Singh, Angela K (DOA)

From: Colombie, Jody J (DOA)
Sent: Wednesday, August 07, 2013 1:25 PM
To: Singh, Angela K (DOA)
Subject: FW: Baker Hughes Further Comments on AOGCC Proposed Changes to AAC Title 20, Chapter 25 Regarding Hydraulic Fracturing
Attachments: 2013-08-05 Baker Hughes Further Comments on AOGCC Proposed Changes to AAC Title 20, Chapter 25 Regarding Hydraulic Fracturing.pdf

process

From: Armstrong, Matt [mailto:Matt.Armstrong@bakerhughes.com]
Sent: Monday, August 05, 2013 3:59 PM
To: Colombie, Jody J (DOA)
Cc: Mathew, Peter V; Fisher, Samantha J (DOA)
Subject: Baker Hughes Further Comments on AOGCC Proposed Changes to AAC Title 20, Chapter 25 Regarding Hydraulic Fracturing

Ms. Colombie –

Attached please find a .pdf copy of Baker Hughes' further comments on the Alaska Oil & Gas Conservation Commission's proposed changes to Title 20, Chapter 25 of the Alaska Administrative Code, with regard to hydraulic fracturing. We are submitting these comments pursuant to the instructions contained in the June 19, 2013 notice.

We greatly appreciate the opportunity to provide comment. If you or anyone else at the Commission have any questions please do not hesitate to contact me or Peter Mathew (cc'd here).

Thanks,

Matt Armstrong

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August 5, 2013

VIA E-MAIL

Cathy P. Foerster
Chair and Commissioner
Alaska Oil and Gas Conservation Commission
333 West 7th Ave., Suite 100
Anchorage, Alaska 99501

Re: Alaska Oil and Gas Conservation Commission proposed changes to Title 20, Chapter 25 of the Alaska Administrative Code, with regard to hydraulic fracturing.

Dear Ms. Foerster:

Baker Hughes Incorporated (Baker Hughes) submits the following comments on the Alaska Oil and Gas Conservation Commission (AOGCC) proposed revision of Title 20, Chapter 25 of the Alaska Administrative Code with regard to hydraulic fracturing (hereinafter, the Proposed Rule).

Baker Hughes is a leading international oilfield technology and service company headquartered in Houston, Texas, with operations in Alaska employing over 200 people. We have a proud, century-long history of providing technological solutions in both products and services for the full life-cycle of oil and natural gas reservoir development, from reservoir development to drilling and evaluation to completion and production. Baker Hughes spent nearly half a billion dollars on research and engineering in 2012, with an emphasis on developing solutions for the unconventional, deepwater, and high-pressure/high-temperature oil and gas frontiers.

Baker Hughes greatly appreciates the opportunity to comment further on AOGCC's efforts to clarify and delineate the requirements associated with hydraulic fracturing in Alaska. We are disappointed to see that the revisions to the Proposed Rule published on June 19, 2013 do not appear to address the substantial concerns articulated in our comment letter dated April 1, 2013. As a result, we respectfully request that AOGCC again consider those comments, and we incorporate them by reference herein. Without repeating those comments, however, we hope to highlight some critical aspects of them here.

The AOGCC Can Achieve Its Chemical Disclosure Policy Goals Through FracFocus Without Abridging Its Oversight Authority.

We understand that the AOGCC's rulemaking is prompted in part by significant and understandable public interest in oil and gas exploration and production operations, particularly

hydraulic fracturing. We agree with the need to ensure that the public has meaningful information about these operations, and Baker Hughes supports the public disclosure of chemical ingredients used during the hydraulic fracturing process as an achievable policy goal.

We believe the tool for public disclosure exists in FracFocus, the chemical disclosure registry established and administered by Ground Water Protection Council (GWPC) and Interstate Oil and Gas Compact Commission (IOGCC). It bears emphasis that the IOGCC and the GWPC are consortiums of state regulators charged, respectively, with regulating oil and gas production and with groundwater protection. Alaska is, of course, a member of both.

The AOGCC has recognized the value in FracFocus by providing in 20 AAC 25.283(i) of the Proposed Rule that the operator must post information to the FracFocus website and attach that information to Form 10-404. However, the Proposed Rule is unclear as to whether the FracFocus disclosure itself is sufficient to satisfy the disclosure required by 20 AAC 25.283(h). If so, this largely dissipated concerns about the lack of trade secret provisions within the Proposed Rule. If not, then the Proposed Rule seems to contemplate multiple filings of slightly different records, those slight differences comprising in part the mandatory disclosure of valuable intellectual property, a requirement more stringent than any other similar federal or state disclosure framework.

We believe that AOGCC's adoption of FracFocus as the primary method of providing chemical disclosure would carry tangible, practical benefits while achieving AOGCC's policy goals. Namely, FracFocus:

- Represents the fruit of extensive, successful discussions between industry, regulators and environmental groups to resolve the same tension between public interest and gratuitously negative effects on the competitive marketplace that the AOGCC is grappling with here;

- Evolves as those discussions evolve, and stakeholder needs evolve, as evidenced by FracFocus 2.0, discussed below;

- Has been widely incorporated into current company practices, meaning relatively smooth implementation and a reduction of the administrative burden on all involved, including the AOGCC;

- Has been widely adopted by the AOGCC's peers and is administered by state groups of which AOGCC is already a member (and funds); and

- Does not abridge the AOGCC's authority to act in the event of spills, accidental exposures or other accidents.

Over 50,000 hydraulic fracturing operations have been reported on FracFocus since the site launched in early 2011, including 50 wells in Alaska. Twelve state regulatory agencies now require company chemical disclosure through FracFocus. The Department of Interior's Bureau of Land Management has proposed requiring company chemical disclosure through FracFocus

for hydraulic fracturing operations on federal and tribal lands, as has California's Department of Oil, Gas and Geothermal Resources.[1]

As part of its hydraulic fracturing study, EPA has analyzed over 12,000 of those reports (with wells from Texas comprising more than 40% of the reports). EPA found that of those reports, only 1,924 (or less than 16%) withheld any chemical name or chemical abstract service registry number (CASRN) as proprietary. According to EPA, of all of the individual chemical ingredients reported across the 12,000 hydraulic fracturing operations studied by the Agency, only 1.3% of the entries withheld any chemical name or CASRN as proprietary.[2]

In addition, FracFocus implemented major upgrades in June 2013 that dramatically improve the site's functionality for state and federal regulatory agencies, industry and public users.[3] In addition to using GIS mapping technology to identify chemicals used in individual wells, users will also have the option to search and pull reports by date ranges, chemical names or CASRN. According to IOGCC and GWPC, FracFocus 2.0 allows individual states to establish within the FracFocus framework a centralized reporting database tailored to that state's specific compliance needs, "saving valuable tax dollars."[4]

On the service company side, Baker Hughes was one of the earliest and largest supporters of FracFocus. We designed an automated disclosure system that allows our customers to comply with any state disclosure rule or make voluntary disclosures in a format that does not jeopardize our and our suppliers' proprietary information. We described in our April 1, 2013 submission the evolution of the FracFocus template to encompass not only material safety data sheet (MSDS)-listed chemical ingredients but also non-MSDS-listed chemical ingredients (meaning that the federal Occupational Hazard and Safety Administration did not deem information regarding the chemicals material to those responding to spills, worker exposures or other accidents). The de-linking of non-MSDS-listed chemical ingredients from the additives greatly reduces but does not eliminate the need to withhold certain information as proprietary. Baker Hughes, for example, has eliminated almost all proprietary designations for our own manufactured hydraulic fracturing additives, but we still list generic chemical family names and withhold CASRN for certain constituents of third-party supplied products.

We have attached as Exhibit A a sample FracFocus disclosure well report based on a real hydraulic fracturing system pumped in California. As you can see, chemical names and CASRN are provided for all but one of the MSDS-listed chemical constituents (which has a generic chemical family name and no CASRN, as per 29 CFR 1910.1200, the statutory standard first proposed by the AOGCC). The maximum concentration of each in its respective additive and in the overall fracturing fluid is provided. Every non-MSDS-listed chemical constituent of each

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[1] *See*, Bureau of Land Management, *Oil and Gas; Hydraulic Fracturing on Federal and Indian Lands*, 78 Fed. Reg. 31636, 31676 (May 24, 2013); Cal. Code Regs. tit. 14, § 1788.2(c) (Dec. 18, 2012 Discussion Draft).

[2] *See* USEPA, *Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources: Progress Report*, (EPA 601/R-12/011, Dec. 2012), at page 61. You may find EPA's report online at http://www.epa.gov/hfstudy/index.html.

[3] *Press Release: FracFocus 2.0 to revolutionize hydraulic fracturing chemical reporting nationwide* (IOGCC/GWPC May 29, 2013) (found at http://fracfocus.org/node/347).

[4] *Id.*

additive is provided in a supplemental list (as contemplated by 20 AAC 25.283(h)(2)(D) in the December 20, 2012 version of the Proposed Rule) along with the maximum concentration of each within the hydraulic fracturing fluid. Where an additive's ingredient list identifies "no hazardous ingredients," all of that additive's ingredients are provided in the supplemental list.

Our FracFocus disclosures thus provide an unprecedented level of operational detail regarding hydraulic fracturing operations. In addition, the MSDS for each additive—and recall that all additive trade names are listed—describes exposure hazards, first aid and firefighting measures, environmental risks and clean-up methods, transportation, handling, storage, personal protection, disposal and other regulatory requirements, and detailed information on the physical, chemical, toxicological, ecological, stability and reactivity properties of the chemical constituents. Baker Hughes publishes all of our product MSDS.

Finally, nothing about adopting FracFocus compromises the authority of the AOGCC to seek information when it needs it. Many states that have adopted FracFocus for routine reporting have emphasized in their regulations the authority to collect additional information.[5]

The Absence of Any Explicit Reference to the Protection of Proprietary Information Is an Abrupt Departure from Alaska Law and Poses Unreasonable Risk and Uncertainty.

Alaska law recognizes the existence and validity of trade secrets.[6] The Alaska Supreme Court has recognized the concept of trade secrets in conjunction with the oil and gas industry.[7] Alaska regulations are replete with examples in which state agencies have recognized the existence of trade secrets within a regulatory reporting scheme and enshrined assurances that such proprietary information would be protected, including in the context of regulatory frameworks ensuring worker safety and consumer protection.[8]

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[5] *See* Ohio Rev. Code Ann. § 1509.10(J) (imposing duty to maintain records available for inspection upon request); 25 Pa. Code § 78.122(d); Cal. Code Regs. tit. 14, § 1788.2(c) (Dec. 18, 2012 Discussion Draft); 2 Colo. Code Regs. § 404-1:205A(b)(5); 16 Tex. Admin. Code § 3.29(c)(4).

[6] Alaska Stat. Ann. § 45.50.940 (West).

[7] *State Dept. of Natural Res. V. Arctic Slope Reg'l Corp.*, 834 P.2d 134, 139 (Alaska 1991) ("the value of the data depends on its secrecy and as the companies obviously have attempted to keep it secret we have no difficulty characterizing the data obtained by the oil companies...as trade secrets.")

[8] *See, e.g.*, 8 AAC 61.060 (providing that confidential business information observed or obtained during occupational health and safety inspections will not generally be publicly disclosed); 6 AAC 93.070 (providing that confidential business information submitted in conjunction with the Community Development Quota program will not be publicly disclosed); 2 AAC 12.770 (authorizing certain state officials to develop procedures for protecting trade secrets encountered during government procurement processes); 3 AAC 48.045 (procedures for classifying records as confidential business information during Alaska Regulatory Commission proceedings); 3 AAC 107.630 (providing that confidential business information submitted in conjunction with the Renewable Energy Grant Program will not be publicly disclosed); 3 AAC 107.770 (providing that confidential business information submitted in conjunction with the Emerging Energy Technology Grant Program will not be publicly disclosed); 3 AAC 233.950 (providing that confidential business

The AOGCC itself recognizes the concept of trade secrets and has seen fit in other circumstances to assure the industry that information submitted in association with a well may be claimed as confidential and will be kept confidential for a time to protect any potential competitive advantage.[9] We remain concerned by this apparent deprivation of state protections enjoyed by all other industries, and enjoyed by other operations within this industry.

As we stated in our April 1, 2013 comments, prohibiting proprietary information protections would have the perverse consequence of impeding the improvement of hydraulic fracturing chemistry. In those comments, we referenced a number of technologies that provide tangible and significant environmental improvements but which rely in part on proprietary chemistry. In particular, we described how our chemical evaluation process review framework (CEPR) and SmartCare™ line of environmentally-preferred products have driven competition among our chemical suppliers to provide higher-ranking (i.e., "better") products, and allowed us and our customers to target and eliminate specific chemicals from several of our products, often in rapid evolution.

We have attached as Exhibit B one of the four scientific papers that our scientists and engineers have published on the CEPR and SmartCare™ products that demonstrate that process.[10] The paper provides several case studies demonstrating how we and our suppliers use the CEPR to evaluate products and target specific chemical constituents for reduction, substitution or elimination. One of the case studies describes how we worked with a supplier to eliminate ethylene glycol monobutyl ether from a line of surfactants, and put the reformulated product line on a path to eliminate the use of methanol. Another describes how we targeted EPA-listed priority pollutants for elimination from our non-emulsification additives and wellbore preflushes, including "winterized" formulations for use in northern climes. Yet another describes how we developed a clay control additive that uses choline chloride—an additive to animal feeds—rather than potassium chloride or liquid quaternary amine salts such as tetramethyl ammonium chloride. In each of these cases we have introduced in the last few years new products that significantly improve the chemical profile of additives that have been deployed for decades. The rapid development of successive generations of products to improve their environmental profile is not easy and it is expensive. The investments are recent and cost recovery ongoing. It would be difficult to justify introducing such products into local markets that do not recognize that investment and where we or our suppliers face an inordinate or uncertain risk to the intellectual property generated by such investments of time, money, human capital and other resources.

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information submitted with proposals to the Alaska Science and Technology Foundation will not be publicly disclosed); 20 AAC 15.830 (providing that confidential business information submitted by banks in conjunction with seeking approval to participate in the state's student loan program will not be publicly disclosed); 18 AAC 31.015 (providing that confidential business information provided to obtain a permit or demonstrate compliance under the Alaska Food Code will not generally be publicly disclosed); 18 AAC 32.925 (same, with milk, milk products and reindeer slaughtering); 18 AAC 34.025 (same, with seafood processing).

[9] 8 AAC 25.537.

[10] *See* Exhibit B, Brannon et al., *SPE 152068, The Quest to Exclusive Use of Environmentally Responsible Fracturing Products and Systems* (Society of Petroleum Engineers, Feb. 2012).

It is possible to read the "modification, variance and waiver" provision in 20 AAC 25.283(j) as providing the AOGCC the authority to waive disclosure of trade secret information upon a showing of good cause. Indeed, we hope that this and our previous set of comments demonstrate that the nominal level of protection which we seek—the substitution of generic chemical family names rather than specific chemical identities and removal of CASRN for a limited number of chemical constituents—meet the criteria set forth in 20 AAC 25.283(j).

Beyond the threshold uncertainty regarding whether it even applies to this issue, there are a number of problems with 20 AAC 25.283(j). First and foremost, the provision applies only "[u]pon the written request of the operator," a condition that would seem to preclude our seeking relief directly. We would respectfully request that the provision be modified to read "[u]pon written request of the operator, vendor, or service provider,..." Even so, the provision is too vague to provide adequate certainty. For example, it is unclear if such a variance of waiver could be sought *prior* to introducing a product to the market, thus protecting the global value of the intellectual property in the event of an adverse ruling, or whether the trade secret would have to be staked, thus essentially negating the value of the provision as it relates to chemical disclosure. It is unclear whether such a variance or waiver would have to be sought relating to each hydraulic fracturing job, thus imposing burdensome administrative burdens and potential delays on all involved, or whether it could be sought on a programmatic, annual or some other periodic basis, potentially providing some efficiencies. The answer to each of this type of basic question generates a cascade of subsequent questions, and so on, so that the cumulative effect is to render the provision a nullity at this point for purposes of planning.

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Again, Baker Hughes shares the AOGCC's commitment to safety and environmental protection in its operations. We believe that the concerns expressed herein can be addressed easily and without compromising the AOGCC's goals. We welcome further discussion of this important rule, and we invite AOGCC to contact us regarding any questions related to these comments or any other topics relevant to AOGCC's work in this area. If you have any questions concerning our comments or require clarification, please contact me at (907) 267-3400. Thank you for your consideration.

Sincerely yours,

Peter Mathew
Director, Alaska GeoMarket

Baker Hughes Further Comments on AOGCC
Proposed Changes to AAC Title 20, Chapter 25
Regarding Hydraulic Fracturing

Exhibit A

Sample FracFocus Disclosure

Hydraulic Fracturing Fluid Product Component Information Disclosure

Last Fracture Date	8/5/2013
State:	California
County:	County A
API Number:	00-000-0000
Operator Name:	Operator B
Well Name and Number:	Well C
Longitude:	0
Latitude:	0
Long/Lat Projection:	
Production Type:	Oil
True Vertical Depth (TVD):	10,190
Total Water Volume (gal)*:	237,972

SAMPLE DISCLOSURE

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments
Water	Operator	Carrier	Water	7732-18-5	100.00%	80.79736%	
Alpha 125	Baker Hughes	Biocide	Glutaraldehyde	111-30-8	30.00%	0.00645%	SmartCare Product
Enzyme G-I	Baker Hughes	Breaker	Hemicellulase Enzyme Concentrate	9025-56-3	3.00%	0.00451%	SmartCare Product
			Water	7732-18-5	97.00%	0.14590%	
High Perm CRB	Baker Hughes	Breaker	Ammonium Persulphate	7727-54-0	60.00%	0.00147%	SmartCare Product
			Crystalline Silica Quartz	14808-60-7	30.00%	0.00073%	
BC-3	Baker Hughes	Breaker Catalyst	No Hazardous Ingredients	Trade Secret	100.00%	0.01116%	SmartCare Product
BF-7L	Baker Hughes	Buffer	Potassium Carbonate	584-08-7	60.00%	0.06697%	SmartCare Product
			Potassium Hydroxide	1310-58-3	1.00%	0.00112%	
			Water	7732-18-5	60.00%	0.06697%	
FSA-1	Baker Hughes	Clay Control	Ethanol	64-17-5	5.00%	0.00603%	
Clay Master-5C (Tote)	Baker Hughes	Clay Control	Oxyakylated Amine Quat	138879-94-4	60.00%	0.05913%	SmartCare Product
XLW-32, 260 gal tote	Baker Hughes	Crosslinker	Boric Acid (H3BO3)	10043-35-3	30.00%	0.01660%	
			Methanol	67-56-1	60.00%	0.03320%	

Hydraulic Fracturing Fluid Composition:

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by mass)**	Maximum Ingredient Concentration in HF Fluid (% by mass)**	Comments
			Methyl Borate	121-43-7	30.00%	0.01660%	
GW-3LDF	Baker Hughes	Gelling Agent	1-Butoxy-2-Propanol	5131-66-8	5.00%	0.03712%	
			Cyrstalline Silica, Quartz (SiO2)	14808-60-7	5.00%	0.03712%	
			Guar Gum	9000-30-0	60.00%	0.44543%	
			Isotridecanol, ethoxylated	9043-30-5	5.00%	0.03712%	
			Paraffinic Petroleum Distillate	64742-55-8	30.00%	0.22271%	
			Petroleum Distillates	64742-47-8	30.00%	0.22271%	
Sand, White, 20/40	Baker Hughes	Proppant	Crystalline Silica (Quartz)	14808-60-7	100.00%	8.54085%	
Sand, White, 100 mesh	Baker Hughes	Proppant	Crystalline Silica (Quartz)	14808-60-7	100.00%	0.91785%	
Super LC, 20/40	Baker Hughes	Proppant	Hexamethylenetetramine	1009-7-0	0.01%	0.00079%	
			P/F Resin	9003-35-4	5.00%	0.39333%	
			Silicon Dioxide (Silica Sand)	14808-60-7	97.00%	7.63051%	
GasFlo G, 330 gal tote	Baker Hughes	Surfactant	Methanol	67-56-1	30.00%	0.02834%	SmartCare Product
			Mixture of Surfactants	Trade Secret	60.00%	0.05667%	
			Water	7732-18-5	50.00%	0.04723%	
Ingredients shown above are subject to 29 CFR 1910.1200(i) and appear on Material Safety Data Sheets (MSDS). Ingredients shown below are Non-MSDS.							
			2-Butoxy-1-Propanol	15821-83-7		0.0005939046%	
			Acetyl Triethyl Citrate	77-89-4		0.0111596257%	
			Cured Acrylic Resin	Trade Secret		0.0007329803%	
			Methanol	67-56-1		0.0000537763%	
			Water	7732-18-5		0.1354770125%	

* Total Water Volume sources may include fresh water, produced water, and/or recycled water

** Information is based on the maximum potential for concentration and thus the total may be over 100%

All component information listed was obtained from the supplier's Material Safety Data Sheets (MSDS). As such, the Operator is not responsible for inaccurate and/or incomplete information. Any questions regarding the content of the MSDS should be directed to the supplier who provided it. The Occupational Safety and Health Administration's (OSHA) regulations govern the criteria for the disclosure of this information. Please note that Federal Law protects "proprietary", "trade secret", and "confidential business information" and the criteria for how this information is reported on an MSDS is subject to 29 CFR 1910.1200(i) and Appendix D.

Baker Hughes Further Comments on AOGCC Proposed Changes to AAC Title 20, Chapter 25 Regarding Hydraulic Fracturing

Exhibit B

SPE Paper # 152068 – The Quest to Exclusive Use of Environmentally Responsible Fracturing Products and Systems

SPE 152068

The Quest to Exclusive Use of Environmentally Responsible Fracturing Products and Systems

Harold D. Brannon, Daniel J. Daulton, Matthew A. Post, Harold G. Hudson, and Andrew K. Jordan, Baker Hughes

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This paper was prepared for presentation at the SPE Hydraulic Fracturing Technology Conference held in The Woodlands, Texas, USA, 6–8 February 2012.

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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.

A new quantitative process based upon the Globally Harmonized System for Classification and Labeling 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 favorable alternatives is discussed.

The fruits of the process will be discussed in this endeavor, 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 favorable alternatives.

Introduction

Environmental stewardship is a critical component of oil and gas industry operations. While some regional authorities have identified critical criteria for chemicals evaluations oriented to their specific ecosystems to reduce the risk of oil and gas development such as Canada and the European North Atlantic, many have no such guidelines, standards, or established regulations outside their sphere of authority. The advent of new technologies including the combination of horizontal drilling and high-volume hydraulic fracturing processes have been employed to unlock the vast potential hydrocarbon reserves within the shales of North America and throughout the world. Manageable risks, as with most industrial efforts or processes, have been to focus of many from regulatory and the public. Of particular interest has been the chemistries and application processes associated with hydraulic fracturing. These concerns include the perceived potential risk that chemicals used in the fracturing process could enter underground safe drinking water (USDW) reservoirs. Many studies both from within the industry and from outside the industry by groups such as the United States Environmental Protection Agency (EPA, 2004), The United States Congress (Energy and Commerce Committee), independent interstate advocacy groups such as the Ground Water Protection Council, the Interstate Oil and Gas Compact Commission and state regulatory agency-sponsored studies (NY Department of Environmental Conservation, 2009) have concluded that hydraulic fracturing does not pose an unreasonable risk to subsurface drinking water supplies. The studies have prompted what is perhaps the largest investigation into a single industry in decades, and have been met with cooperation and opportunities for the oil and gas industry to educate and inform the public, legislators, and academia.

State regulatory agencies in the United States have worked with organizations such as STRONGER to review and update oil and gas regulatory guidelines with a focus on particular focus on raising the veil of perceived secrecy associated with hazardous components of hydraulic fracturing chemicals. By law all hazardous chemistries must be reported and made available through formal disclosure documents known as Material Safety Data Sheets (MSDS) or Safety Data Sheets (SDS) outside the US. These documents require documentation of toxic components at greater than 1.0% by volume, and carcinogens greater than 0.1%, and are primarily designed to ensure that individuals manufacturing, receiving and handling products are informed and utilize proper Personal Protective Equipment (PPE, for example , protective eyewear, proper gloves and garments which reduce potential risk of exposure during use of such products) .

Although continuous improvement of environmental footprint has been a design criterion for development of fracturing chemical additives for over 20 years, a standardized, scientifically-based systematic process or methodology had not existed to facilitate such efforts. A process to systematically develop and manage environmental information for well stimulation chemicals was defined and presented in SPE 135517, documenting a new methodology to identify, develop, test and implement a well services chemical rating system. Further, the new system is transparent, processed and qualified by environmental experts, and based upon a broadly adopted, globally applicable chemical hazard evaluation system.

The system design requirements included:

- Credibility
- Transparency
- Scientific soundness
- Validity
- Practicality
- Quantitative characteristics.

Processes world-wide have historically been highly variable for evaluating and communicating the hazards of chemicals. The Global Harmonized System for Classification and Labeling of Chemicals (GHS) was developed by the United Nations sponsored Inter-organization Program for Sound Management of Chemicals (IOMC) (United Nations 2003) to establish a methodology to unify and

standardize hazard communication, while including quantitative level of risk. GHS is a comprehensive approach to:

- Define health, physical and environmental hazards of chemicals;
- Create classification processes that use available data on chemicals for comparison with the defined hazard criteria; and
- Communicate hazard information, as well as protective measures, on labels and Safety Data Sheets (SDS)

Quantitative Process for Environmental Risk Assessment

A GHS-based quantitative process to evaluate and rank the hazards posed by well stimulation treating fluids and additives was presented as SPE135517 at the 2010 SPE ATCE. The jointly developed process involved the fracturing services company and a well established, globally recognized independent environmental consultancy firm. Cardno-ENTRIX was charged with the responsibility for performing the assessments, reporting of information including the risk assessment data and the supporting information for determining the respective assessments to the fracturing services company. Concerns over third party supplied proprietary information were overcome by managing communication of the proprietary information through Confidentiality Agreements executed between each supplier and the unbiased consultancy.

The risk assessment system criteria evaluated include Environmental, Human Health, and Physical Hazards. Figure 1 illustrates the specific risk sub-categories for each general criterion. Most of the criteria are the same as those incorporated within the GHS system. Two of the Environmental criteria, however, are 'List-based,' meaning those chemistries appear on lists maintained by the United States Environmental Protection Agency (EPA).

In reviewing the existing systems, it became clear that some common hazards are utilized for evaluating how products affect people and their environment. Many systems focus only on environmental impact, while others evaluate a full range of criteria, including human health and physical hazards. Most rating systems are based on the inherent hazards of the products at "full strength," without taking use conditions or actual exposures into consideration. No one existing system had the breadth of scope desired for this project.

Environmental	Human Health	Physical hazards
Aquatic toxicity	Mammalian toxicity	Explosive
Bioaccumulation	Irritation/corrosion	Flammability
Biodegradation	Carcinogenicity	Oxidizer
Priority pollutants[1]	Genetic toxicity	Corrosive
VOC content [1]	Reproductive and developmental toxicity	

GHS based
[1]List Based

Globally Harmonized System of Classification and Labeling of Chemicals (GHS)
•Addresses health, physical and environmental hazards of chemicals
•Creates a hazard classification process
•Establishes standards for labels and Safety Data Sheets (SDS)
•In USA currently waiting on OSHA Final Ruling –probable implementation in 2012/2013

Figure 1. Hazard Assessment Categorization

Based on the review of existing systems, three distinct classes of Hazards (Environmental, Physical, and Human Health) were chosen as important for an oilfield products evaluation process, and for each of the classes a set of hazards were defined for assessment, as shown in Figure 1. After defining the specific hazards to be assessed, it was necessary to select a method to quantify each chemical's

hazard level. Some level of international consensus for hazard criteria and definitions has been achieved by the GHS, which therefore was chosen to serve as the basis for the ranking of well service products. The GHS scoring scheme was mimicked for each applicable hazard criteria, and a simple pass/fail evaluation was utilized for the 'list-based' criteria. As originally devised, all hazards are rated on a scale of 0 to 3 with equal weighting, but the ranking tool could allow alternative weighting of a score if a particular hazard is considered more or less important than the others. Using published chemical data and these hazard ratings a score for the three sets of hazards (environmental, physical and human health) is generated, with individual and/or aggregate totals. The scoring criteria for the sub-categories are illustrated in Figure 2. Sub-category scores are scientifically based upon verifiable data where possible. In situations where no conclusive data exists (so-called 'data gaps') to confidently score a given criteria, a score of "1" is utilized, rather than a "0" score which would denote a non-hazard.

Environmental	Score	Hazard
Aquatic toxicity	3-2-1-0	High-Moderate-Possible-Not
Bioaccumulation	3-2-1-0	High-Moderate-Possible-Not
Biodegradation	3-2-1-0	Not-Slow-Moderate-Readily
Priority pollutants	3.....0	Yes.....No
VOC content	3.....0	Yes.....No
Human Health		
Mammalian toxicity	3-2-1-0	High-Moderate-Possible-Not
Carcinogenicity	3-2-1-0	Known-Presumed-Suggestive-Not
Genetic toxicity	3-2-1-0	High-Moderate-Possible-Not
Reproductive toxicity	3.....0	Evidence.....Not
Irritation/corrosion	1.....0	High–Moderate...Slight -Not
Physical Hazards		
Explosive	3-2...0	High-Moderate.....Not
Flammability	3-2-1-0	High–Moderate – Slight -Not
Oxidizer	3-2-1-0	High–Moderate – Slight -Not
Corrosive	3.....0	Yes.....No

Not Known = 1

Figure 2. Hazard Assessment Criteria Scoring Guide

Hazard Assessment Applied Process to Fracturing Additive Products and Blended Systems

The following provides examples of product evaluation within performance categories or frac systems. As stated earlier, in order to overcome issues related to "trade secret" or "proprietary" chemical content associated with third-party chemistry, a qualified environmental consultant facilitated communication with third-party providers, gathered data and performed final evaluation based upon fixed criteria.

An example of a common surfactant additive evaluation is given in Figure 3. This example demonstrates the degree of product formulation confidentiality that is maintained between the chemical supplier, consulting environmental analyst and the user. Although the specific chemical identity of Components A and B are not disclosed, their associated hazards are clearly defined. Furthermore, it shows how specific hazards can be quickly identified to guide targeted efforts for improved product development. In this example, replacement of methanol, Component A, and/or Component B with more benign chemistries would yield an improved product from a hazardous risk perspective.

The 'weighted product score' is calculated by multiplying the individual component total scores by the concentration of the component as a percent of the product composition and then normalizing sum of those scores to 100. Lower scores reflect less onerous materials; higher scores, more hazardous. In general terms, products with scores of 10.0/100 or less are considered 'good', scores of 15.0/100 are considered 'acceptable' to 'marginal', and scores of 20.0/100 or higher should be employed cautiously. However, such assessments must be tempered with knowledge that a diluted concentration of the respective additive will be employed in the actual blended treating fluids.

Component	Methanol	Component A	Component B	Water	Total Score	Weight Score
CAS Number	67-56-1	CAS# A	CAS# B	7732-18-5		
%	x	x	x	x		
Environmental Criteria						
Acute Aquatic Toxicity	1	3	2	0		
Air Pollutants (VOCs)	3	0	0	0		
Priority Water Pollutants	0	0	0	0		
Bioaccumulation	0	0	0	0		
Biodegradation	0	1	1	0		
total score/component	x	x	x	x	176	4.4
Toxicological Criteria						
Acute Mammalian Toxicity	0	0	0	0		
Carcinogenicity	0	0	0	0		
Genetic Toxicity	1	1	0	0		
Reproductive and Developmental	3	3	3	0		
Corrosive/Irritant	1	1	1	0		
total score/component	x	x	x	x	223	5.6
Physical Hazards						
%					100	
Explosive					0	
Flammable					1	
Oxidizer					0	
Corrosive					0	
total score					100	2.5
Product Score (Environmental, Toxicological and Physical Hazard Criteria)					499.0	12.5
						(out of 100)
Data gap = 1						

Figure 3. Hazard Assessment of Surfactant A

An evaluation of the environmental hazard assessment scores associated with several surfactant products is shown in Figure 4. The report format permits quick identification of the preferred product in a particular product category, or the most favorable product chemistry with respect to a particular hazard category. Such comparisons do not account for relative product effectiveness or product concentration to be employed, and if these parameters differ among the products in question, some attempt must be made to normalize the product scores. Based solely upon the Figure 4 comparisons Surfactant Product H can be identified as the most favorable from the assessment, followed closely by Surfactant Product F, and Surfactant Product C is the least preferred.

Surfactant Product	A	C	D	E	F	G	H
Environmental Criteria	4.4	4.1	2.9	4.4	3.7	3.1	1.4
Toxicological Criteria	5.6	6.6	4.1	6.8	2.2	3.7	3.9
Physical Hazards	2.5	5.0	0.0	2.5	0.0	2.5	0.0
Product Score	12.5	15.7	7.0	13.7	5.9	9.3	5.3

worst case
best case

Figure 4. Hazard Assessment Comparisons of Several Surfactant Additives

Diesel Oil Eliminated from Polymer Slurry Concentrates and Friction Reduction Additives

The next step was to prioritize the targets, i.e. the additive products that posed the greatest potential risk. Risk is commonly defined as the magnitude of the hazard multiplied by the size of the exposure (volume). In this case, however, additional variables involved, including pending regulation of certain substances and the resources available for allocation. The actual hazard to drinking water aquifers posed by the subterranean injection of fracturing fluids comprised of diesel oil-containing components is reported to be highly unlikely with proper well construction. However debatable the degree of the

hazard may be, any perceived risk can be lessened by eliminating diesel from fracturing additives. Removal of diesel oil-containing additives was therefore deemed of greatest importance, including by all BTEX-containing additives (benzene, toluene, ethyl benzene, and xylene), as they have been identified as the diesel components offering the greatest health hazards if exposed to underground drinking water aquifers. The composition of common diesel oil varies significantly, with the BTEX content ranging from 0.1% to about 1%, as reported within standard technical references.

Guar polymer slurry additives had previously been addressed, with diesel content having been progressively replaced by environmentally friendly oil since the mid-90s. The pace of the conversion was accelerated by the voluntary Memorandum of Agreement with the EPA in 2003, and the conversion completed in the spring of 2008. Likewise, diesel oil use was eliminated within friction reduction products (polyacrylamide-based additives for slickwater) replaced in the company's FR products by mineral oil during the mid- to late-1990s. As a point of reference, the authors' company pumps on the order of 15 million gallons per year of these products in US hydraulic fracturing applications, which have 50% to 70% oil content by volume. The polymer slurry loading employed in the fracturing fluid is typically about 6 gallons per thousand gallons of water, or 3 gallons of oil per thousand gallons of water. The friction reduction products are employed at lower additive rates, typically 1 gallon per thousand gallons of water, or 0.7 gallons of oil per thousand gallons of water.

Additional diesel-containing products within the fracturing product line were identified, including crosslinkers, breakers, and fluid loss additives. In each case, the products have been reformulated to eliminate the diesel oil and subsequently commercially released, followed by deletion of their predecessors from the product line. The company pumps, collectively, on the order of 2 million gallons per year of these products. Conversion to the new non-diesel oil containing additives, which is essentially complete, eliminates of over 1.25 million gallons of diesel oil per year. Removal of diesel oil from the polymer-slurries and other additives as discussed has reduced the potential environmental risk posed within US fracturing applications by about 7.5 million gallons per year, and that of BTEX chemistries by about 7,500 -75,000 gallons per year (assuming 0.1 - 1 % by volume content in diesel). Although the oil volumes associated with these products are significant in the context of the additives themselves, it should be recognized that in the blended systems pumped downhole, the oil is substantially diluted and typically accounts for less than 0.1% to as much as 0.3% of the fracturing fluid system compositions.

Priority Pollutant(s) Eliminated from Non-Emulsification Additives and Wellbore Preflushes

EPA listed priority pollutants as defined by the 1977 US Federal Clean Water Act were identified as the next target for elimination from fracturing additives. The list includes aromatic hydrocarbons such as naphthalene and the afore-mentioned BTEX chemistries in addition to heavy metals. Aromatic hydrocarbons have historically been used as solvents for removal of paraffin and asphaltene deposition in the near wellbore, as well as co-solvents in surfactant additive compositions, particularly non-emulsifiers (NEs). Fracturing treatments in oil-producing wells have commonly incorporated xylene or BTEX-containing diesel oil as a spearhead to clean the wellbore and perforations prior to introduction of the water-based treating fluid. This practice has been largely discontinued, but in wells where a spearhead is required, terpene-based solvent products are used instead of the older products. Terpenes are plant-based hydrocarbons derived from pine-oil or citrus materials, contain no priority pollutants, and are generally classified as environmentally acceptable.

The preferred non-emulsifier additive (NE-1) historically used by the company contained naphthalene, a priority pollutant at about @ 5 % volume. When subjected to the hazard assessment process, the score suggested that reformulation was desirable. Over 100,000 gallons of NEs are used monthly by the company in hydraulic fracturing applications, typically at loadings of 1 to 2 gallons per thousand gallons of water. Chemical suppliers were encouraged to submit a reformulated NE additive with a more favorable environmental profile (i.e. no priority pollutant content) and, at least comparable performance in a wide range of crude oils. With intense R&D, a supplier submitted a new NE product (NE-2) to Cardno-ENTRIX for the environmental hazard assessment, and to several regional labs for

performance evaluation. As shown in Figure 5, the hazard assessment on the proposed NE-2 additive compared very favorably relative the original NE-1 product, with a total score of 13.3 versus the 25.2 exhibited by NE-1. The NE-2 product was commercially released for fracturing applications in October 2010 and has currently displaced over 85% of the usage of the NE-1 additive. An alternative supplier recently submitted a new non-emulsifier (NE-3) with an even better hazard assessment of 3.6. The NE-3 has performed well in laboratory testing and was introduced within the commercial product line as the third-generation improved additive.

Non-emulsifier Product	NE-1	NE-2	NE-3
Environmental Criteria	9.3	3.9	1.5
Toxicological Criteria	10.9	6.9	2.1
Physical Hazards	5	2.5	0
Product Score	**25.1**	**13.3**	**3.6**

Figure 5. Hazard Assessment Rating of Non-Emulsifier Additive Products

The process being fostered is one of continuous improvement. Remaining usage of the NE-1 appears to be limited to applications where the new product does not provide the desired non-emulsifying performance or, where the pour points of the new products are unacceptable for cold weather climates.The NE-2 supplier has submitted a reformulation to further reduce the hazard assessment score by removing the nonylphenol component. Both suppliers have provided new, "winterized" formulations, which are currently being introduced in northern climes. It is anticipated that once the winterized formulations have been field proven, that the NE-1 product will be deleted from our product line.

EGMBE Eliminated from Surface Tension Reduction Surfactants and Polymer Slurries

Since the late 1970s the preferred surface tension reduction products were based upon fluorosurfactants, which were ultimately flagged for HSE concerns. A new breed of nonfluorocarbon surfactants was introduced in 2005 to alleviate those concerns and have proven to be quite effective for the intended purposes. The then new non-fluorocarbon surface tension reduction surfactant formulation, STRS-1, subsequently enjoyed wide-spread acceptance in hydraulic fracturing applications, averaging usage of over 25,000 gallons per month.

Ethylene glycol monobutyl ether (also known as EGMBE or 2-BE) is a mutual solvent that has been used within many fracturing fluid additive compositions, particularly surfactants for surface tension reduction, including the STRS-1 non-fluorcarbon surfactant commonly used to improve fluid recovery and post-frac cleanup. Recently, studies have suggested that EGMBE may be considered an endocrine disrupter (ED). Although evaluation standards for endocrine disrupters have not been established, the perceived risks posed by use within hydraulic fracturing resulted in recommendations for minimizing exposure to the material. Consequently, the two suppliers of STRS-1 surfactants were requested to reformulate the product without EGMBE. One supplier submitted a new product (STRS-2) reformulated simply by removing the EGMBE, with performance comparable to that of STRS-1. The STRS-2 was commercialized in October 2010 as an EGMBE-free replacement for the STRS-1. It should be noted that, as shown in Figure 6, the hazard assessment score was only slightly reduced, although neither was deemed as a significant hazard.

A second supplier submitted a reformulated product in which not only the EMGBE content, but also the methanol content was eliminated. Methanol is commonly used as a pour point suppressant within

formations with application in cold weather environments. As illustrated in Figure 6, the hazard assessment for the STRS-3 provided a total score of 5.3, better than either of the prior products. It should be noted that the majority of the score improvement due to removal of the methanol was in the "Physical Hazards" category (due to the MeOH flammability). The STRS-3 was also found to perform comparably to the widely used predecessors. The STRS-3 was introduced in October 2010; it and the STRS-2 have completely supplanted the use of the STRS-1. The supplier of the STRS-2 is currently being encouraged to remove the methanol from its formulation. With this effort EGMBE content has been essentially eliminated from the fracturing additive product line.

Surface Tension Reduction Product	STRS-1	STRS-2	STRS-3
Environmental Criteria	3	3.1	1.4
Toxicological Criteria	4.4	4.1	3.9
Physical Hazards	2.5	2.5	0
Product Score	**9.9**	**9.7**	**5.4**

Figure 6. Hazard Assessment Ratings of Surface Tension Reduction Products

Replacement of Quaternary Amine Salts for Clay Stabilization

Clay swelling or mobilization due to reservoir contact with water can be a significant concern during fracturing application with water-based fluids. Since the inception of water-based fluid fracturing, potassium chloride (KCl) has been widely used, to provide clay control. Liquid quaternary amine salts such as tetramethyl ammonium chloride (TMAC, labeled as CS-2) were introduced in the mid-1980s as "KCl-substitutes" to better facilitate continuous-mix fracturing operations. In most reservoir mineralogy's, the CS-2 employed at 0.2% by volume was observed to be an adequate performance replacement for KCl, which was most commonly used at 2% by weight (167 lb/Mgal). Liquids are typically considered easier to handle than particulates, and in combination with significantly lower volumes required for 'equivalent' clay control performance, the CS-2 came to be preferred both logistically and economically. The hazard assessment scores for those additives are shown in Figure 7, with the KCl product designated as CS-1. Although environmental characteristics were not a significant factor in the consideration to convert from CS-1 to CS-2, CS-2 used at 2 gallons per thousand (gpt) is environmentally preferable to 2% KCl due to the relatively large volumes required.

Since the use in water-based fracturing operations has become so large (+/- 2,000,000 gal/yr in US applications), CS-2 and some known clay control additive alternatives were subject to the hazard assessment process. The CS-2 exhibited a score of 7.5, which in most circumstances would have qualified it as a preferred chemistry for that application. An alternative product, however, received a hazard assessment score of 0, or environmentally benign. The alternative material, CS-3, is an aqueous solution of choline chloride. The United States FDA recommends human consumption of 1,000 mg per day of choline chloride, and it is widely used as an additive to animal feeds. The 'perfect' rating of the CS-3 dictated more in-depth consideration as the primary clay control additive for fracturing.

Comparative laboratory testing in several shales showed the clay stabilization performance of choline chloride, TMAC, and KCl to be essentially equivalent. With the higher costs being the only remaining hurdle, supply of the product was successfully sourced in large volume at pricing only marginally higher than the TMAC, but significantly reduced from previous experiences. Consequently, CS-3 was commercially introduced as the preferred clay control additive in October 2010.

Clay Stabilizer Product	CS-1	CS-2	CS-3
Environmental Criteria	0	2.5	0
Toxicological Criteria	2.5	5	0
Physical Hazards	0	0	0
Product Score	**2.5**	**7.5**	**0**

Figure 7. Hazard Assessment Ratings for Clay Control Additives

Progress to Utilization of More Environmentally Responsible Fracturing Additives & Systems

A primary objective of the current effort is to quantify progress towards utilization of more environmentally responsible fracturing processes by quantifying hazardous risk 'removed' from applications, i.e. amount of hazardous material removed by replacement with more favorable alternatives. Success in achieving the objective of conducting hydraulic fracturing treatments using additives containing only environmentally safe chemistries may be estimated by the comparing the volume of the hazard process qualified products to the total volume of all fracturing additives employed.

A 'menu' of qualified fracturing additive products vetted, developed and selected using the hazard assessment process, intra-additive compatibility, and functional performance was commercially introduced in October 2010. For purposes of this paper, additive usage for the fracturing company's US division were audited for the period ending on September 30, 2011, providing the opportunity to quantify the market uptake of the hazard assessment qualified products for one full year.

Over the course of one year, as shown in Figure 8, the 83.4% of the NE-1 usage has been replaced with the more favorable NE-2 and NE-3 products. It is anticipated that winterized versions of the NE-2 and NE-3 products currently being introduced will substantially replace the balance of the NE-1 usage. CS-3, the choline chloride, has replaced 99.3 % of the CS-2 usage (TMAC) since its classification in mid-2010 as the more environmentally favorable temporary clay control additive alternative, as illustrated in Figure 9.

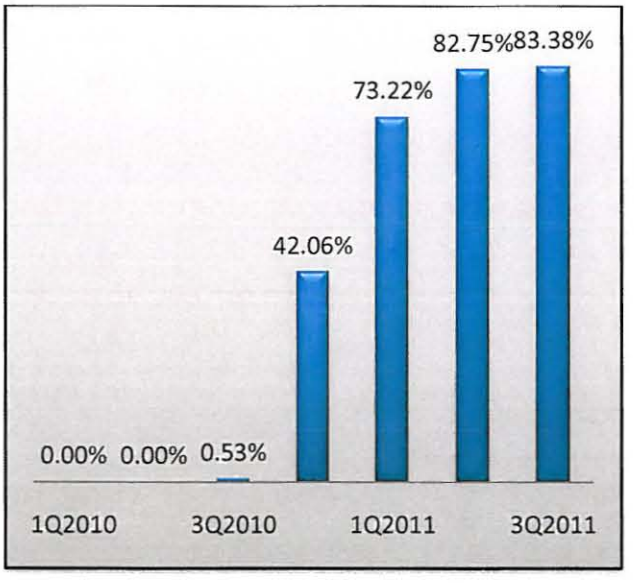

Figure 8. US Market Usage of NE-2 + NE-3 Products as % all NE usage for fracturing applications

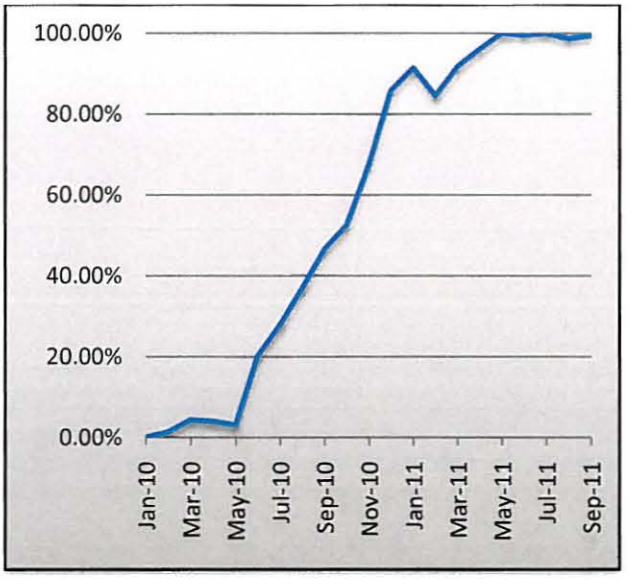

Figure 9. US Usage of CS-3 Temporary Clay Control Products as a % of total CS product usage

As originally introduced in October 2010, the menu was comprised of 59 fracturing products, 12 of which were formulated with new, or repurposed additive chemistries and introduced with the roll-out in the fall of 2010, and another 11 of which had been introduced in the past 3 years (2008 – 2010). An audit of the fracturing additives employed during the first quarter of 2011 in the company's onshore US hydraulic fracturing services was studied to make the comparisons. The data are reported in gross percentages of the total fracturing additives used. The reported information excluded proppant, nitrogen, and acid volumes used during the period since inclusion of such large commodity volumes would cloud any conclusions with respect to the additive chemistries of concern.

As defined, the cumulative volume of all hydraulic fracturing additives employed represents the baseline for comparison (100%). Recall that among the 59 qualified additives 36 products had been in use for greater than 3 years. During the first nine months of 2011, those products accounted for 18.5% of the total volume of products employed fracturing treatments, as illustrated in the left-hand bar within Figure 10. Eleven qualified products were introduced in the 2008-2009 period, including the mineral oil-based polymer slurries that replaced diesel-based slurries in 2008. Use of those products accounted for 45.1% of the total. Cumulatively with the products introduced pre-2008, 63.6% of all fracturing products employed would have been hazard assessment qualified had the process been in place at that time.

Four new and subsequently hazard assessment qualified products were introduced in 2010 prior to the October 2010 introduction of the qualified additive product line. These accounted for 9.2% of the total pumped at the end of the audit period. These data show that as of October 2010, 72.8% of fracturing products employed were hazard assessment qualified materials. The 8 qualified additives with new or re-purposed chemistries that were introduced in October 2010 accounted for 12.7% of the total fracturing products pumped as of a March 2011 usage audit. In that those products were new to the market for only three months before the audit period, the degree market adaption experienced in such a short period of time is evidence of remarkable success. Since the March 2011 audit, newly qualified product additions have contributed to increase the volume of the post-October 2010 qualified product additions to 17.2%.

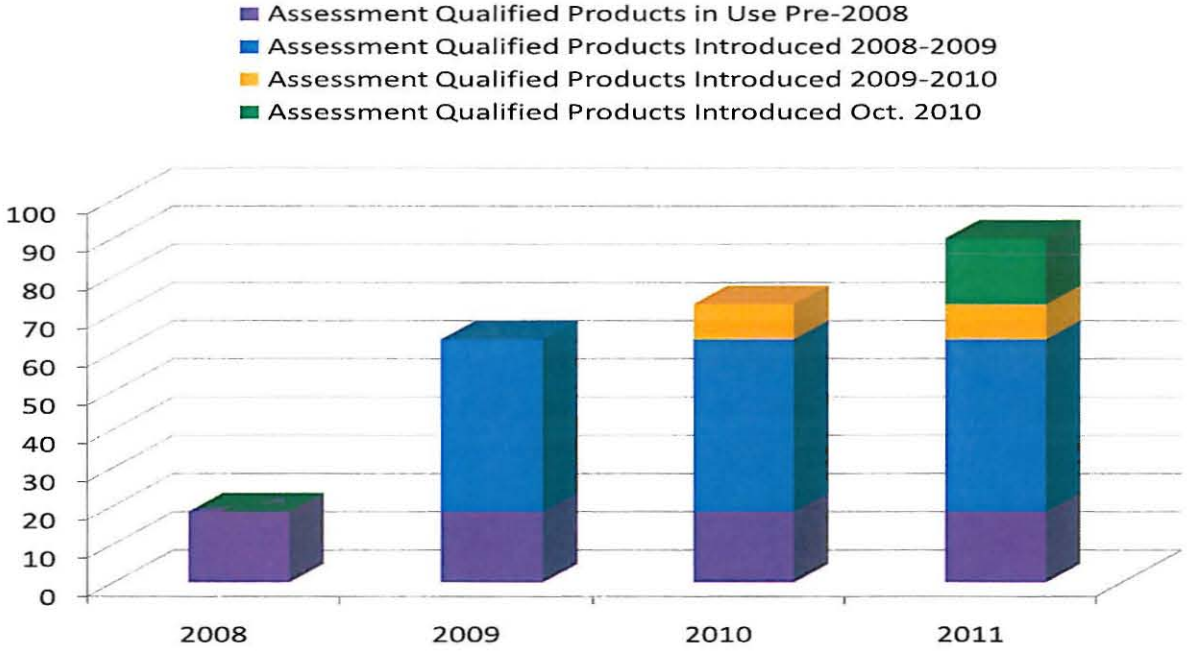

Figure 10. Hazard Assessment Qualified Products Used as a Percent of the Total Products Employed During the October 2010 – September 2011 Period.

A fracturing product utilization audit for the period ending September 30, 2011 disclosed that environmentally preferable additives qualified via the hazard assessment process accounted for 90.05% of all fracturing additives used in the USA, exclusive of proppant, nitrogen, and bulk acid.

Many commercial fracturing products have not yet been subjected to the hazard assessment process, thus it should be noted the presented quantifications undercount the volume of environmentally acceptable products employed. Recall, processing priority given to those materials believed to pose the greatest risk due to known or anticipated chemistries and/or, high volume use increasing exposure. As a result, many, if not most, of the fracturing products yet to be qualified are expected to be acceptable when they undergo formal assessment. Among those products yet to be subjected to the qualification process, for example, are enzyme-based breakers, citric acid and sodium erythorbate-based iron control solutions, powdered guar polymer products used in lieu of polymer slurries, and oxidative salts such as the sodium hypochlorite and sodium persulfates used for water sanitization or as gel breakers, respectively. These materials collectively account for a significant volume of the total product used during the audited period, but despite posing minimal environmental risk were not included in the '90% qualified category' due to their not having documented qualification assessments in place. The remaining fracturing additives are being regularly submitted for hazard assessments following the previously described prioritizations, and as additional materials are qualified they will be included in the accounting.

The environmental hazard assessment of product chemistries and the associated product improvement process has resulted in substantial volumes of hazardous material removed from fracturing processes through replacement with more favorable alternatives. These changes reduced environmental footprint and removed of substantially reduced risk from fracturing operations. Whereas it would be very difficult to quantify a definitive volume of all hazardous materials removed, the preceding discussions can provide some specifics for consideration. Assuming comparable additive use to that observed in the audit, the 2008 commitment to exclusive use of diesel-free polymer slurries and friction reducer products resulted in the elimination +/- 10 million gallons per year of diesel oil from fracturing applications. Replacing diesel oil preflushes with non-hazardous alternative chemistries such as mineral oil or terpene systems removed +/- 1.6 million gallons per year, and the 2010 conversion of all diesel oil in other fracturing additives reduced the exposure by an additional one million gallons per year. Collectively, based upon the assumptions above, perhaps 14 million gallons per year of diesel oil have been eliminated from subterranean injection in US fracturing applications. It should again be noted, however that when these materials were employed in water-based fracturing applications, they were typically diluted on the order of 100:1 up to 1000:1 with base water.

Other than the BTEX present in diesel oil, the predominant priority pollutants previously used in the fracturing product line were xylene, pumped occasionally to prepare wellbores susceptible to paraffin or asphaltene deposition for the water-based fracturing fluids, and naphthalene, as a constituent of non-emulsifier formulations. Replacing the xylene preflushes and removing the naphthalene content from non-emulsifiers have reduced the potential for exposure from within fracturing application by about 1.5 million gallons per year.

Process of Continous Improvement of the Hazard Assessment Tool

The Hazard Assessment Tool continues to an integral component of our Research and Development efforts associated with environmentally responsible chemical development for hydraulic fracturing products. Examination of the system with respect to currently established regulatory condition may require further modification in the future. Some areas will be addressed in further work to develop the tool, under study at the time of writing, and will include increased use of globally accepted and/or region specific list based elements; management of generated data and communication tools.

Conclusions

A hazard assessment process based upon the Globally Harmonized System for Classification and Labeling of Chemicals in addition to elements of the United States EPA; VOC and Priority Pollutants Lists has been adopted to standardize information regarding the hazards and toxicities of chemicals.

The process provides scientifically-based quantification of the hazards posed by various treating additives and potential alternatives with the objective of reducing risks of each hydraulic fracturing additive and by extension, the entire treating fluid systems. Ratings or scores of individual additives can be compared with like-purposed additives for their respective safety, health, environmental and total hazard risk. The quantified knowledge of the most preferred chemistries from an environmental perspective combined with reasoned consideration of performance and cost provides clearly justified selection of the most preferred additive options for product line inclusion.

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The process has developed into a valuable tool to guide fracturing product line management, applied chemical R&D, and chemical suppliers toward continuous development of more environmentally acceptable products and systems. The chemical evaluation process continues to expand in scope and purpose.

A highly flexible menu of fracturing additive products environmentally qualified using the hazard assessment process, intra-additive compatibility, and functional performance was formally introduced commercially in October 2010. An audit of product utilization at the end of the first calendar year post-offering disclosed that hazard assessment-qualified fracturing additives comprised greater than 90% of total volume of fracturing additives employed in the US market.

The flexibility of the qualified products offer allows operators ability to select hazard-assessment qualified product to formulate fluid systems having performance characteristics to meet their stimulation objectives, meaning that operators don't need to sacrifice well performance to achieve their environmental goals.

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