements, GHS and REACH is proof of the constant changes in the chemical industry. Organizations must not only understand the science behind chemical regulations, but also the sociopolitical aspects of any upcoming regulatory changes.

Organizations should aim to move away from a passive compliance and instead adopt a proactive regulatory compliance system. Integral processes within the system are identification, investigation, implementation and integration. Finally, putting in place an inspection and auditing process provides proof and a documented certification that a system is performing. This system is known as the 5I process.

Aims & Research Methods: The introduction of new regulations such as the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) and the Registration, Evaluation and Authorization of Chemicals (REACH) increase the challenges for companies to keep up with regulatory requirements. In addition, upcoming chemical regulatory requirements are being developed and implemented in all areas around the world where international exploration and production (E&P) companies operate.

In addition to initiatives by companies, to provide more environmentally friendly products and greener technology, there is also an increased demand for transparency and accountability. Companies have to ensure regulatory compliance with the continuously changing regulatory landscape. There are increased requirements for proper management of documentation (safety data sheets (SDS), labels, etc.), integrated software/IT resources, training, auditing and more importantly internal and external communication to ensure compliance. A practical management system is required to monitor and implement these regulatory changes.

The implementation of health, safety and environment (HSE) and regulatory programs can be supported through the effective management of regulatory changes. These regulatory changes can have a significant impact on corporate behaviour and reputation. Identification, investigation, implementation and integration are key elements when managing regulatory impact. Identification and documentation of the regulations to monitor and track industry changes is critical in the process. Investigation requires the review and assessment of the regulatory requirements, considering the potential impact on products and business lines. Implementation involves updating relevant documentation to ensure compliance. The final step of integrating controls in the supply chain to ensure regulatory compliance is especially critical with international movement of chemicals and substances. This also involves training and communication to implement changes.

This paper seeks to highlight the importance of monitoring and implementing regulatory updates and changes within the industry. It also explores an effective system for managing regulatory changes.

Citation: T.F. Manapov, TNK-BP Centre of Expert Support, A.A. Ruchkin, TNK-BP Centre of Expert Support, E.V. Ustyugova, TNK-BP Centre of Expert Support, A.N. Levanov, TNK-BP TNNC LLC, ‘Improvement of the efficiency of remaining oil reserves recovery at mature field' (Paper presented at SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition, Moscow, Russia, 16-18 October 2012)

Topic Area: Reservoir Description and Dynamics

Jurisdiction: Russia

Abstract: Currently, over 600 hydrocarbon fields have been discovered at the territory of West-Siberian oil and gas bearing province, two thirds of which are associated with Jurassic sediments. Potential oil reserves in Jurassic formations account for 40% of total resources of West-Siberian basin. Within them, the Upper-Jurassic oil and gas bearing complex carries 42% of reserves, 75% of which are characterized as hard to recover, since they are found in low permeability reservoirs (less than 20 mD on average), two thirds of which are at the late development stage. The development is complicated by formation of dead fluid zones with bypassed oil and reserves scattered throughout formations in volume, which is directly due to the reservoir heterogeneity.

At present, half of TNK-BP remaining recoverable oil reserves are concentrated in highly watered reservoirs (Fig. 1). It is apparent that with the existing resource base of the Company, issues of technological and economic efficiency of producing mature fields, in particular, Upper Jurassic objects, are one of priorities of TNK-BP development strategy.

One of the key commercial oil- and gas-rich TNK-BP regions in Western Siberia is Nizhnevartovsk region, with its concentration of the main remaining oil reserves of Upper Jurassic deposits. In the structure of the resource base, each year the portion of hard-to-recover reserves is growing. Beside the low permeability, they feature a complex architecture (compartmentalization ratio is 7.5, and NTG is 0.55), lower initial oil saturation (0.57 on average), and significant facial variation. As a result, the current RF of Nizhnevartovsk oil fields is 0.160 with 67.6% watercut, while the RF on balance books is 0.300 to 0.375 (Levanov, 2010).

To increase the efficiency of producing such reservoirs, several technologies have been implemented with varying success, such as conformance control, water shutdown, hydraulic fracturing, forced liquid withdrawal, and focal waterflooding. Therefore, the major focus in the paper will be on results of operation and field F development technologies, beginning from 70% withdrawals from the initial recoverable reserves, where the development of highly watered reservoirs is connected with the systematic optimization of available EOR methods, and at the final stage – with sidetracking technologies and withdrawal and injection control.

Aims & Research Methods:

This paper presents the results and the concept of increasing the efficiency of recovering remaining strongly watered hard-to-recover oil reserves based on the example of developing Upper Jurassic reservoirs of a typical field of TNK-BP in Western Siberia, Russia, that has entered the final stage of development. In particular, the paper describes the positive outcome of implementing such technologies as hydraulic fracturing at extremely watered wells, forced liquid withdrawal coupled with targeted focal waterflooding supplemented by flow diverting technologies in injection wells and water shutdown in producers, optimization of perforation intervals, with sidetracks targeting blind unrecovered zones.

The work is different from previous projects in provisioning a comprehensive integrated flow production and injection regulation with low-cost technologies with an emphasis on reducing injection costs and producing liquids to the surface to optimize cash flows. As a result, the accepted recovery concept is described, which provides increased energy efficiency and production profitability, together with targeted production of remaining oil reserves.

Citation: Khalil Rahman, SPE, Abbas Khaksar, SPE, Baker Hughes, 'Fracture Growth and Injectivity Issues for Produced Water Reinjection Wells C"" Case Studies with Fields from offshore Australia and UK North Sea' (Paper presented at SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 22-24 October 2012)

Topic Area: Production and Operations

Jurisdiction: Global

Abstract: The concept and application of produced water reinjection is familiar in the petroleum industry during the last two decades (Paige and Fergusion 1993; Al-Muscati et al. 1997; Van den Hoek et al. 2000). However, its applications to challenging conditions are recently demanded in the industry due to increased rate of water production from mature fields, injection from deviated wells and exceptionally high solids loading in produced water in certain cases. Addressing such challenging issues requires careful planning and design of the injection system including well planning, well completion, wellhead injection pressure and pump capacity, injection-induced fracture growth and maintenance of long-term injectivity.

This paper presents two case studies addressing these issues: (1) UK North Sea case and (2) Australia case. The UK North Sea case involved a highly deviated injector well from an existing platform. Unless oriented optimally, such a well is a potential source for complex non-planar fracture growth and eventual loss of injectivity (Martins et al. 1994). This issue was investigated for the North Sea case by modelling the offset between the direction of fracture initiation and the preferred direction for fracture propagation. An optimum well trajectory was recommended to avoid the potential fracture complexity and injectivity loss for the highly deviated well. Effects of different parameters such as solids concentration and injection temperature were investigated to recommend completion and operational guides for the well.

Aims & Research Methods: Produced water reinjection is gradually becoming a preferable option for water disposal because of increasing stringent environmental regulations. During long-term injection, a fracture usually initiates from the injection well and then grows deep into the formation. The growth of this fracture and the long-term injectivity are mainly influenced by formation properties, solids loading in water, in-situ stresses and well trajectory. Fracture growth and injectivity during produced water reinjection are influenced by long-term leak-off processes, thermo-poroelastic changes within the formation and the intermittent injection nature.

This paper presents an approach for systematic considerations of critical issues that greatly influence the well trajectory, completion, fracture growth and long-term injectivity. The approach was applied recently to two field cases for planning and decision-making: one field in Australia and the other field in the UK North Sea. The effects of the following issues on fracture growth and injectivity were addressed in the North Sea field case: in-situ stress magnitudes and direction; thermo-poro-elasticity; solids loading; perforations, tubing strength and pump capacity; and operational issues to maintain injectivity. Although the above issues were common to the Australia case, the special challenge came from high solids loading in water requiring a very large fracture to store solids particles.

Highlights of the study results include (1) potential fracture growth complexity and injectivity loss, (2) high pressure loss requiring high pump capacity, (3) undesirable fracture growth risking well completion and surrounding structures, and (4) fracture tip plugging by formation debris during intermittent injection. Mitigation strategies for all these complexities are also addressed in the paper.

The paper will guide engineers when addressing geomechanical, fracture growth and injectivity issues at the planning and designing stages of a produced water reinjection well.

Citation: C. Holt and N. Lahoti, SPE, TESCO Corporation, 'Dynamic Cementation Improves Wellbore Construction and Reduces the Hazards of Groundwater Contamination in Shale Plays' (Paper presented at SPE Canadian Unconventional Resources Conference, Calgary, Alberta, Canada, 30 October-1 November 2012)

Topic Area: Drilling Equipment and Operations and Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: USA

Abstract: Well cementing is one of the most critical steps of the well completion procedure. As the last step in well construction, cementing is sometimes is not given the attention it deserves. The effects of a bad cement job are remedial jobs and environmental and safety concerns. Various laboratory studies and field experiments have proven that methods like pipe movement during cementing, casing centralization and proper hole cleaning will increase the quality of the cement job. In this paper, pipe movement is presented as the single most cost effective method and should become a standard best practice.

Aims & Research Methods: The well construction process only allows one chance to install a primary cementing system. The industry has long understood the advantages of the method of pipe movement during cementing operations, yet it is not commonly practiced in spite of API recommendations. One barrier to implementing this methodology has been the availability of tools and technology. Application of a modern casing running tool (CRT), with a top drive allows the casing string to be safely conveyed to bottom, and subsequently rotated and reciprocated during cementing.

The standard industry toolbox uses long bails attached to the traveling block, conventional casing elevators and a standard cement head. Practically, this does not allow for rotation during cementation. Rigging up this equipment is time consuming and leaves the pipe motionless on bottom. Cement jobs under these circumstances are more prone to failure and frequently require remedial cementing.

Most North American operators are drilling extended reach wells in the prolific onshore shale plays. Long laterals combined with tortuous wellbores make it difficult to conventionally run casing; as a result, usually these sections require casing rotation to pass through challenging trajectories and get to bottom. Moreover, the horizontal shale wells are often completed with multi-stage frac jobs. It is imperative to have high quality cement job to insure zonal isolation, otherwise communication between zones can occur; this can result in a lower quality frac job and well completion. A poor completion can result in lost production and leaks can lead to ground water contamination. After pumping stops, there is no known method to affect additional mud removal from continued pipe movement, but cement job quality is not dependent solely on mud removal.

The drilled section is of little value until it is cased and a competent cement job is completed. Dynamic Cementation™ consists of rotating and reciprocating the casing from the time the cement operation commences until cement is set. It can increase the quality of the cement job by increasing mud removal and decreasing pressure loss while cement cures. This paper discusses the benefits of casing movement during cementing, the methodology and results.

Citation: D.V. Satya Gupta, SPE, Paul Carman, SPE and Rupa Venugopal, SPE, Baker Hughes, ‘A Stable Fracturing Fluid for Produced Water Applications’ (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Production Enhancement, Hydraulic Fracturing and Gravel Packing and Produced Water Management and Control

Jurisdiction: USA

Abstract: Produced water typically is the water that is produced along with the oil and/or gas, and it generally consists of formation water, flow back fluids, surface water, and water from any other sources. Formation water usually consists of salty water that may be the ancient seawater trapped in the formation. It can also be the result of injected water dissolving the minerals in the formation and flowing back as salt water. Produced water has been identified as the largest waste generated during the production process, and the volume of produced water can be several times that of hydrocarbons produced (Stephenson, 1992). In the United States, 18 billion bbl of produced water, 149 million bbl of drilling waste and 21 million bbl of associated waste generated through E&P operations are disposed of or managed at the well site (Puder, 2007). The potential benefit of using such produced water, if feasible, for oilfield operations is at least twofold. First, the cost related to the proper disposal of produced water can be reduced. Produced water treatment and disposal have gained importance due to increasing volumes, stringent discharge standards, and the more attractive option of reducing capital and operating costs (Evans and Robinson, 1999; Khatib and Verbeek, 2002). Typical costs associated with disposal range from $0.30 to $10.00/bbl for injection or cavern disposal, and $15 to $22/bbl for solidification and burial in a landfill (Puder, 2007). Offshore produced water treatment and disposal costs were reported to be more than US $400 million per annum (Khatib and Verbeek, 2002). Produced water usually contains high levels of salt and hardness as well as bacteria. Without proper treatment, produced water is environmentally hazardous. It can be, however, costly to clean up produced water following the local, state, or federal regulations. If produced water can be used to prepare fracturing fluids, the operating cost is expected to decrease. Second, as hydraulic fracturing uses a large volume of fresh water, reusing produced water can cut the consumption of fresh water (Gleick, 1994) that is becoming more costly and more difficult to obtain since neighbouring residents and municipal and state governments increase restrictions on water availability from surface and subsurface aquifers. Hence, there is incentive for operators, as well as service companies, to develop fluids using produced water to reduce operating costs and gain a competitive edge.

Aims & Research Methods: As shale fracturing operations continue to increase, so do the required volumes of relatively fresh water – which in some areas is limited in availability for fracturing. Exacerbating the issue, the water that is produced back after fracturing typically contains large amounts of total dissolved solids (TDS), including sodium, calcium, magnesium, barium and other salts. Storing and disposing of this water is becoming very expensive, and operators increasingly seek options for recycling and reusing this water. An ideal solution would be to reuse it in subsequent fracturing, but conventional fracturing fluid systems require fairly low TDS to achieve reliably stable rheology, so produced water typically requires extensive treatment before it can be reused for fracturing.

A new polymer system has been designed to viscosify produced waters a minimal filtration to eliminate large solid particulates. In addition to achieving stable viscosity despite the dissolved solids in the water, the system simplifies operations, requiring only a gellant, surfactant and breaker added on the fly to the water. No buffer, crosslinker or other additives are necessary. The unique polymer system uses a specialized surfactant to create an association with the produced water and generate viscosity. The resulting fluid is elastic and has excellent proppant transport characteristics. The system can be broken efficiently to achieve good regain conductivity. This paper will present the chemistry and results of complete laboratory testing to evaluate the fluid for fracturing operations. Testing will include demonstrations of fluid properties with typical produced water samples from the Bakken and Marcellus shales.

Citation: E. Muslimov, P. Medvedev / JSC TNK-BP Management, 'Experience with dual completions in TNK-BP' (Paper presented at SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition, Moscow, Russia, 16-18 October 2012)

Topic Area: Drilling and Completions

Jurisdiction: Russia

Abstract: Drilling separate wells in every reservoir are economically unviable in some cases. Aside from that, construction of many wells entails technical or logistical restrictions and limitations. Successive development of reservoirs slows down the production of reserves. Developing different reservoirs with the same well via dual completion technologies can decrease the scope of drilling, increase production, accelerate development of reserves, and help mitigate adverse environmental impact. It should be noted that the use of dual completion technologies must meet the requirements of FDP documents and provisions for production allocation, provide the required level of reliability and cost efficiency, and fulfill the requirements to optimal development of reservoirs. According to Rostekhnadzor's resolution, dual completion of several reservoirs with the same well shall be permitted when replaceable down hole equipment is available for separate metering of produced hydrocarbons, separate testing and logging of every reservoir, and safe servicing of wells with due consideration for pressure differential and the properties of reservoir fluids. The actual operating conditions of TNK-BP's fields are such that 98 percent of wells are worked

by artificial lift, 90 percent of them using electrical submersible pump (ESP) units. The average depth of wells exceeds 2,000 m, the diameter of most production casings is 168 mm or less, and hydraulic fracturing technologies are used extensively (approximately 1,500 hydraulic fracturing jobs a year). Many fields have three or more reservoirs and a number of complicating factors, such as asphalt-paraffin deposits, salts, abrasive suspended solids, a high gas-oil ratio, and frequent crossflows behind casings. In such conditions, the requirements for dual completions equipment are more stringent. Despite the fact that dual completion systems do not constitute an essentially new technology, their use requires application of advanced methods of artificial lift, geophysical studies, metrology, and well completion.

Aims & Research Methods: The majority of fields in Russian Federation contain multiple stratified oil reservoirs. In many cases the fluid properties, geological parameters and reservoir pressure conditions are such that each reservoir has to be developed separately, as dictated by legislation. This means additional drilling grids or producing zones consecutively over time using the same wellbore. The first option implies heavy CAPEX commitments, while the other means significant production delay with a drastic negative impact on NPV. The alternative is dual completion technology. Its advantages include drilling cost reduction, production acceleration, independent control and optimal drawdown on each layer, elimination of undesirable fluids' mixing, ability to continue production if one of the pumps fails, elimination of well shutdown to test separate zones, reduced environmental footprint and full compliance with legal requirements. There is a range of dual completion and dual monitoring technologies which can be applied to meet the legal requirement with a certain degree of accuracy. Selection of the right technology is critical to obtain the optimal value from the investments. The article discusses the challenges in the domain of completion and production technology for multilayered reservoirs in TNK-BP; covers main objectives of dual completions /dual monitoring and key functional requirements; highlights the classification of dual completion types (covering single lift and dual lift categories and subgroups) including high level overview of specific technologies available on the market. The current situation with multilayered reservoirs in TNK-BP regions will be presented with highlights on the results of the performed dual completion pilots as well as outlook on future activities.

Citation: Dan Daulton, SPE, Matt Post, SPE, JoAnn McMahon, Bill Kuc, Charles Ake, Baker Hughes, and Denise Hill, Cardno ENTRIX, 'Global Chemical Evaluation Process to Qualify Regulatory and Environmental Characteristics of Oilfield Chemical Products' (Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility, Drilling and Completions and Production and Operations

Jurisdiction: Global

Abstract: Environmental qualification of chemical products is a critical component of the oil and gas industry. However, regulatory and chemicals evaluation criteria, if available, are typically designed for local ecosystems and vary within specific regions and regulatory entities. Although some qualification schemes have been adopted across multiple geomarkets, there is a lack of uniform, globally coordinated, strategic objectives to address this issue for the industry. This has created disjointed, ineffective responses by vendors, chemical manufacturers, and suppliers involved in creating and delivering complex chemical solutions to meet oil and gas industry challenges.

Recent movements of international organizations sponsored by the United Nations (2009) have addressed communication of chemical hazards via the Global Harmonized System of Classification and Labelling (GHS/CLP). Adoption of GHS by numerous regulatory bodies has brought international consensus to hazard criteria and definitions. Implementation of GHS is proving to be long, slow, and arduous. Furthermore, the intended scope of GHS focuses on standardization of hazard communication. As such, the core elements of GHS are applicable to evaluating chemical hazards. However, several hazard endpoints are either inappropriate or need modification to address the unique needs of the oilfield chemical market. Therefore, it is incumbent upon global chemical suppliers to identify an effective chemical evaluation process. This process must facilitate the offering of product solutions which meet the performance demands of petroleum exploration and production, while protecting human health and the environment and complying with existing and future regulatory statutes, as well as specific local concerns.

Aims & Research Methods: This paper describes our continued efforts to globalize the chemical evaluation for all oilfield products. Comparative scoring of chemicals is accomplished through a practical, transparent, and quantitative process, based upon their potential safety, health, and environmental impact. Since initially introduced, the evaluation process has been updated to include review of key global regulatory requirements (chemical prescreening, transportation, handling, and application). Benefits include:

a. Reducing redundant development efforts,
b. b) Improving research and development focus using specific guidelines for regulatory and chemical hazard assessments,

   c) Enhancing marketing value by providing a comprehensive view of inherent benefits or potential concerns associated with chemical products;

c. Clarifying expectations in the supply chain and

e) Effectively managing issues of confidential business information (CBI) when multiple parties are involved in research and development chemistry.

Citation: Ana Djuric, Halliburton, 'Land-Based Disposal Rules and Regulations: How Three Different High-Performance Fluids Rate in Three Different Regions' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Drilling Fluids, Handling, Processing and Treatment, Waste Management, Environmental and Social Impact Assessments and Solids Handling and Disposal

Jurisdiction: Global

Abstract: The process of drilling for oil and gas generates what is commonly termed exploration and production (E&P) waste that comprises spent fluids and cuttings. For the purpose of this study, the term "regulation" is used to represent guidelines, directives, orders, rules, acts, or any other termed employed to determine compliance. Two mature sets of regulations were selected, and one very distinctive regulation was included to compare and contrast three different high-performance fluid formulations and a standard potassium-chloride (KCl) polymer fluid.

Aims & Research Methods: Not all drilling fluids are created equal. With that being said, not all rules and regulations applicable to the management and disposal of drilling waste are either. The intent of this paper is to impose three different disposal standards to one basic KClreference drilling fluid and threehigh-performance drilling fluid formulations to compare and contrast the differences in disposal compliance. The three selected drilling waste-disposal standards in this study include Germany's GWK Standard for Groundwater Protection, Alberta's Directive 50, and Louisiana's 29-B Order

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Citation: Quanxin Guo, Lujun Ji, Vusal Rajabov, and James Friedheim, SPE, M-I SWACO; Rhonna Wu, Cornell University, 'Marcellus and Haynesville Drilling Data: Analysis and Lessons Learned' (Paper presented at SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 22-24 October 2012)

Topic Area: Drilling Fluids, Handling, Processing and Treatment and Performance Measurement, Technical Limit

Jurisdiction: USA

Abstract: Natural gas production from organic shale is one of the most rapidly expanding trends in North America's onshore oil and gas exploration and production today. In some areas, this has included bringing drilling and production to regions that have seen little or no activity in the past. Advances in horizontal drilling technology and hydraulic fracturing have made shale gas/oil production economically viable.

Haynesville and Marcellus shale plays are among the most active shale plays in the United States. The potential for production from these shale plays, coupled with other unconventional shale gas plays, is predicted to contribute significantly to North America's energy outlook. Although drilling experience has been gained since the development of these shale plays, we are still in the early stages of the learning curve for shale gas drilling. Due to its proven performance parametrics and advantages, invert emulsion drilling fluid, is often the preferred drilling fluid or "mud" used to drill the horizontal sections of the wells in Haynesville and Marcellus shale plays. However, water-based drilling fluid (WBM) has also been used and usage is increasing in horizontal sections of the Marcellus wells due to its technologically enhanced performance and environmental advantages. A comparative analysis was performed between invert-emulsion-based and water-based drilling fluids used in Haynesville and Marcellus shale plays to assess their performances and to identify the key challenges with both fluid types.

Aims & Research Methods: The analyses include mud chemistry, drilling days, mud weight and well architectures such as hole sizes and casing sizes as well as depths of the casing shoe. A statistical analysis of drilling performance (P10, P50, and P90) was also performed to evaluate drilling days for wells of various depths of different operators over the past few years with different fluid types.

The analysis of 238 horizontal wells drilled in Haynesville shale play between 2006 and early 2011 shows that there is a continuous improvement in drilling performance over the years. This improvement is more pronounced in the wells drilled with oil-based drilling fluids (OBM). The analysis also shows that some operators drill the wells of similar depths much faster than others. Seepage losses and controllable kicks were also identified as some of the key issues in both Haynesville and Marcellus shale drilling. Although, laboratory results show that the clay content and reactivity of both Haynesville and Marcellus shale are very close to each other, the same WBM systems have shown much better performance in Marcellus shale drilling than in Haynesville shale play. The effects of high temperature and high pressure of the Haynesville shale formation on inhibition capabilities of water-based drilling fluids are among the key factors that have limited the performance of WBM in Haynesville shale drilling. Higher well depths and the increased drilling days in Haynesville shale play result in much more exposure time of the wellbores to drilling fluids, and are the key factors that resulted poor performance with WBM systems.

Citation: Ray Hatley, Golder Associates, 'Coal Seam Gas (CSG): What Becomes of Produced Water? Regulation and Strategies' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Health, Safety, Security, Environment and Social Responsibility

Jurisdiction: Australia

Abstract: Strong LNG demand, both here in Australia and overseas, *fuelled* by worldwide transition to a low carbon economies is driving unprecedented growth in *coal seam gas* (CSG) exploration and development of east coast resources, not to mention the other conventional gas resources around Australia. With this accelerated growth in demand for gas, particularly with the onshore CSG production, comes the matter of the associated environmental affects and the need for socially responsible environmental management and mitigation of impacts.

Why do I single out the CSG industry in this regard – after all the oil and gas industry has been the subject of considerable environmental regulation during the many decades of production in this country, and has a very proud record in doing the right thing.

Aims & Research Methods: This paper relates specifically to one unique attribute associated with the production of CSG, namely the need to extract groundwater from the gas production wells in order that they be depressurised as a precursor to gas release. Pumping groundwater from of the coal seam 'aquifers' targeted for the resource reduces the hydraulic pressure to the point that the adsorption bonds holding the methane to the surfaces of the coal cleats (or micro-fractures) are reversed and the gas moves into the gaseous phase, and is hence available to flow to the well under the prevailing hydraulic gradients. Typically, a CSG well is pumped for its groundwater, producing its peak flows early in the life of the well, with flows of water tapering off with time, as gas flows increase and peak some years into its life.

Citation: Juan C. Glorioso, Aquiles Rattia, Repsol, 'Unconventional Reservoirs: Basic Petrophysical Concepts for Shale Gas' (Paper presented at SPE/EAGE European Unconventional Resources Conference and Exhibition, Vienna, Austria, 20-22 March 2012)

Topic Area: Reservoir Description and Dynamics

Jurisdiction: Global

Abstract: Unconventional reservoirs have burst with considerable force in oil and gas production worldwide. Shale Gas is one of them, with intense activity taking place in regions like North America. To achieve commercial production, these reservoirs should be stimulated through massive hydraulic fracturing and, frequently, through horizontal wells as a mean to enhance productivity.

In sedimentary terms, shales are fine-grained clastics rocks formed by consolidation of silts and clays. In log interpretation of conventional reservoirs, it is very common to observe that the clay parameters used to correct porosity and resistivity logs for clay effects are in fact read in shaly intervals rather than in pure clay. Although no considerable deviation have been observed in shaly sandstones, anyway these concepts and procedures must be reviewed to run log analysis in shale gas. Organic matter deposited with shales containing kerogen that matured as a result of overburden pressure and temperature, giving rise to source rocks that have yielded and expulsed hydrocarbons. Shale gas reservoir type is a source rock that has retained a portion of the hydrocarbon yielded during its geological history so that to evaluate the current hydrocarbon storage and production potential it is necessary to know the kerogen type and the level of TOC - total organic carbon - in the rock. Produced gas comes from both adsorbed gas in the organic matter and "free" gas trapped in the pores of the organic matter and in the inorganic portions of the matrix, i.e. quartz, calcite, dolomite.

In these unconventional reservoirs, gas volumes are estimated through a combination of geochemical analysis and log interpretation techniques. TOC, desorbed total gas content, adsorption isotherms, and kerogen maturity among other things can be measured in cores, sidewall samples and cuttings, in the laboratory. These data are used to estimate total desorbed gas content and adsorbed gas content which is part of the total gas. Also in laboratory, porosity, grain density, water saturation, permeability, mineral composition and elastic modules of the rock are measured. Laboratory measurement uncertainty is high and consistency between different providers appears to be low, with serious suspicions that procedures followed by different laboratories are the source of such differences. The permeability is one of the most important parameters, but at the same time, one of the most difficult to measure reliably in a shale gas. Core calibrated porosity, mineral composition, water saturation and elastic modules can be obtained through electric and radioactive logs. All these information is used to estimate log derived total gas volume which results are also subject to a high degree of uncertainty that must be overcome.

Once this key information is obtained, it is possible to estimate different gas in-situ volumes. Indeed, an estimate of porosity-resistivity based total gas in-situ and, on the other hand, geochemical based adsorbed gas in-situ can be performed. Log total gas in-situ can be, and it is advisable to do, compared with adsorbed gas estimations and also with another gas measurement called direct method - total gas desorption performed on formation samples. The difference between log total gas in-situ and adsorbed gas in situ should be the "free" gas in situ. Free gas occupies the pores of kerogen and matrix; also it can be stored in open natural fractures if such fractures are present.

Citation: Arash Shadravan, Texas A&M University, Mahmood Amani, Texas A&M University at Qatar, 'HPHT 101: What Every Engineer or Geoscientist Should Know about High Pressure HighTemperature Wells' (Paper presented at 2012 SPE Kuwait International Petroleum Conference and Exhibition, Kuwait City, Kuwait, Dec 10 - 12, 2012 2012)

Topic Area: Drilling Project Management

Jurisdiction: Global

Abstract: The high-profile blowout at Macondo well in the US Gulf of Mexico, brought the challenges and the risks of drilling into high-pressure, high-temperature (HPHT) fields increasingly into focus. Technology, HSE, new standards, such as new API procedures, and educating the crew seem to be vital in developing HPHT resources. High-pressure high-temperature fields broadly exist in Gulf of Mexico, North Sea, South East Asia, Africa, China and Middle East. Almost a quarter of HPHT operations worldwide is expected to happen in American continent and the majority of that solely in North America. Oil major companies have identified key challenges in HPHT development and production, and service providers have offered insights regarding current or planned technologies to meet these challenges. Drilling into some shale plays such as Haynesville or deep formations and producing oil and gas at HPHT condition, have been crucially challenging. Therefore, companies are compelled to meet or exceed a vast array of environmental, health and safety standards.

Aims & Research Methods: This paper, as a simplified summary of the current status of HPHT global market, clarifies the existing technological gaps in the field of HPHT drilling, cementing and completion. It also contains the necessary knowledge that every engineer or geoscientist might need to know about high pressure high temperature wells. This study, not only reviews the reports from the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and important case studies of HPHT operations around the globe but also compiles the technical solutions to better manoeuvre in the HPHT market. Finally, the HPHT related priorities of National Energy Technology Laboratories (NETL), operated by the US Department of Energy (DOE), and DeepStar, as a strong mix of large and mid-size operators are investigated.

Citation: Guang Yu, SPE, and Roberto Aguilera, SPE, Schulich School of Engineering, University of Calgary, 'Software Development for Petrophysical Analysis of Shale and Tight Formations' (Paper presented at SPE Canadian Unconventional Resources Conference, Calgary, Alberta, Canada, 30 October-1 November 2012)

Topic Area: Well Logging

Jurisdiction: Canada

Abstract: Tight and shale formations containing oil and gas are important components of unconventional resources. A tight reservoir is defined as a petroleum reservoir in "low-permeability sandstone and carbonate reservoirs where stimulation or specialized drilling technology is required to establish economic flow rate or recovery" of oil and gas (Aguilera et al., 2008). A shale reservoir is a fine-grained organic rich formation defined by the Alberta Energy Resources Conservation Board (ERCB) as "a lithostratigraphic unit having less than 50% by weight organic matter, with less than 10% of the sedimentary clasts having a grain size greater than 62.5 micrometers and more than 10% of the sedimentary clasts having a grain less than 4 micrometers" (Oil and Gas Conservation Regulations, Part 1, 1.020(1) (27.1)). For these two types of formations, petro physical interpretation has posed great challenges to geologists and engineers for decades, because of the complexity of their constituent materials, their structure and their complicated impact on well log responses.

Aims & Research Methods: Shale and tight formations have long been a challenge for petro physical interpretation. In the case of shales, the presence of clays and organic matter, complex mineralogy and pore structure make the log responses complicated. In tight reservoirs, the presence of connected and non-connected dissolution pores, microfractures and slot porosity also complicates the interpretations. This work seeks to integrate and digitize new petro physical techniques and procedures that address these problems into a software system to assist with shale and tight reservoirs characterization.

A petrophysics software system that includes dual and triple porosity models as well as elastic geomechanical properties has been developed to assist with the evaluation of shale and tight formations. Some critical petro physical parameters can be quantified, such as matrix, fracture, non-connected and effective porosities, water saturation, total organic carbon, level of organic metamorphism, flow regimes (continuous vs. diffusion-like) at any pressure of interest, as well as Young modulus, Poisson's ratio and minimum horizontal stress. Based on these estimates, detailed shale and tight reservoirs characteristics can be analysed and the original hydrocarbons in place can be determined with good accuracy.

Practical workflows for calculating each parameter are also organized and integrated. Object-oriented programming techniques are utilized for the development of this software considering its development life cycle for large-scale software development. Optimization capacity adopted in the current development for the reuse of the software components for future development is also explained.

Two case studies using data from the Nikanassin formation in the Deep Basin of the Western Canada Sedimentary Basin (WCSB) and the Haynesville shale formation in Texas are presented to illustrate the software development and the application of the software. Conventional well log data, such as gamma ray, density, neutron, acoustic, resistivity, and cores and drill cuttings are utilized in the examples, which is further validated with other sources of information.

It is concluded that the methodology developed in this software will prove valuable and facilitate the petro physical evaluation of shale and tight formations.

Citation: J. Montilva, J. Mota, R. Billa, Shell Exploration & Production Company, 'Onshore US MPD Use by an Operator' (Paper presented at SPE/IADC Managed Pressure Drilling and Underbalanced Operations Conference and Exhibition, Milan, Italy, 20-21 March 2012)

Topic Area: Drilling and Completions

Jurisdiction: Global

Abstract: Shell developed and operated gas fields in South Texas for over 50 years (Fig. 1). These 10,000 ft – 16,000 ft high pressure, high temperature (HPHT) wells normally have

initial shut in tubing pressures approaching 10,000 psi when virgin sands are completed. Most wells have multiple low permeability pay sands, which require hydraulic fracture treatments to produce economically. Severe pressure depletion intermingled with high pressure sands is often encountered. The limits imposed by those conflicting conditions create narrow windows in which the difference between equivalent circulating density (ECD) and static bottom hole pressure (BHP) can be the difference between lost circulation and influx.

Aims & Research Methods: In the development of onshore gas fields SWEPI LP (Shell) has encountered margins in which the difference between dynamic ECD and static BHP is the difference between lost circulation and influx. The limits imposed by those conflicting conditions create narrow mud weight windows.

The reasons for the tight pore pressure and fracture gradient windows in these vertical and horizontal onshore HPHT tight gas environments vary. Some are old fields challenged by depletion. In the case of South Texas, the main problem is losses in the production hole due to depletion. The pressure in different zones is often difficult to predict due to complex geology further complicated by years of commingled production without knowing what each zone has contributed. In some of the new shale plays, like the Haynesville, slim hole well plans are used which have problems with low kick tolerance design and unexpected kicks through fractured intervals. These pose unique well control challenges to minimize non-productive time. In all of these wells, there is the high cost associated with losing mud and/or constantly changing mud weights to prevent losses or influxes.

To mitigate these potential problems, Shell has recognized the use of the Managed Pressured Drilling (MPD) concept which enables the use of the lowest possible mud weight to drill these challenging wells. By lowering the mud weight and manipulating the annular pressure during drilling, the risk of mud losses and/or quick sudden transitions into over-pressured zones is reduced. There are some direct benefits of drilling with lower mud weight such as higher ROP's, lower stand pipe pressures and lower circulating temperatures. In addition, there are lower ECD's and higher pump rates that improve the hole cleaning.

Field trials using a fully-automated MPD solution were performed by Shell in South Texas and North Louisiana Haynesville from late 2010 to mid-2011. This paper describes implementation of a fully automated MPD, small rig foot print system which incorporates a Rig Pump Diverter (RPD) that allows smooth transition from circulating to non-circulating down hole during connection while maintaining continuous rig pump circulation.

Results from the field trials will be documented in the paper. We will show the impact of drilling with lower mud weights on well performance. Additionally, a comparison of vertical and horizontal HPHT wells that were drilled conventionally and wells drilled using MPD will be made showing the effects of drilling with lower mud weights on ROP, down hole circulating temperature, ECD, stand pipe pressure and pump rate.

Citation: Saad Saeed, Randy Lovorn, and Kjetil Arne Knudsen, Halliburton, 'Automated Drilling Systems for MPD C-The Reality' (Paper presented at IADC/SPE Drilling Conference and Exhibition, San Diego, California, USA, 6-8 March 2012)

Topic Area: Drilling Design and Analysis, Pressure Management (MPD, Underbalanced Drilling), Drilling Equipment and Operations and Drilling and Well Control Equipment

Jurisdiction: USA

Abstract: Managed pressure drilling (MPD) has not only facilitated the introduction of innovative control solutions, but spurred the development of real-time automated systems in the drilling industry, heralding an era of accurate and precise down hole pressure control. However, these advancements are not universal. It is important to note that MPD comes in a number of different forms with varying automation influence. Interestingly, the term MPD, is unique in that it not only relates to a specific technique, but is also commonly used as an umbrella term to describe an entire technology. The industry has tried to clarify this situation by taking one of two approaches. The first path is by defining MPD in broad, generic terms, which cover a variety of divergent techniques. The second path takes the opposite approach and counters generality by distilling and defining each technique into distinct categorical delineations based primarily on physical phenomena. As the primary focus of this paper is the reality of the automated drilling system in MPD, it is important to note that all MPD is not equal when it comes to automation. Actually, many are surprised that automation does not apply equally to all forms of MPD, irrespective of the definition that is used. Rather, automation (as we know it) has primarily been developed and applied in primarily one segment of MPD. This segment is focused on the precise prediction and control of bottomhole pressure (BHP) within predefined limits. The most well-known of these techniques is constant bottomhole pressure (CBHP) drilling, where applied surface (back) pressure is manipulated by a choke device to indirectly control the BHP profile. This workflow naturally lends very well to an automated philosophy and is not only the primary focus of MPD automation today, but the core focus of this paper.

Aims & Research Methods: Managed pressure drilling (MPD) has heralded an era of accurate and precise down hole pressure control. Not only can today's MPD systems operate in tight operational envelopes, but they, more importantly, provide dynamic real-time well control while drilling. This dynamic precision has directly enabled access to assets that were previously considered virtually "undrillable." But, how can MPD boast such success? One of the major reasons is automation. Automation can provide levels of functional control that are difficult, if not impossible, for human operators to achieve and maintain. MPD's inherent closed-loop setup, coupled with conventional methodology, naturally lends to automated applications.

Furthermore, despite all the advancements in MPD automation within the past few years, there is a common misconception that current MPD systems can provide fully automatic control ("cruise control") of the entire drilling process. This is far from reality, as MPD systems today provide "supervised automation."

Though there is a lot of material pertaining to the benefits and functionality of MPD automated drilling systems, there is very little technical information on how the systems actually function. The primary focus of this paper is to fill this disparate gap by examining the internals of such a system and, in turn, detailing how it actually works.

The paper will start by developing a generic framework, which is common to all MPD automated drilling systems (independent of the company). The components, technology, and architecture will all be presented in detail, which will be augmented by tracing the information flow through the system to clearly illustrate how the MPD process is actually carried out. Having established the technologies, capabilities, and limitations will become apparent. This will then be followed by examples of concrete implementations.

Citation: Miguel O. Mota, SPE, Gregory W. King, SPE, ExxonMobil Development Company; William D. O'Donnell, ExxonMobil Production Company; Kerr Hewit, KCA Deutag - RDS; Paul A. Dumont, Shell Exploration & Production, 'Near Field Developments With an Upgraded Brown-Field Platform Rig: Sharing the Learning From a Three-Well Extended Reach Drilling (ERD) Program' (Paper presented at IADC/SPE Drilling Conference and Exhibition, San Diego, California, USA, 6-8 March 2012)

Topic Area: Drilling and Completions

Jurisdiction: Global

Abstract: The Beryl field (located about 200 miles northeast of Aberdeen, UK in the North Sea in a water depth of 390 ft) was discovered in 1972. Its discovery led to the installation of the Beryl Alpha platform in 1976 and the Beryl Bravo platform in 1984. The Beryl Alpha platform is a 40–slot twin drilling rig, three–leg concrete structure with storage capacity in its base for more than 1 million bbl of oil. The Beryl Bravo platform is a 21–slot single drilling rig steel–jacket structure with an oil export line to the Beryl Alpha platform. Oil export from the field is by tanker loading from a single point mooring. Gas export from the field is via the SAGE pipeline (Fig. 1).

Aims & Research Methods: This paper will summarize the concept selection, concept definition, and modifications for a two-stage upgrade of a 35-yr old platform rig on a production platform to extend the drilling radius from 15 to 25 kft (Cutt 2007), the maximum working pressure (MWP) from 5 to 10 ksi, and how combined projects enabled the development of new fields which could not support subsea infrastructure.

The paper will highlight the lessons learned at each stage of the upgrade and the drilling programs, focusing on how the legacy limitations of the original rig design and inherited constraints of 200% well slot utilization were mitigated to enable the drilling of a next generation of wells. The upgrade of the rig in two separate projects allowed the lessons learned from the first extended reach drilling (ERD) upgrade (Cutt 2007) to be applied to the second 10-ksi upgrade. This approach also allowed different approaches to be taken to achieve improved results.

The drilling of redrilled wells on an old platform through depleted reservoirs constrained many aspects of well design; most specifically, casing sizes and maximum mud weights through intervals of reactive shale and depleted sands (Bennett et al, 1998). The company has global experience in new field developments with world class ERD wells (Elks et al, 2002; Walker 2008; Armstrong et al, 2011; McDermott et al, 2005; Viktorin et al, 2006; Elsborg et al, 2005; Woodfine et al, 2011) and the different approaches for new wells and redrilled wells will be compared.

The paper will show how the challenges of ERD operations to 25 kft in a 6-in. hole size were overcome and will comprehensively address how some risk mitigations introduced new risks, with specific emphasis on managing an operation where the extreme requirements did not allow any fallback contingencies in the event of a problem.

Citation: Sam Delisio, Courtney Grosvenor, Niels Meissner, Jeremy Ogg, Natalie Wagner, National Oilwell Varco, 'Integrating Improved Environmental Performance Into Rig Design'

(Paper presented at SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA, 8-10 October 2012)

Topic Area: Remediation, Sustainability/Social Responsibility, Performance Measurement, Technical Limit, Risk Reduction and Air Emissions

Jurisdiction: USA

Abstract: In an industry continually in the public eye, doors are constantly opening for environmentally-conscious initiatives. In December 2011, the U.S. Army Corps of Engineers issued a permit (Associated Press, 2012) allowing for infrastructure development for the first commercial oil well in in the National Petroleum Reserve in Alaska (BUREAU OF LAND MANAGEMENT, 2009), with 22 special conditions meant to minimize the environmental impact of the project (Gilbert, 2011). In October, Samsung's Green Future drillship roadshow was accompanied by a request to manufacturers for components that matched their environmental goals (Ensco, 2012).

Throughout the preceding decades, the energy industry matched increased activity with an increased appetite for advances in drilling technology. As an industry, we have made marked advances in safety, drilling automation, waste management and containment. The next step will be to integrate environmental performance, moving environmental accountability away form an oversight function and making it a part of the functioning drilling system. Key items that are already part of the conversation are: biodegradable & non-toxic hydraulic fluids; natural gas powered generators; inert fracing and drilling fluids replacing conventional oil-based fluids and conventional drilling fluids (Rogers, 2010).

The energy industry is aware of its operational footprint and has a growing appreciation of the associated environmental liabilities, including regulatory, energy and maintenance costs. The economics of compliance, waste management, remediation, maintenance, and employee health are quickly coalescing in support of a low-impact drilling rig solution. Managing cost and environmental responsibility are no longer mutually exclusive. As global restrictions for offshore rig emissions grow to mirror those in the North Sea**,** the current climate is ripe for exploring a reduced-environmental-impact rig design. These patently "green" solutions are no longer unmentionable topics of discussion, but rather, could represent the industry's new economic business model. This paper proposes a new definition for "green" in the oilfield and explores examples of how this definition applies in terms of best practices and improved equipment.

Aims & Research Methods: As sustainability and environmental stewardship become an elevated priority in energy policy around the world, the oil and gas industry faces ever-more-stringent regulations, while investors and stakeholders increasingly expect quantification of environmental performance and health and safety factors. With these evolving concerns and pressure from customers, the public, and government to reduce environmental impact, the financial costs and public backlash from making mistakes are growing. As the liaison between the public and many natural resources, the oil and gas industry is in a very important position to protect and sustain these resources for future generations. Thus, technological advances and a re-evaluation of standard drilling practices are required in the field in order to continue meeting the nation's growing energy demand while simultaneously working to eliminate environmental and human safety hazards via equipment automation; reduced air emissions, water consumptions, fuel use, land use, and waste streams; improved well control technology; and use of more energy-efficient materials. These advances are also a prerequisite to improve market access to environmentally-sensitive areas and heavily regulated regions of the world. A shared goal between supply companies and operators to develop and deploy environmentally-friendly drilling solutions based on operator and customer needs, public concerns, and government regulations will help move the industry toward a safer, more efficient, zero-spill, low-carbon future. This paper discusses some of the technologies and examples of how effectively managing environmental performance are also good business practice.

Citation: Nicolas Strauss, Buenos Aires Technological Institute (ITBA), 'The Role of the Oil and Gas Industry in the Transition Toward a Sustainable World' (Paper presented at SPETT 2012 Energy Conference and Exhibition, Port-of-Spain, Trinidad, 11-13 June 2012)

Topic Area: Onshore Projects Planning and Execution, Fundamental Research in HSE, Primary and Enhanced Recovery Processes, Intelligent Completions and Platforms and Floating Systems

Jurisdiction: Global

Abstract: Einar Steensnaes, Minister for Petroleum and Energy of Norway, said during a speech given at the 2002 World Summit on Sustainable Development and speaking about the Petroleum Industry's perspectives for the future that "Increasingly, good ethics is good business". This simple and brief statement might be one of the clearest and most accurate ways of perceiving where the Energy Industry stands today and how it is preparing to face the challenges that the decades to come will bring. Today, the energy playing field is changing. Technology is advancing at the most vertiginous rate in history and it is only likely to accelerate. Energy has become an integral and fundamental part of human modern society and, most probably, man-kind's dependence and demand of energy will dramatically increase throughout this century. So, how will the Energy Indus-try overcome the complex challenges that ensuring energy security for such a fast moving world mean? The answer is right there: with good ethics.

Aims & Research Methods: Throughout the decades to come world's population is expected to rise as well as the energetic, food and water demand. All that, together with the everyday more rigid international environmental regulations alongside with the ongoing vertiginous technological advancement, will induce to a restructuration of global economy on the inter-governmental and institutional level in order to reinforce the fundamental pillars of sustainability: the environmental, social and economic. New energy systems will be implemented and scarcity of resources will be more severe, leading the economy not only to shift but to adapt to unconventional energy carriers and commodities. This combined with the targeted impact of these policies, concerning living standard improvements, social inclusion and carbon mitigation among others, will raise new and demanding challenges to face. This paper intends to present an overview of the energetic playing field throughout the transition towards a more sustainable world and the role of the Oil & Gas industry within this period. This article will identify and explain the challenges and constraints to be faced as well as the opportunities of undertaking ventures in this shifting environment. Also, the paper will broaden the concept of Green Economy, main theme of the 2012 UN's Conference on Sustainable Development, and present strategies to develop an energy system to function and sustainably endure in time within the mentioned framework and ex-plain why the O&G industry is a fundamental participant and a major "game changer" in this process. Petroleum holds a key role in this transition as being the most widespread energy carrier and the most competitive element of the current energy system. Therefore, the O&G industry has the opportunity to become the main "driver of change" and to impulse a more prosper and sustainable energy network for the world. It's imperative that the O&G sector keeps a long-term perspective in order to remain in force and profitable. This paper pro-poses some guidelines to do so and intends to raise awareness on the fact that sustainability is not only changing the way we analyse a project but moreover the way we do business in the O&G industry.

Citation: Reem Freij-Ayoub, CSIRO, Australian Resources Research Centre, 'Numerical Simulation of the Production of Methane and Water from Coal Seams and the Associated Ground Surface Subsidence' (Paper presented at SPE Asia Pacific Oil and Gas Conference and Exhibition, Perth, Australia, 22-24 October 2012)

Topic Area: Drilling and Completions, Wellbore Design/Construction and Fundamental Research in Drilling & Completions

Jurisdiction: Australia

Abstract: Coal seam gas (CSG) refers to gas-methane- that is generated during coalification and stored within coal on internal surfaces. This gas can be generated by microbial processes but is mainly generated through thermal decomposition of coal. CSG has attracted worldwide attention as a source of unconventional natural gas supply. Its development in Australia is an emerging challenge for resource professionals seeking to conserve the environment while meeting energy demands. CSG production involves extracting methane from coal seams by reducing groundwater pressure that keeps the methane trapped in the coal. A primary by-product of this process is water, which is often rich in salts and other constituents that render it unsuitable for many direct beneficial uses.

Aims & Research Methods: Production of methane from coal seems is achieved by pumping out large quantities of water leading to cleat pressure drawdown and hence methane desorption from the matrix, its diffusion through the micropores to the cleat system and out of the wellbore.

A coupled numerical model is developed within FLAC3D to simulate the production of methane and water from coal seams through depressurization and to investigate possibilities of land subsidence around the wellbore. The axisymmetric model simulates the drilling of a vertical wellbore through a formation containing 2 coal seams. The model couples Geomechanics and fluid flow. Langmuir desorption isotherms control the maximum volume of gas desorbed in the coal matrix at any specific pressure. The cleats are assumed to be initially full of water. Desorption of methane from the coal matrix and its diffusion into the cleat system is assumed to be instantaneous. The geomechanical behaviour of the formations follows a Mohr Coulomb yield criterion.

The model qualitatively predicts the quantities of produced methane and water from coal seams separated, overlain or underlain by lithologies of contrasting permeabilities. The presence of an aquitard between both seams ensures higher methane production and less water production. The highest methane production and least amounts of produced water were predicted for seams separated, overlain and underlain by aquitards. The model can predict the amount of ground surface subsidence in the region around the wellbore. Sunsidence up to 11 cm was predicted near the wellbore.

Citation: Steinar Nesse (Det Norske Veritas) and Ulf Einar Moltu (TOTAL E&P NORGE AS), 'Frigg Cessation Project. Environmental footprint and EIA comparison' (Paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Facility Decommissioning and Land Reclamation, Air Emissions. Waste Management and Environment

Jurisdiction: Global

Abstract: The Frigg Field Cessation Project, operated by TOTAL E&P NORGE AS, is the single largest offshore field decommissioning project during the recent years. This project comprised the execution of the removal of three steel substructures, five topside facilities and several sea-lines from the Frigg Field has formed a complex scope of work involving disposal / recycling of 73,000 tonnes of materials, lasting over five years and involving some 4,500 maritime vessel days. An Environmental Impact Assessment (EIA) was performed for the Frigg field installations as part of the decommissioning planning in accordance with the programme approved by Norwegian authorities. This was based upon current knowledge and assumptions. During execution of the project relevant environmental aspects have been quantified and/or recorded. Based on the recorded data and information a comparison is made between the Impact Assessment and the actual experienced environmental performance. Further, an evaluation of the overall impacts or "footprint" of the disposal work is made. Experiences gained from this can be valuable input to future decommissioning planning processes as well as clarify the actual environmental impacts related to a major offshore field being shut in and associated installations disposed of (decommissioned). In the 2010 SPE HSE conference in Rio a paper was presented on Key Performance Indicators for Energy consumption and CO2 emissions (SPE 126825) developed based on the Frigg Cessation Project.

Citation: Alex Large, Jordi Serra, Environmental Resources Management; Myna Letlow, Janette Marczak, Baker Hughes, 'Solving an Acute Problem and Developing a Long-Term Sustainable Solution for an Operational Facility Supporting the Oil and Gas Industry' (paper presented at International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, Australia, 11-13 September 2012)

Topic Area: Remediation

Jurisdiction: UK

Abstract: An oilfield service company has been operating a site in Knowsley, Liverpool, UK for more than 20 years. The site was first developed during WWII as a Royal Ordnance Factory, and since that time has been used almost continually for the manufacture of specialty chemicals (including organic chemicals, organotin compounds, and lead-based compounds) by various companies.

Historical use and disposal practices have resulted in significant subsurface impacts including the presence of free-phase hydrocarbons (LNAPL) and mobile organotins within a complex geological and hydrogeological setting. Despite a number of efforts over the years to characterize and address site contaminants, issues remained and required clarification to resolve the regulatory roadblock that was preventing successful closure of the on-site remediation.

Aims & Research Methods: This case study presents the results of the recent successful efforts to develop a robust and defensible conceptual site model, highlighting the key lessons learned in terms of data assessment, integration and visualization. Two important areas of focus include:

- Engaging with the regulators on a pragmatic, risk-based approach to managing LNAPL remediation. This included developing a remedial strategy focused on understanding whether there are actual risks rather than the mere presence of LNAPL.
- Understanding the relationship and interaction of tributyl-tin (TBT) with LNAPL, where the LNAPL was acting as a preferential solvent, enhancing the mobility of the TBT. As such, the risks and any subsequent remedial solution could not be considered as two separate problems and an integrated strategy was developed.

The use of risk-based approaches, robust conceptual models and a detailed understanding of contaminant distribution are critical to the development of long term sustainable solutions to remediate contaminated sites.

Citation: Thomas Kipker, Bentec, 'Innovative HSE Management at Drilling Rigs and Their Components' (Paper presented at SPE Middle East Health, Safety, Security, and Environment Conference and Exhibition, Abu Dhabi, UAE, 2-4 April 2012)

Topic Area: Drilling Rig Mangement

Jurisdiction: Global

Abstract: The API is concerned with such matters as the exploitation of storage facilities, oil consumption, taxes, trade, environmental protection, occupational safety, and the design of components. One important field of endeavour is the development of technical guidelines and standards, which naturally are a crucial factor affecting the components' construction. The API has had an influence that extends far beyond the USA, and it has achieved virtually worldwide acceptance. The API is the most important instrument for the construction of the components of a drilling rig. Drilling contractors all over the world are specifying the API as the basis for drilling rig components. Safety assessments must therefore take these standards into account, regardless of whether the manufacturer of the components is located in the USA or in Germany. Nevertheless, new European standards offer an ideal supplement to the API, since European standards provide an even more comprehensive consideration of machine safety than the API does. It would be desirable, of course, if the European standards for

machine safety were valid on an even broader, more global scale. This would further reduce the burden of design and documentation costs for exporting machine manufacturers.

Aims & Research Methods: HSE management at drilling rigs involves many disciplines. These disciplines can be thought of as two pillars that together provide the foundation for effective HSE management at drilling rigs. That the drilling contractor must have an effective management system goes without saying. An effective management system is one that results in work processes designed to ensure the safety of every aspect of a drilling rig's operation. This is normally the responsibility of the drilling contractor and, to a certain extent, of the operator as well. The other pillar this paper is concerned with is the safety of the drilling rig itself – specifically, the safety of the individual machine in a drilling rig. An assembly of machinery consisting of many such machines also must be safe, and it must undergo the appropriate safety inspections. The definition of "safe" machinery is subject to a broad range of national and international legislation that must be considered. In this paper we shall describe which laws must be observed, which aids are used for safety analysis, and how the various laws and directives are implemented in practice by the mechanical engineer. European drilling rig manufacturers who manufacture both the rig and its components have an enormous responsibility.

1. The construction of appropriately safe components that bear the CE conformity marking and, when necessary, have ATEX confirmation as well.

2. The combination of individual safe machines into one functioning drilling rig system. This drilling rig must be able to demonstrate its functional safety.

This requires compliance with those European standards that have the appropriate worldwide validity and are recognized in the country of operation. One must also determine whether there are other laws in the country of operation that affect the construction of rigs and their components.

Citation: Tina Hunter, 'Unconventional Gas and the Right to Food and Water: A comparative Analysis of Australia, Poland and France' (Paper presented at Food Law and Food Security Colloquium Bond University Centre for Commercial Law, Gold Coast, Australia, 2012)

Topic Area: Energy, Water and Food Security

Jurisdiction: Australia, Poland and France

Abstract: Energy security versus food security is real

    - For France: food security is more important that energy security
    - nuclear power is central to this
- For Poland – Shale gas energy security is vital:
    - the Russians
    - reduction of GHG emissions through decreased use of oil and increased use of gas

- For Australia attempting to balance the two –
    - require energy security in west- balance to be exported as LNG
    - LNG export is dominant in East Coast – balance with 'Australia's Breadbasket'?

Aims & Research Methods: This presentation analyses unconventional gas resources, UGR in the chosen jurisdictions of comparison, issues in UGR exploitation and energy extraction versus the right to food and water.

Citation: Sarah Moran, 'Coal Seam Gas & Land Use Conflict' (2012) Bond University

Topic Area: Land Use and Land Access

Jurisdiction: Australia

Abstract:

1. Introduction to the CSG industry

2. Regulatory framework for CSG in QLD

3. Land use conflict:

    (a) Landholders

    (b) Overlapping tenures

Aims & Research Methods: This presentation analyses the coal seam gas industry, the history of coal seam gas in QLD, coal seam gas production and regulatory framework for coal seam gas in Queensland.

Citation: Susan L. Sakmar, 'The Future of Unconventional Gas: Legal, Policy and Environmental Challenges to the Development of North American Shale Gas' (Paper presented 29th USAEE/IAEE North American Conference, Calgary, Canada, 14-16 October 2010)

Topic Area: Legal, Policy and Environmental Challenges to the Development of North American Shale Gas

Jurisdiction: USA

Abstract: One of the most promising trends in North American energy supplies is the development of unconventional gas resources, and in particular, shale gas. Until relatively recently, these deposits were thought to be uneconomical to develop. However, recent advancements in hydraulic fracturing and horizontal drilling technologies have led to the successful development the vast reserves of shale gas found in North America and many view shale gas as an "energy game changer" that can help bridge the gap between conventional resources and the development of renewable energy sources. As the oil and gas industry applies the hydraulic fracturing technology to more wells in more parts of North America, it is critical to ensure that the process is safe and environmentally sound. A number of concerns have been raised about the potential impact of the injection of hydraulic fracturing fluids in wells located near drinking water sources. Issues have also been raised about the quantity of water used and the disposal of flow-back water. These policy, regulatory and environmental questions must be addressed before the development of shale gas can meet its full potential. With major reserves of shale gas, North America and in particular the United States, is leading the way in terms of addressing these issues. The results and outcome of shale gas development in North American may inform future development of global shale gas resources.

Aims & Research Methods: The development of unconventional resources such as shale gas could have a significant impact on the future of the global energy supply. At the same time, however, the development of these resources requires careful analysis of the policy, legal and environmental challenges involved. In the United States, this analysis is currently underway with two bills pending in the U.S. Congress and a detailed study of the environmental impacts of hydraulic fracturing being conducted by the U.S. EPA. While it is difficult to predict the outcome of the EPA study and whether the U.S. Congress will impose new or additional regulations on shale gas development in the United States, these developments should be closely watched as the world searches for the right energy policies for the 21st Century.

Citation: John W. Ely, 'Gas Land Debunked' *Ely & Associates of Texas, LLC* (2012)

Topic Area: Seismic Activity

Jurisdiction: USA

Abstract: This presentation tries to address most of the issues of "Gasland the documentary" and also illustrate how our industry is working hard to improve our image and more importantly discuss the fact that with an oilfield "Sputnik Moment" that we could be totally energy independent creating jobs and returning to solvency as a nation.

Aims & Research Methods: This presentation concludes with the following points:

- The multiple interviews with people whose water was contaminated should obviously be investigated and rectified if by some weird set of circumstances the multiple fail safe criteria to eliminate aquifer contamination fails. Again most of the interviews related to other aspects of the industry not fracturing.
- Like so many of this type of documentary investigation, it was obvious that no real expert on fact Sadly it is obvious that not everyone likes our industry but we must realize that we must do a better job of communicating what is good and right about our people, equipment and technology.
- We are in perhaps the most exciting time in the history of our industry in that we have the ability to become energy independent due solely to technological advances in hydraulic fracturing. We must be forthright in telling everyone exactly what is being pumped and what is being done to insure the safety of not only our aquifers but our rivers lakes and streams.

- Exciting advances in fracture design which basically eliminate virtually all chemicals and or the use of environmentally safe products will, I believe, put to rest the concerns of most.
- Finally we need to get across to our representatives the absolute necessity to develop safely and environmentally responsibly the resources that we have.
- By doing so we will eliminate the tremendous outflow of cash to the OPEC nations.
- By utilizing the natural gas to diesel technology and perhaps simultaneously CNG and LNG we can turn our country around, creating jobs and quickly reducing the deficit.

Citation: Seismik, 'Preliminary report for Cuadrilla Resources 13/01/2012' (2012)

Topic Area: Seismic Activity

Jurisdiction: USA

Abstract: This presentation analyses the comparison of major seismic events including:

•Location of the event of August 2nd, 2011

•Mechanism of the event of August 2nd, 2011

•Event August 8th, 2011?

•Detection on regional stations

•Comparison of master events 01/04, 27/05, 02/08/2011

•Detection range from local stations AVH and HHF

Aims & Research Methods: This presentation concludes by presenting the following points:

Computed theoretical reliable detectable range by simple detection method (SNR = 2) is Mw = -0.45

Predicted detectable range by simple detection method (SNR = 2) from dependence of amplitude on relative magnitude is M = -0.7

Predicted detectable range by X-corr. detection method (SNR = 1) from dependence of amplitude on relative magnitude is M = -1.0

Completeness of catalogue of an events from HHF and AVH stations can be down to M = -0.7

The seismic activity close to the injection intervals can be well monitored by surface monitoring network.

Citation: Carlos R. Romo and J. Scott Janoe, ‘Regulatory Regimes for Recycling Produced and Frac Flowback Water’ (2012) Paper 2012-A-453-AWMA

Topic Area: Hydraulic Fracturing Activities, Water Use and Distribution

Jurisdiction: USA

Abstract: Despite promising new water treatment services that can help oil and gas operators conserve freshwater and recycle produced and hydraulic fracturing flow back water, there is little consistency across jurisdictions as to how produced water recycling operations are regulated. Some jurisdictions differentiate between commercial and non-commercial operations. Others treat water recycling like solid waste recycling. The goal of this paper is to present information on the various state regulatory schemes that exist for the recycling of produced water and the permitting issues associated with these regimes. The presentation will cover basic regulatory considerations in recycling oil and gas wastes and will briefly detail how specific high-growth shale field states such as Texas, Colorado, Louisiana, New Mexico, Pennsylvania, and Wyoming manage the permitting process for produced water recycling. A particular focus will be on issues affecting water scarce areas like the Eagle Ford Shale. The presentation highlights potential changes in the near future regarding oil and gas regulatory exemptions that may affect produced water recycling and advocates for states to examine ways to reduce regulatory obstacles to encourage recycling.

Aims & Research Methods: The technologies and regulation of recycling produced and frac flow back water are constantly evolving. Because of new emerging technologies to recycle and reuse oil and gas wastewaters, states have been prompted to review relevant regulations to encourage these promising new methods to reduce water consumption and oilfield wastes. 41 Still, significant uncertainty and inconsistency exists in many states. The DOE’s Shale Gas Subcommittee recently made three recommendations related to water use, including the need to estimate volumes of water flows throughout the hydraulic fracturing process and minimize water use.42 While this paper attempts to provide some general considerations and key information regarding the current state of regulation of recycling produced water, states should continue to review their regulations to evaluate whether obstacles exist to recycling produced water and whether changes could be made to facilitate promising new recycling technologies.

Citation: Ali Sharifzdeh, ‘Unconventional Gas Resources in Onshore Western Australia’, Australia-India Energy and Minerals Forum (June 8 2010)

Topic Area: Tight Gas Characteristics

Jurisdiction: Australia (WA)

Aims & Research Methods: This presentation provides a general outline of Unconventional Gas Production in the US, tight gas sands, tight gas resources, right gas wells (Northern Perth Basin) (Onshore Canning Basin), the primary characteristics of shale gas generally and critical parameters for developing Unconventional Gas.

Conclusions:

•WA has huge potential for Unconventional Resources

•It is not unreasonable that unconventional gas resources could match or exceed WA offshore conventional gas reserves

•Some estimates of Queensland Coal Seam Gas puts the resources at270 TCF (twice the current WA conventional gas resources)

Market Drivers

•Increasing Demand

•Decreasing Supply

•Increasing Price

•Short term markets to supply local resource projects and infrastructure developments

•Large local companies are seeking alternative sources of gas supply

•Medium term contribution to the domestic gas supply network through pipeline extensions

•Longer term aim to add to potential gas reserves for LNG hub currently proposed for development by Woodside at James Price Point to help meet any shortfall for LNG trains that are being proposed

Issues and Challenges

•High Recovery Cost

•Price Volatility

•Land Access

•Shale gas production at economic rates depends primarily on the volume of gas in place, matrix permeability and completion quality.

•Gas in place is often the critical factor for evaluating economics, taking precedence over matrix permeability and completion quality.

•Reservoir / Fluid Compatibility (Drilling and Frac Fluid)

Citation: Peter Styles, 'Tight Gas, Fracking and All that Jazz' (2012) Keele University

Topic Area: Hydraulic Fracturing Activities

Jurisdiction: EU

Abstract: This presentation discusses the following topics:

- What is Shale Gas?
- What is Fraccing?
- What chemicals are used?
- Environmentalissues/ Water!ContaminaFon/

- Visual Amenity/Well Integrity
- Seismic issues
- Economic considerations

Citation: Barry Goldstein, 'Progress Towards National Harmonisation of Land Access Approvals' (Paper presented at APPEA 2012 CSG Conference, Brisbane, 9th September 2012)

Topic Area: Land Access

Jurisdiction: Australia

Aims & Research Methods: This presentation discusses the harmonisation of land access approvals and a regulatory framework for CSG in light of current CSG projects and potential CSG projects.

Citation: Tina Hunter, 'Coal Seam Gas What the Frack is it all About?' (Paper presented at Bond University)

Topic Area: Land Access

Jurisdiction: Australia

Aims & Research Methods: This presentation discusses the following topics:

1. What is Coal Seam Gas
2. Where is CSG
3. How do we get it out
   - Fracking
4. What are the problems with CSG removal
   - Land Access
   - Water Contamination
