OUR DRINKING WATER AT RISK

What EPA and the Oil And Gas Industry Don't Want Us to Know About Hydraulic Fracturing

OIL & GAS ACCOUNTABILITY PROJECT

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Acknowledgements

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All views and opinions expressed in this report are those of OGAP, and do not necessarily reflect the views of reviewers or funders. Any errors are the responsibility of OGAP.

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Cover photo of hydraulic fracturing operation: Peggy Utesch.

About the Oil & Gas Accountability Project

OGAP is the only organization in the United States with the sole mission of working with tribal, urban and rural communities to protect their homes and the environment from the devastating impacts of oil and gas development. In our five-year history, we have succeeded in building alliances with economically, racially and politically diverse constituencies. By bringing together such diverse partners as Native Americans, ranchers and environmentalists to work towards a common –and critically important– goal, their ability to voice their concerns and work to lessen impacts has increased.

OGAP's multi-tiered approach involves people who are directly affected by the impacts of oil and gas development in working for strong reforms. Our campaign strategies include media, public education and community organizing components.

OGAP coordinates four program areas: Citizen and Community Support; Governmental Reform; Best Practices; and Public Health and Toxics.

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List of Acronyms and Abbreviations

AFL-CIO	American Federation of State, County and Municipal Employees
AOR	area of review
BLM	Bureau of Land Management (U.S.)
BTEX	benzene, toluene, ethylbenzene and xylene
CBM	coalbed methane
CO_2	carbon dioxide
DOE	Department of Energy (U.S.)
EPA	Environmental Protection Agency (U.S.)
GAO	Government Accountability Office (previously U.S. General Accounting Office)
GRI	Gas Research Institute
GC/MS	gas chromatography and mass spectrometry
MCL	Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
MOA	Memorandum of Agreement
MSDS	Material Safety Data Sheet
NSJB	Northern San Juan Basin
OGAP	Oil and Gas Accountability Project
OGB	Oil and Gas Board (Alabama)
OSHA	Occupational Safety and Health Association
PAH	polycyclic aromatic hydrocarbons
RBC	Risk-based Concentration
UIC	Underground Injection Control
USDW	underground source of drinking water
USGS	U.S. Geological Survey
VDMR	Virginia Division of Mineral Resources
Mcf	thousand cubic feet
μg/l	micrograms per liter

Executive Summary

Hydraulic fracturing is a common technique used to stimulate the production of oil and natural gas. Typically, fluids are injected underground at high pressures, the formations fracture, and the oil or gas flows more freely out of the formation. Some of the injected fluids remain trapped underground. A number of these fluids qualify as hazardous materials and carcinogens, and are toxic enough to contaminate groundwater resources.

There are a number of cases in the U.S. where hydraulic fracturing is the prime suspect in incidences of impaired or polluted drinking water. In Alabama, Colorado, New Mexico, Virginia, West Virginia and Wyoming, incidents have been recorded in which residents have reported changes in water quality or quantity following fracturing operations of gas wells near their homes. Natural gas development is booming in the U.S., particularly coalbed methane (CBM) development; hundreds of companies are looking to drill for CBM wherever there are viable deposits of coal. In at least ten states (Alabama, Arkansas, Colorado, Kansas, Montana, New Mexico, Virginia, Washington, West Virginia and Wyoming), these coal formations contain drinking water aquifers.

According to the Interstate Oil and Gas Compact Commission, 90 percent of oil and gas wells in the U.S. undergo fracturing to stimulate production.[1] Despite the widespread use of the practice, and the risks hydraulic fracturing poses to human health and safe drinking water supplies, the U.S. Environmental Protection Agency ("EPA") does not currently regulate the injection of fracturing fluids under the *Safe Drinking Water Act*. The oil and gas industry is the only industry in America that is allowed by EPA to inject hazardous materials –unchecked– directly into or adjacent to underground drinking water supplies.

In 1997, the U.S. Court of Appeals for the 11th Circuit (Atlanta) ordered the EPA to regulate hydraulic fracturing under the *Safe Drinking Water Act*. This decision followed a 1989 CBM fracturing operation in Alabama that resulted in the contamination of a residential water well.

In 2000, in response to the 1997 court decision, the EPA initiated a study of the threats to water supplies associated with the fracturing of coal seams for methane production. The primary goal of the study was to assess the potential for fracturing to contaminate underground drinking water supplies. The EPA completed its study in 2004, finding that fracturing "poses little or no threat" to drinking water. The EPA also concluded that no further study of hydraulic fracturing was necessary.[2]

Meanwhile, in 2001, a special task force on energy policy convened by Vice President Dick Cheney recommended that Congress exempt hydraulic fracturing from the *Safe Drinking Water Act*. The National Energy Bill currently pending before the U.S. Congress includes this exemption. If the energy bill passes with the exemption intact, states, municipalities and individual property owners will have to bear the burden of the cleanup costs, health risks

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[1] Testimony Submitted To The House Committee On Energy And Commerce By Victor Carrillo, Chairman, Texas Railroad Commission, Representing The Interstate Oil And Gas Compact Commission. February 10, 2005. http://www.rrc.state.tx.us/commissioners/carrillo/press/energytestimony.html

[2] U.S. Environmental Protection Agency (EPA). June, 2004. *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*. EPA Document# 816-R-04-003. pp. 1-3. http://www.epa.gov/safewater/uic/cbmstudy.html

and loss of property values associated with ground water contamination caused by hydraulic fracturing.

The 2004 EPA study has been called "scientifically unsound" by EPA whistleblower Weston Wilson.[3] In an October 2004 letter to Colorado's congressional delegation, Wilson recommended that EPA continue investigating hydraulic fracturing and form a new peer review panel that would be less heavily weighted with members of the regulated industry.[4] In March of 2005, EPA Inspector General Nikki Tinsley found enough evidence of potential mishandling of the EPA hydraulic fracturing study to justify a review of Wilson's complaints.[5]

The Oil and Gas Accountability Project (OGAP) has conducted a review of the EPA study. We found that EPA removed information from earlier drafts that suggested unregulated fracturing poses a threat to human health, and that the Agency did not include information that suggests fracturing fluids may pose a threat to drinking water long after drilling operations are completed. OGAP's review of relevant data on hydraulic fracturing suggests that there is insufficient information for EPA to have concluded that hydraulic fracturing does not pose a threat to drinking water.

OGAP's Main Findings

Hydraulic fracturing fluids contain toxic chemicals.

The EPA states that many chemicals in hydraulic fracturing fluids are linked to human health effects. These effects include cancer; liver, kidney, brain, respiratory and skin disorders; birth defects; and other health problems. The draft EPA study included calculations showing that even when diluted with water at least nine hydraulic fracturing chemicals may be injected into USDWs at concentrations that pose a threat to human health. These chemicals are: benzene, phenanthrenes, naphthalene, 1-methylnapthalene, 2-methylnapthalene, fluorenes, aromatics, ethylene glycol and methanol. This important information was removed from the final study.

Chemicals are injected directly into drinking water aquifers.

Some geological formations contain groundwater of high enough quality to be considered underground sources of drinking water. According to EPA, ten out of eleven coalbed methane basins in the U.S. are located, at least in part, within USDWs, and EPA determined that in some cases, hydraulic fracturing chemicals are injected directly into USDWs during the course of normal fracturing operations. Additionally, even if hydraulic fracturing does not occur directly in USDWs, it is possible that USDWs adjacent to hydraulically fractured formations may become contaminated by fracturing fluids. EPA cited a study conducted in six U.S. states, which found that in 50% of CBM hydraulic fracturing stimulations the fracturing fluids moved out of the coals and into adjacent formations.

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[3] Wilson, W. October 8, 2004. Letter to Senators Allard, Campbell and Representative DeGette. Available on the Oil and Gas Accountability web site: http://www.ogap.org/resources/wes_wilson_letter.pdf

[4] ibid.

[5] Alan C. Miller and Tom Hamburger. March 17, 2005. "EPA Watchdog to Investigate Drilling Method." *Los Angeles Times.*

Hydraulic fracturing company recommends that unused fluids be disposed of as hazardous waste.

The hydraulic fracturing company Schlumberger recommends that many of its fracturing fluids be disposed of at hazardous waste facilities. Yet these same fluids are allowed to be injected directly into or adjacent to USDWs. Under the *Safe Drinking Water Act* no other industries are allowed to inject hazardous wastes –unchecked-directly into USDWs. EPA does not provide any scientific data to demonstrate that the hazardous characteristics of fracturing fluids are reduced enough to make it safe to inject these chemicals into or close to USDWs.

Citizens from across the country have been affected by hydraulic fracturing.

Citizens from Colorado, New Mexico, Virginia, West Virginia, Alabama and Wyoming have reported changes in water quality and quantity following hydraulic fracturing operations. Common complaints include: murky or cloudy water, black or gray sediments, iron precipitates, soaps, black jelly-like grease, floating particles, diesel fuel or petroleum odors, increased methane in water, rashes from showering, gassy taste and decrease or complete loss of water flow. In most cases, the agencies conducting follow-up water quality sampling do not know what chemicals have been used in fracturing operations because companies are not required to disclose this information. Consequently, state agencies and EPA do not test for all fracturing fluid chemicals. Citizens have also experienced soil and surface water contamination from spills of hydraulic fracturing fluids.

Some contamination may not show up for decades.

When wells are hydraulically fractured, a portion of the fracturing fluids remains stranded in the target formation. In some areas, hundreds or thousands of wells are hydraulically fractured, often multiple times. At least two hydrogeologists wrote to EPA expressing concern that as groundwater tables rise (post oil or gas development), the groundwater could mobilize these stranded fluids. EPA does not address this issue in its study.

EPA ruled out further study despite huge gaps in scientific data.

The EPA study is essentially a scientific literature review. What becomes clear from reading EPA's study is that there are huge gaps in data on fracturing fluid toxicity, fracture behavior, quantities of fracturing fluid left stranded in the formation, chemical fate and transport of fracturing fluids trapped underground, and groundwater quality following fracturing events. Given the dearth of information, it is irresponsible to conclude that hydraulic fracturing of coal beds or any other geological formations does not pose a risk to drinking water and human health. Yet this is exactly what EPA does.

EPA's findings absolutely support the need to continue to Phase II of the study.

In its study methodology, EPA stated that it would not conduct Phase II of the study if the investigation found that: 1) No hazardous constituents were used in fracturing fluids; 2) Hydraulic fracturing did not increase the hydraulic connection between previously isolated formations; and 3) Reported incidents of water quality degradation could be attributed to other, more plausible causes. As mentioned above, the EPA found that there are numerous hydraulic fracturing chemicals that are toxic or hazardous in their pure and diluted forms. It has been shown that fractures and fracturing fluids move out of targeted formations. And while EPA was unable to find conclusive evidence to directly link citizen water quality concerns with hydraulic fracturing, this in itself does not prove that harm has not occurred or will not occur. The data that are available support the need to continue evaluating the environmental and human health risks posed by hydraulic fracturing.

OGAP's Recommendations

1. **Further study of the effects of hydraulic fracturing on underground sources of drinking water should be conducted.**

   EPA should continue with Phase II of its hydraulic fracturing study to verify the Agency's scientifically unsubstantiated assertion that no harm has occurred or will occur from hydraulic fracturing practices. The study design should be broadened to include impacts related to hydraulic fracturing of all types of oil and gas formations—not just coalbed methane.

2. **EPA should develop hydraulic fracturing regulations under the *Safe Drinking Water Act*.**

   Under the *Safe Drinking Water Act*, EPA and EPA-authorized states are required to have effective programs to prevent underground injection of fluids from endangering USDWs. At the present time, there are no federal regulations and very limited state regulations governing hydraulic fracturing. In all but one state, Alabama, the oil and gas industry is allowed to inject hazardous chemicals directly into drinking water sources. Clearly, EPA is not fulfilling its responsibility of protecting our nation's drinking water.

3. **Hydraulic fracturing <u>should not</u> be exempted from the *Safe Drinking Water Act*.**

   Approximately half of the water that Americans rely on for drinking comes from underground sources. It is in the public interest to ensure –with a very high degree of certainty– that any substances that are injected underground do not pose a threat to drinking water quality and human health. The EPA study does not provide adequate scientific proof that hydraulic fracturing does not pose a threat to drinking water. Exempting the practice from the *Safe Drinking Water Act* could result in long-term contamination liability for oil and gas companies, and for the American public.

4. **Until they can be proven safe, all potentially toxic substances should be eliminated from fracturing fluids.**

   Unless companies can produce data to prove that fracturing fluid constituents and mixtures of fracturing fluids do not pose a threat to human health when injected underground, the chemicals and mixtures should be banned from hydraulic fracturing operations. This includes requiring all companies to stop using diesel fuel as a constituent in hydraulic fracturing fluids.

5. **Public accountability mechanisms should be put in place.**

   EPA and state agencies should require that companies disclose all of the chemicals used in hydraulic fracturing operations, and agencies should track what substances are being injected, where injection into is occurring, and where the safety of USDWs may be threatened. All of this information should be made available to the public.

1. Introduction

Hydraulic fracturing is a technique used to stimulate oil and gas production from conventional oil and gas wells, as well as from nonconventional oil and natural gas sources (e.g., coalbed methane, tight sands). Typically, it involves high pressure injection of water, sand and chemicals into underground geological formations, which causes the formations to fracture. The fractures are held open by the sand, thus allowing more oil or gas to flow to the production well.

In 2000, the U.S. Environmental Protection Agency ("EPA" or "the Agency") launched a study to evaluate the environmental risks posed by the hydraulic fracturing of coal beds (the study did not examine fracturing of any other type of conventional or nonconventional oil or gas formations). Hydraulic fracturing is used in many coalbed methane (CBM) production areas. The potential problem with fracturing coal beds is that many coal beds contain groundwater of high enough quality to be used as drinking water (and are referred to as "underground sources of drinking water" or "USDWs"). A primary concern is that hydraulic fracturing may contaminate USDWs, which would waste a precious resource and endanger human health.

Hydraulic fracturing fluids typically contain a host of chemicals used to optimize the fracturing. These additives include gels, polymers, biocides, fluid loss agents, thickeners, enzyme breakers, acid breakers, oxidizing breakers, friction reducers, and surfactants. Some of these chemicals are toxic in their pure form.[6] It is not known how toxic these chemicals are when mixed together, diluted and injected into groundwater-bearing formations.

EPA has determined that in some cases, hydraulic fracturing chemicals are injected directly into USDWs during the course of normal CBM fracturing operations.[7] Not all coal formations are USDWs, but according to EPA ten out of eleven CBM basins in the U.S. are located, at least in part, within USDWs.[8] The co-location of coalbeds and USDWs is known to occur in Alabama, Arkansas, Colorado, Kansas, Montana, New Mexico, Virginia, Washington, West Virginia and Wyoming, and possibly occurs in Nebraska, Pennsylvania and Kentucky.[9]

In some parts of CBM basins, coal beds may not be USDWs, but they may be located adjacent to rock formations that contain useable sources of drinking water. It is possible that USDWs adjacent to hydraulically fractured coal formations may become contaminated by fracturing fluids. A study conducted in six U.S. states found that in 50% of coal bed hydraulic fracturing stimulations the fracturing fluids moved out of the coal and into adjacent formations.[10]

The *Safe Drinking Water Act* is designed to protect underground drinking water sources from contamination caused by underground injection of fluids. Under the *Safe Drinking*

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6 U.S. Environmental Protection Agency (EPA). June, 2004. *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*. EPA Document# 816-R-04-003. pp. 4-5. http://www.epa.gov/safewater/uic/cbmstudy.html (Hereafter referred to as U.S. EPA. June, 2004.)

7 U.S. EPA. June, 2004. p. ES-1.

8 U.S. EPA. June, 2004. Page ES-13.

9 U.S. EPA. June, 2004. Chapter 5. "Summary of Coalbed Methane Basin Descriptions."

10 U.S. EPA. June, 2004. p. 3-17.

Water Act, the EPA and EPA-authorized states are required to have effective programs to prevent underground injection of fluids from endangering USDWs.[11]

In 1997, the United States Court of Appeals (Eleventh Circuit) ruled in LEAF v. EPA that hydraulic fracturing fluid activities constitute underground injection under Part C of the *Safe Drinking Water Act*.[12] Following the Eleventh Circuit Court's decision, EPA expressed the need for additional information before the Agency could make any further regulatory or policy decisions regarding hydraulic fracturing.[13]

As mentioned above, in 2000, EPA launched Phase I of a study to assess the potential for contamination of USDWs from the hydraulic fracturing of CBM wells. Based on the Phase I findings, EPA would determine whether or not further study (i.e., Phase II) was warranted.[14]

In June, 2004, EPA released the final version of its study *Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs* ("hereafter referred to as "the study" or "the EPA study.") The main finding of the EPA study is that "the injection of hydraulic fracturing fluids into CBM wells poses little or no threat to Underground Sources of Drinking Water."[15] Based on this finding, EPA concludes that further study of the issue is not warranted.

The EPA study has been criticized by EPA staff and federal legislators. In October, 2004, an EPA whistleblower, Weston Wilson, risked his job in order to express his deep concern about the inadequacy of the EPA hydraulic fracturing study. Wilson called the study "scientifically unsound," and recommended that the Agency conduct additional studies and also form a peer review panel that is not composed of reviewers who have conflicts of interest (e.g., who work for the and gas industry or hydraulic fracturing companies).[16]

Similar criticisms have been expressed by several members of Congress in letters to the EPA Administrator (Michael Leavitt) and EPA Inspector General (Nikki Tinsley).[17] In March of 2005, these concerns prompted Inspector General Tinsley to undertake a review of Wes Wilson's complaints.[18]

The Oil and Gas Accountability Project ("OGAP") has thoroughly reviewed the EPA study. Like those mentioned above, OGAP challenges EPA's conclusions. As outlined in this report, EPA does not provide sufficient data to convincingly demonstrate that hydraulic fracturing does not pose a threat to drinking water. By refusing to study this issue further, EPA is avoiding its obligation to protect drinking water supplies, as required of the Agency under the *Safe Drinking Water Act*.

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[11] Endangerment is defined as: "Underground injection endangers drinking water sources if it may result in the presence of any contaminant in underground water that supplies (or can reasonably be expected to supply) any public water system, and if the presence of such a contaminant may result in such system's noncompliance with any national primary drinking water regulation or may otherwise adversely affect the health of persons." (U.S. EPA. June, 2004. p. ES-7.)

[12] LEAF v. EPA, 118 F. 3d 1467 (11th Cir. 1997).

[13] U.S. EPA. June, 2004. p. 1-3.

[14] ibid. p. 2-1

[15] U.S. EPA. June, 2004. p. ES-16.

[16] Wilson, W. October 8, 2004. Letter to Senators Allard, Campbell and Representative DeGette. Available on the Oil and Gas Accountability web site: http://www.ogap.org/resources/wes_wilson_letter.pdf

[17] Tom Hamburger and Alan C. Miller. October 15, 2004. "Investigation of Drilling Regulations is Urged." *Los Angeles Times.*

[18] Alan C. Miller and Tom Hamburger. March 17, 2005. "EPA Watchdog to Investigate Drilling Method." *Los Angeles Times.*

2. Fracturing Fluids: some are hazardous

What are the chemical constituents of hydraulic fracturing fluids? Are these fluids injected into USDWs at concentrations that are harmful to humans? Do hydraulic fracturing fluid chemicals break down into products that are non-toxic or more toxic to humans? These are questions of great concern to members of the public, especially those living with oil or gas operations on their property or in their communities. As will be elaborated below, there are many problems with EPA's investigation into hydraulic fracturing fluids. Consequently, OGAP does not believe EPA has enough information to conclude that hydraulic fracturing fluids do not pose a threat to water quality and human health.

2.1 Some hydraulic fracturing fluids are hazardous to human health

From information contained in the EPA study, and through *Freedom of Information Act* (FOIA) documents that OGAP received from EPA, it is clear that some of the fracturing fluids injected into USDWs are considered to be hazardous. Some of the chemicals used are known to be toxic to human beings, both in their pure form, and at their injected concentrations. In most other circumstances these mixtures of chemicals would not be allowed to be injected into USDWs.[19]

2.1.1 In their pure form, numerous fracturing fluid chemicals are toxic to humans.

Fracturing fluids and their additives are mixtures of a variety of chemicals and water. The EPA study lists general health effects related to a number of fracturing fluids and additives. The health effects range from eye, skin, respiratory, internal organ and reproductive disorders, to cancer.[20]

The Argonne National Laboratory reports that several chemicals used during hydraulic fracturing operations (i.e., biocides, corrosion inhibitors, breakers, organic components such as benzene and naphthalene) "can be lethal at levels as low as 0.1 parts per million."[21] This paper is not cited by EPA.

EPA summarizes the health hazard information collected by the Agency in a table entitled "Characteristics of Undiluted Chemicals Found in Hydraulic Fracturing Fluids (Based on MSDSs)."[22] The Agency states that the information in this table refers to a pure, undiluted product. Thus, the toxicity information presented in EPA's study is more relevant to oil and gas industry workers, who may be exposed to pure hydraulic fracturing fluids, than to members of the public who may be exposed to a diluted form of the fracturing fluids in drinking water.

Two out of fifteen fracturing fluids and additives listed in the EPA table are provided in Table 1 (on the following page) as an example of the information presented in the EPA study.

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[19] For more information, see Section 5.4.1 of this report.

[20] U.S. EPA. June, 2004. p. 4-9. Table 4-1.

[21] J.A. Veil, M.G. Puder, D. Elcock and R.J. Redweik Jr. 2004. *A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas and Coalbed Methane.* Prepared for U.S. Department of Energy by Argonne National Laboratory. pp. 7,8. http://www.ead.anl.gov/pub/dsp_detail.cfm?PubID=1715

[22] U.S. EPA. June, 2004. p. 4-9. Table 4-1.

TABLE 1. EXAMPLES OF TOXICOLOGICAL INFORMATION PRESENTED IN EPA STUDY.

Product	Composition	Hazards	Toxicological Information
Linear Gel Delivery System	30-60% by wt. Guar gum derivative 60-100% by wt. Diesel	Harmful if swallowed Combustible	Chronic effects / Carcinogenicity (contains diesel, a petroleum distillate and known carcinogen); causes eye, skin, respiratory irritation; can cause skin disorders; can be fatal if ingested
Crosslinker	10-30% Boric Acid 10-30% Ethylene Glycol 10-30% Mono-ethanolamine	Harmful if swallowed Combustible	Chronic effects / Carcinogenicity (may cause liver, heart, brain, reproductive system, kidney damage, birth defects - embryo and fetus toxicity); causes eye, skin, respiratory irritation; can cause skin disorders and eye ailments

Given that hydraulic fracturing chemicals are being injected directly into USDWs,[23] it is crucial to know the concentrations of these chemicals in drinking water, and at what concentrations health effects may occur. Yet the EPA study does not include this information. (For more information on this topic, see Sections 2.3.2 and 3.1.3 of this report.)

2.1.2 Company information shows that many fracturing fluid chemicals should be disposed of at hazardous waste facilities. EPA does not include this information in the study.

When companies have an excess of hydraulic fracturing fluids, they either use them at another job or dispose of them. (See Section 2.3.5.) A few companies provided EPA with Material Safety Data Sheets (MSDSs), which OGAP received through a *Freedom of Information Act* request.[24]

Some of the MSDSs include information on disposal options for fracturing fluids and additives. Table 2 summarizes the disposal considerations that the company Schlumberger Technology Corp. ("Schlumberger") includes in its MSDSs. This information is not included in the EPA study.

As seen in Table 2, Schlumberger recommends that many fracturing fluid chemicals be disposed of at hazardous waste facilities. Yet these same fluids (in diluted form) are allowed to be injected directly into or adjacent to USDWs. Under the *Safe Drinking Water Act*, hazardous wastes may not be injected into USDWs.[25] Moreover, even if hazardous wastes are diluted with water so that the hazardous characteristics of the fluids are removed, the wastes still cannot be injected into USDWs. (See section 5.4.1

[23] U.S. EPA. June, 2004. p. ES-1.

[24] In October of 2004, OGAP filed a *Freedom of Information Act* request with EPA to obtain the Material Safety Data Sheets (MSDS) supplied to the agency by hydraulic fracturing companies. (*Freedom of Information Act*, 5 U.S.C. 552, Request Number HQ-RIN-00044-05).

[25] According to EPA's *Underground Injection Control Regulations:* **Class I wells,** "shall be sited in such a fashion that they inject into a formation which is beneath the lowermost formation containing, within one quarter mile of the well bore, an underground source of drinking water," (40 CFR Ch. 1 §146.12) and, "in no case shall injection pressure initiate fractures in the confining zone or cause the movement of injection or formation fluids into an underground source of drinking water." (40 CFR Ch. 1 §146.13) For both **Class II and III wells**, "In no case, shall injection pressure initiate fractures in the confining zone or cause the migration of injection or formation fluids into an underground source of drinking water." (40 CFR Ch. 1 §146.23 and §146.33). **Class V wells,** "inject non-hazardous fluids into or above formations that contain underground sources of drinking water." [emphasis added] (40 CFR Ch. 1 §146.51) **Class IV wells** allow for the injection of hazardous waste directly into USDWs, BUT these wells have been banned. (EPA. 2002. *Protecting Drinking Water through Underground Injection Control.* Drinking Water Pocket Guide #2. EPA 816-K-02-001. p.7)

of this report for a discussion on the injection of hazardous and nonhazardous wastes.)

TABLE 2. RECOMMENDED DISPOSAL OPTIONS ACCORDING TO SCHLUMBERGER'S MSDSs.

Hydraulic fracturing fluids or additive	Recommended Disposal
Foaming Agent F104 Corrosion Inhibitor A186 Organic Acid L36 Chelating Agent Liquid Breaker Aid J318 Breaker J218 Biocide B69 PSG Polymer Slurry J877	Hazardous waste disposal facility.
Water Gelling Agent J424	Hazardous waste landfill, incineration, or sanitary landfills in some jurisdictions.
Potassium Chloride M117	Hazardous waste landfill. Material may be acceptable in some sanitary landfills.
Coalbed Methane Additive J473	Incineration, disposal well injection or other acceptable methods according to local regulations.
Borate Crosslinker J532	Inject in disposal well. Small amounts may be acceptable in sanitary sewer.
Gelling Agent U28	Neutralized material is generally acceptable in sanitary sewers.

If unused hydraulic fracturing fluids are indeed "hazardous wastes," it is unconscionable that EPA is allowing these substances to be injected directly into underground sources of drinking water.

2.1.3 Numerous fracturing fluid chemicals are injected into USDWs at concentrations that pose a threat to human health. EPA removed this information from the final study.

As mentioned above, EPA admits that pure hydraulic fracturing chemicals pose a threat to human health. In this next section, it is shown that numerous chemicals, even though they are mixed with water and other substances, are injected into USDWs at concentrations that exceed water quality standards.

In the final version of its study, EPA evaluates the potential contamination threat posed by one substance: benzene (a constituent of diesel). In an earlier draft of the study, however, EPA had calculated the concentrations of an array of hydraulic fracturing fluid chemicals at the point where they were injected into the coal formations (i.e., the "point-of-injection"). EPA's calculations were based on volumes of chemicals identified by hydraulic fracturing service companies.[26] According to EPA, the Agency performed these point-of-injection calculations "in order to evaluate the potential threat to human health."[27]

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[26] EPA states that, "The estimated concentrations presented in Table 4-2 were calculated using the mid-range volumes identified through discussions with service companies." [emphasis added] U.S. Environmental Protection Agency (EPA). August, 2002. *DRAFT Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*. p. 4-4. (Hereafter referred to as U.S. EPA. August, 2002).

[27] U.S. EPA. August, 2002. p. 4-3.

These calculations should have been done for all of the potentially toxic chemicals in fracturing fluids. Instead of finding the necessary data to perform more point-of-injection calculations, however, EPA removed the point-of-injection calculations for all chemicals except benzene. EPA's point-of-injection concentration table, which was in the draft EPA study but not the final study, has been reproduced as Table 3 in this report.

It should be noted that in the final study EPA revised its calculation for benzene, toluene, ethylbenzene and xylene ("BTEX").[28] Using the new calculations, EPA finds that, "If the maximum value for benzene in diesel is used to estimate the concentration of benzene at the point-of-injection, the resulting estimate is 17 times higher than that presented in the Draft Report,"[29] [emphasis added] which is 4,400 micrograms of benzene per liter (μg/l). This concentration is 880 times the acceptable benzene level (5.0 μg/l) in drinking water. Even using the minimum value for benzene in diesel, and injecting the smallest quantity of diesel reported by the companies, benzene at the point-of-injection is estimated to be nine times the acceptable concentration in drinking water.

In Table 3, EPA provides information on the point-of-injection concentrations for some hydraulic fracturing chemicals. There is also information on acceptable concentrations of these chemicals in drinking water (either federal or state water quality standards – see footnote for more information).[30] Importantly, nine out of 12 hydraulic fracturing chemicals that have water quality standards associated with them exceed the standards. Not only is this not mentioned by EPA in the final study, but this information is actually removed from the final study.

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28 "EPA has revised the fraction of BTEX compounds in diesel used to estimate the point-of-injection concentrations from a single value to a documented broader range of values for the fraction of BTEX in diesel fuel. For example, the fraction of benzene in diesel was revised from 0.00006 g benzene/g diesel to a range with a minimum value of 0.000026 g benzene/g diesel and a maximum value of 0.001 g benzene/g diesel." (U.S. EPA. June, 2004. p. 4-11.)

29 U.S. EPA. June, 2004. p. 4-11.

30 The three water quality standards were: **EPA's Maximum Contaminant Level (MCL**), which is the highest level of a contaminant that EPA allows in drinking water under the *Safe Drinking Water Act*; **EPA's Risk-Based Concentration (RBC) tables**, which combine toxicity information with "standard" exposure scenarios to calculate levels of risk; and **Massachusetts Contingency Plan (MCP),** groundwater standards for drinking water protection.

TABLE 3. ESTIMATED CONCENTRATIONS OF FRACTURING CHEMICALS AT THE POINT OF INJECTION.
(Adapted from Table 4-2 in the August, 2002 DRAFT version of EPA's study *Evaluation of Impacts of Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs*)

Product	Chemical Composition of Existing Products	Concentration of Interest (µg/L)	
	Chemical Compound	Point-of-Injection	MCL, RBC or *MCP*
Linear gel delivery system	guar gum derivative		
	diesel, which contains the following:		
	benzene	313.20	5.00
	toluene	522.00	1,000.00
	ethylbenzene	522.00	700.00
	xylene	522.00	10,000.00
	naphthalene	14,094.00	20.00
	1-methylnapthalene	71,340.00	***20 / 6,000***
	2-methylnapthalene	34,974.00	121.67
	dimethylnapthalenes	270,570.00	na
	trimethylnapthalenes	160,080.00	na
	fluorenes	31,320.00	2190.00
	phenanthrenes	7,830.00	***300 / 50***
	aromatics	574,200.00	***200 / 30,000***
Water Gelling Agent	guar gum		
	water	495,049.50	na
	fumaric acid	132,337.87	na
Linear Gel Polymer	fumaric acid	529,351.49	na
	adipic acid	366,257.43	na
Gelling Agents (BLM Lists)	benzene		5.00
	ethylbenzene		700.00
	methyl tert-butyl ether		2.64
	naphthalene		20.00
	polynuclear aromatic hydrocarbons (pahs)		na
	polycyclic organic matter (pom)		na
	sodium hydroxide		na
	toluene		1,000.00
	xylene		10,000.00
Crosslinker	boric acid	170,998.00	na
	ethylene glycol	285,788.42	73,000.00
	monoethanolamine	na	na
Crosslinker	sodium tetraborate decahydrate		na
Crosslinker (BLM Lists)	ammonium chloride		na
	potassium hydroxide		na
	zirconium nitrate		na
	zirconium sulfate		na
Foaming Agent	isopropanol	234,945.16	na
	salt of alkyl amines	na	na
	diethanolamine	na	na
Foaming Agent	ethanol	236,081.75	na
	2-butoxyethanol	269,641.08	na
	ester salt	na	na
	polyglycol ether	na	na
	water		na
Foamers (BLM)	glycol ethers	na	na
Acid Treatment	hydrochloric acid	na	na
Acid Treatment	formic acid	na	73,000.00
Breaker Fluid	diammonium peroxidisulfate	na	na
Breaker Fluids (BLM Lists)	ammonium persulfate		na
	ammonium sulfate		na
	copper compounds		1,460.00
	ethylene glycol		na
	glycol ethers		na
Microbiocide	2-bromo-2nitrol,3-propanediol		na
Biocide	2,2-dibromo-3-nitrilopropionamide		na
	2-bromo-3-nirtrilopropionamide		na
Bactericides	polycyclic organic matter (pom)		na
	polynuclear aromatic hydrocarbons (pahs)		na
Acid Corrosion Inhibitor	methanol	236,070,000.00	18,250.00
	propargyl alcohol	47,425,000.00	na
Acid Corrosion Inhibitor	pyridinium, 1-(phenylmethyl)-,ethyl methyl deriv.	na	na
	thiourea	210,750,000.00	na
	propan-2-ol	39,275,000.00	na
	poly(oxy-1,2-ethanediyl)-nonylphenyl-hydroxy	na	na

[shaded box] = Exceeds regulatory standard

MCL = Maximum Contaminant Level - The highest level of a contaminant that is allowed in drinking water.

RBC = EPA's Risk Based Concentration Tables. (http://www.epa.gov/reg3hwmd/risk/index.html, developed by Region 3, serving: Delaware, District of Columbia, Maryland, Pennsylvania, Virginia, West Virginia)

MCP = Massachusetts Contingency Plan - Risk-based ground water standards for drinking water protection chosen because Massachusetts has developed standards for many constituents in diesel fuel. Two numbers are given (the first is drinking water standard, the second is standard for groundwater discharging to surface water).

Table 4, below, summarizes information on the nine chemicals that exceeded a water quality standard in the draft EPA study.

TABLE 4. HYDRAULIC FRACTURING CHEMICALS EXCEEDING A WATER QUALITY STANDARD[31]

Chemical Compound	EPA's Estimated Point-of-Injection Concentration (µg/l)	Acceptable Concentration in Drinking Water (µg/l)	How many times more than the acceptable concentration	Water Quality Standard Used
Benzene	313	5	63	MCL
Naphthalene	14,094	20	705	RBC
1-methylnapthalene	71,340	20	3,567	MCP
2-methylnapthalene	34,974	121	289	RBC
Fluorenes	31,320	2,190	14	RBC
Phenanthrenes	7,830	300	26	MCP
Aromatics	574,200	200	2,871	MCP
Ethylene glycol	285,788	73,000	4	RBC
Methanol	236,070,000	18,250	12,935	RBC

The information from the draft EPA study shows that in addition to benzene at least eight chemicals are injected at concentrations that pose a threat to human health. These chemicals may be injected at concentrations that are anywhere from 4 to almost 13,000 times the acceptable concentration in drinking water. EPA does not include any data in the draft or final study to show that these chemicals will undergo physical or chemical transformations to significantly minimize their concentrations in USDWs. Consequently, <u>EPA is knowingly permitting companies to inject chemicals at concentrations that endanger drinking water quality and human health</u>.

Why was the point-of-injection information removed from the final EPA study?

Instead of admitting that numerous chemicals are injected at concentrations that pose a threat to human health, EPA removed the information from the study. No clear reason is provided in the final study as to why point-of-injection calculations are not included for substances other than benzene.

In the final study, EPA does state that, "...only BTEX compounds originating from diesel fuel are regulated under the *Safe Drinking Water Act*. None of the other constituents in Table 4-1 appear on the Agency's draft Contaminant Candidate List (CCL)."[32] This suggests that EPA may have removed the information on other fracturing constituents because they are not regulated under the *Safe Drinking Water Act*.

Discounting chemicals that are not regulated under the *Safe Drinking Water Act* is problematic because *Safe Drinking Water Act* standards do not cover the majority of synthetic chemicals that can often be found in water.[33] (For example, water quality standards do not exist for many of the constituents in hydraulic fracturing fluids - see Table 3). Considering that approximately 80,000 chemicals are now being used

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31 U.S. EPA. August, 2002. Table 4-2.

32 U.S. EPA. June, 2004. p. 4-17.

33 Pye, V. and Kelley, J. 1984. "The Extent of Groundwater Contamination in the U.S." **<u>in</u>** *Groundwater Contamination.* (Geophysics Study Committee, National Research Council). p. 23.

and distributed through the environment,[34] and an additional 1,500 are being added each year,[35] it is not surprising that EPA has not developed water quality standards for all chemicals. This does not mean, however, that chemicals without water quality standards are harmless.

In the executive summary of the final study, EPA states that:

> ***Underground injection endangers drinking water sources if. . . the presence of such a contaminan****t may result in such system's noncompliance with any national primary drinking water regulation (i.e., maximum contaminant levels (MCLs))* <u>*or*</u> ***may otherwise adversely affect the health of persons.***[36] [emphasis added]

It is reasonable to assume that if water quality standards for certain chemicals do not exist under the *Safe Drinking Water Act*, that EPA would look to other water quality standards for guidance on what may "adversely affect the health of persons."

In its draft study, EPA did recognize other water quality standards, e.g., EPA's own Risk-Based Concentrations and Massachusett's Contingency Plan standards. EPA's calculations revealed that the concentrations of numerous chemicals in hydraulic fracturing fluids occur at concentrations high enough to pose a threat to human health under a state or federal water quality standard. It is logical, therefore, to conclude that these chemicals may adversely affect the health of persons, and that the underground injection of some hydraulic fracturing fluids endangers drinking water sources.

By removing this information from the final study <u>EPA is downplaying the very clear threat that these chemicals pose to USDWs</u>. Instead of discounting this information, EPA should be conducting groundwater sampling to determine whether or not these and other chemicals remain in formations in high enough concentrations to harm human health.

2.1.4 EPA calculations show that fracturing fluids that contain diesel are likely to result in benzene levels that are 9 to 880 times the acceptable level in drinking water.

In the draft and final versions of the study, EPA calculated the concentration of benzene at the point-of-injection for hydraulic fracturing fluids containing diesel. EPA's point-of-injection calculations indicate that when diesel is used in hydraulic fracturing operations, benzene will be present at concentrations that are from 9 to 880 times the Maximum Concentration Level ("MCL") allowed in drinking water.[37]

Despite the large exceedences of the MCL for benzene, EPA concludes that:

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[34] U.S. EPA. Office of Prevention, Pesticides and Toxic Substances. *Endocrine Disruptor Screening and Testing Advisory Committee. Final Report*. Washington DC. 1998.

[35] Food and Agriculture Organization of the United Nations. 2003. "Treaty on hazardous chemicals and pesticides trade to become law." http://www.fao.org/english/newsroom/news/2003/24790-en.html

[36] U.S. EPA. June, 2004. p. ES-7.

[37] Table 4-2 of the final EPA study (U.S. EPA. June, 2004. p. 4-18) shows the minimum point-of-injection (POI) concentration of benzene to be 45 micrograms per liter (ug/L), and the maximum POI concentration to be 4,400 ug/L. The MCL for benzene is 5 ug/L. Thus, the POI concentration is 9 times the MCL in the low-benzene scenario, and 880 times the MCL in the high-benzene scenario.

In situations when diesel fuel is used in fracturing fluids, a number of factors would decrease the concentration and/or availability of BTEX. These factors include fluid recovery during flowback, adsorption, dilution and dispersion, and potentially biodegradation of constituents. . . EPA expects fate and transport considerations would minimize the possibility that chemicals included in fracturing fluids would adversely affect USDWs.[38]

In order for EPA's conclusion to hold true, no benzene should be left in the USDW, since the EPA has concluded elsewhere that there is no safe level of benzene in drinking water.[39] In Chapter 4 of the EPA study, the Agency simply theorizes that dilution, dispersion and adsorption and perhaps biodegradation will adequately decrease the levels of benzene and any other chemicals stranded in the coal formations. (For more details, see Section 3.2.) The EPA study does not provide any empirical data to show that concentrations of benzene (or other chemicals) are reduced to safe levels.

Since EPA provides no data on concentrations of benzene that remain in coal beds or adjacent formations following hydraulic fracturing events (see Section 3.1.3), and no data to verify that various processes successfully reduce the levels of benzene or other injected chemicals, OGAP disputes EPA's conclusion that benzene trapped in USDWs will not pose a threat to human health and water quality.

Furthermore, if the risk of benzene contamination is as low as EPA would have the public believe then why did the Agency bother encouraging companies to sign an agreement to stop injecting diesel into USDWs? (See Section 2.2, below.)

2.2 Voluntary agreement to stop using diesel does not eliminate health threat

In December 2003, EPA signed a Memorandum of Agreement ("MOA") with three hydraulic fracturing companies (Halliburton Energy Services, Inc. "Halliburton"; Schlumberger Technology Corp. "Schlumberger"; and BJ Services Co. "BJ Services").[40] According to industry sources, these three companies conduct 95% of the hydraulic fracturing jobs in the country.
The MOA states that:

The Companies agree to eliminate diesel fuel in hydraulic fracturing fluids injected into CBM production wells in USDWs within 30 days of signing this

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[38] U.S. EPA. June, 2004. p. 4-19.

[39] "In 1974, Congress passed the *Safe Drinking Water Act*. This law requires EPA to determine safe levels of chemicals in drinking water (levels that will not cause health problems). These non-enforceable levels, based solely on possible health risks and exposure, are called Maximum Contaminant Level Goals. The MCLG for benzene has been set at zero because EPA believes this level of protection would not cause any of the health effects described below. Based on this MCLG, EPA has set an enforceable standard called a Maximum Contaminant Level (MCL). The MCL has been set at 5 parts per billion (ppb) because EPA believes, given present technology and resources, this is the lowest level to which water systems can reasonably be required to remove this contaminant should it occur in drinking water. **Health effects:** (Short-term) EPA has found benzene to potentially cause the following health effects when people are exposed to it at levels above the MCL for relatively short periods of time: temporary nervous system disorders, immune system depression, anemia. (Long-term) Benzene has the potential to cause the following effects from a lifetime exposure at levels above the MCL: chromosome aberrations, cancer." [emphasis added] http://www.epa.gov/safewater/contaminants/dw_contamfs/benzene.html

[40] *A Memorandum Of Agreement Between The United States EPA and BJ Services Company, Halliburton Energy Services, Inc., and Schlumberger Technology Corporation Elimination of Diesel Fuel in Hydraulic Fracturing Fluids Injected into Underground Sources of Drinking Water During Hydraulic Fracturing of Coalbed Methane Wells*. December, 2003. http://www.epa.gov/safewater/uic/pdfs/moa_uic_hyd-fract.pdf

agreement. If necessary, the Companies may use replacement components for hydraulic fracturing fluids that will not endanger USDWs.

There is a very clear need to eliminate diesel from hydraulic fracturing fluids. As mentioned previously, EPA calculated that when diesel is used in CBM fracturing operations benzene is injected at 9 to 880 times the acceptable level in drinking water set by EPA.

For the following reasons, OGAP believes the MOA is not enough to protect USDWs.

Only three companies signed the MOA.

The MOA only prevents three companies from injecting diesel into USDWs during CBM production. In other words, by signing this MOA rather than regulating the injection of diesel, EPA is continuing to condone, for all other companies, a practice that allows benzene to be injected into USDWs at levels that are clearly harmful to human health. (See Section 2.1.4.)

For example, Shell Exploration and Production Company ("Shell") did not sign the MOA. In fact, Shell explicitly expressed a desire to continue using diesel in CBM operations. In an October, 2002 letter to the EPA, Shell wrote:

> *We believe that operators should be able to use hydraulic fracturing fluids containing diesel when necessary to fracture CBM reservoirs provided that endangerment to a USDW is not a concern (e.g., a confining layer between the CBM reservoir and the USDW is present or the operator can demonstrate to the State regulatory agency that the USDW will not otherwise be endangered).*[41]

Because Shell did not sign the MOA, the company is free to inject diesel into USDWs. Furthermore, because neither EPA nor state hydraulic fracturing regulations exist (except in Alabama), there is no requirement for Shell or any other company to prove that the diesel will not endanger a USDW.

All companies may still inject diesel into formations that are not USDWs.

Studies have shown that hydraulic fracturing fluids can move out of coal formations and into nearby formations, even when it is predicted that the fluids will be confined to the coal. (See Section 4.1.) Thus, diesel or some of its potentially toxic components may move out of non-USDW coal beds and contaminate nearby USDWs.

All companies may use diesel in non-CBM fracturing jobs.

The MOA does not prevent the injection of diesel-based fracturing fluids in conventional oil and gas operations and other unconventional (oil shales/tight sands, etc.) hydraulic fracturing operations – some of which may be located in or close to USDWs.

All companies may directly inject other potentially toxic substances into USDWs.

[41] Letter from B. Redweik, Shell Exploration and Production Co. to EPA. Oct. 25, 2002. (Docket W-01-09-11, Document OW-2001-0002-0127). http://docket.epa.gov/edkpub/do/EDKStaffCollectionDetailView?objectId=0b0007d480070a09&docIndex=4

Even though the MOA signatories agreed that any chemicals that replace diesel "will not endanger USDWs," there is nothing in the MOA that requires companies to report the chemicals that they are using to fracture CBM formations. Since EPA does not regulate the injection of fracturing fluids, the Agency has no way of requiring companies to prove that non-diesel fracturing fluids are not endangering USDWs.

If non-endangerment was the true intent of the MOA, then the agreement should also have banned the use of ethylene glycol and methanol. As outlined in Section 2.1.3 of this report, EPA calculated that these constituents of non-diesel-based hydraulic fracturing fluids exceeded EPA's Risk-Based Concentrations (RBC)[42] at the point-of-injection. Ethylene glycol was four times and methanol was almost 13,000 times the "safe" RBC level. (See Table 4, Section 2.1.3 of this report.)

The agreement is voluntary.

The three companies may terminate the agreement at any time and begin using diesel in CBM operations that occur in USDWs.

Diesel is not a necessary constituent in fracturing fluids. According to Halliburton, "Diesel does not enhance the efficiency of the fracturing fluid; it is merely a component of the delivery system."[43] Since it is technologically feasible to replace diesel with other "delivery systems," such as water, there should be no question but that EPA should create regulations that prevent all hydraulic fracturing companies from injecting diesel into or close to USDWs.

Through the MOA the EPA appears to be encouraging Halliburton, Schlumberger and BJ Services to take a "precautionary approach," in an effort to protect USDWs and human health. The MOA, however, does not prevent benzene and other toxic substances from entering USDWs. The EPA should take stronger precautionary measures and stop all companies from injecting diesel and other potentially toxic chemical mixtures into and close to USDWs – at least until empirical data on chemical toxicity and the fate and transformation of chemicals trapped underground can be gathered, and it is proven that the concentrations of hydraulic fracturing fluids do not pose a threat to human health.

2.3 Much more information is needed to understand the toxicity and health hazards posed by hydraulic fracturing fluids

As mentioned above, EPA does not include data on the concentrations of all chemicals at the point where they are injected. This is only one of many gaps in information in the EPA study. As described below, EPA does not provide a comprehensive list of the chemicals used in hydraulic fracturing; EPA does not review existing literature on the toxicity of fracturing fluid chemicals; EPA does not address the potential for chemical interactions between fracturing chemicals, or between injected chemicals and naturally occurring compounds in coals; and EPA does not

[42] **Risk-Based Concentration (RBC)**: the "concentration of a chemical that a person or ecosystem could be exposed to that would not result in a risk of cancer or other adverse health effects above a specified level of concern." http://yosemite.epa.gov/oar/communityassessment.nsf/Glossary?OpenForm

[43] U.S. EPA. June, 2004. p. 4-4.

discuss the potential environmental and health impacts associated with fracturing fluid disposal.

2.3.1 EPA fails to provide a comprehensive list of fracturing fluid constituents.

The information that EPA presents on fracturing fluid constituents and the toxicity of these components comes from a literature review, and from information received from companies. EPA received Material Safety Data Sheets ("MSDS")[44] from three fracturing service companies, and reviewed MSDSs from another company's web site.[45] For several reasons, the information received cannot be considered representative of all fracturing fluids used in coalbed methane wells.

There is a dearth of literature on the chemical constituents of fracturing fluids.

In an attachment to the study (but surprisingly absent from the main chapter on hydraulic fracturing fluids), EPA states:

> *The chemical composition of many fracturing fluids may be proprietary, and EPA was unable to find complete chemical analyses of any fracturing fluids in the literature.*[46]

EPA literature review did not reveal the use of radioactive tracers during hydraulic fracturing operations.

The Petroleum Technology Transfer Council has reported that "many operators tag the tail end of their proppant with radioactive tracer."[47] This raises questions and concerns related to concentrations of radioactive materials used, and how hazardous these chemicals may be in drinking water. Unfortunately, no where in the chapter of the EPA study dealing with hydraulic fracturing fluids (Chapter 4) is it mentioned that radioactive tracers may be injected along with fracturing fluids.

EPA did not collect information from all hydraulic fracturing companies. EPA states that, "The formulations or recipes for fracturing fluids differ among service companies and among sites."[48] Since EPA only reviewed MSDSs from a select group of companies, the data cannot be considered representative

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[44] MSDSs provide lists of the chemicals contained in various chemical products, such as fracturing fluids, and information on potential health effects posed by the fluids.

[45] According to the Study Methodology in Chapter 2 (p. 2-5), four fracturing fluid companies were supposed to be contacted by EPA: Halliburton Energy Services, Inc., Schlumberger Technology Corp., BJ Services Co., and Hercules, Inc. BJ Services did not provide EPA with any MSDS sheets (or if they did, EPA did not include this information in the study). Through a *Freedom of Information Act* request (No. HQ-RIN-00044-05), OGAP found that Hercules Inc. did provide some data, but the company was not cited in the final study references. It appears that EPA used information from the Messina Inc. web site, as this company was cited in the EPA study references.

No other companies involved in hydraulic fracturing or the production of fracturing fluids, e.g., Drilling Specialties Company, LLC (a subsidiary of Chevron Phillips Chemical Company), Marathon Oil Inc., (mentioned in Attachment A-1 and/or A-2 as being companies that produce fracturing fluid gels) were contacted directly by EPA, according to the study references.

[46] U.S. EPA. June, 2004. Attachment 1. p. A1-7.

[47] Rodney R. Reynolds. 2003. *Produced Water and Associated Issues -- Manual for the independent operator.* Prepared for the South Midcontinent Region of the Petroleum Technology Transfer Council (PTTC) and Oklahoma Geological Survey (OK Geological Survey Open-file Report 6-2003). http://www.pttc.org/pwm/pw_stoc.htm#toc2

[48] U.S. EPA. June, 2004. p. 4-13.

of fracturing fluids used across the country. Notably, no MSDSs were received from BJ Services, a major hydraulic fracturing company.[49]

Proprietary fracturing chemicals do not have to be disclosed in MSDSs.

As mentioned above, EPA reports that information on fracturing fluids may not be available because it is proprietary. The issue of non-disclosure of proprietary chemical constituents in MSDSs has been recognized by the American Federation of State, County And Municipal Employees (AFL-CIO). In information provided to employees, the federation writes, "The manufacturer may be able to withhold ingredient information from the MSDS if any ingredients are trade secrets."[50]

Lack of disclosure of proprietary information is downplayed in the EPA study. This is a significant issue, because without a complete list of chemicals or complete chemical analyses of fracturing fluids, there is no way to predict all of the risks posed when these substances are injected into the ground.

MSDSs may not include a complete listing of hazardous ingredients in a chemical product (even if the information is not proprietary).

According to the AFL-CIO, state laws differ about which chemicals are required to be listed on an MSDS. Those states with laws similar to the Federal Occupational Safety and Health Association ("OSHA") hazard communication standard require evaluation of all chemicals. Some states, however, require coverage of only the chemicals that have OSHA standards (about 500 chemicals).[51]

This is problematic, according to the Connecticut Department of Environmental Protection, because:

> *MSDS sheets do not include all of the ingredients in a certain material, but only those that make up greater than 1% of the total constituents of that material. This means that **a waste may contain a toxic constituent exceeding the regulatory limit** (making it a hazardous waste), **but this constituent may not necessarily be included on the MSDS**.*[52] [emphasis added]

The following example illustrates the lack of detailed information on hydraulic fracturing fluid chemicals in the EPA report. The EPA study mentions that glycol ethers can be a component of hydraulic fracturing fluid foaming agents. Glycol ethers are a family of chemicals. It is impossible to estimate the toxicity of fracturing fluids that contain glycol ethers (or any other chemical family) because the individual glycol ethers have different toxicities. For example, a 1984 study conducted by Schuler and

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49 In a *Freedom of Information Act* request to EPA (Request No. HQ-RIN-00044-05), OGAP requested all MSDSs for fracturing fluids received from Halliburton, Schlumberger and any other sources for the period of 2001-2004. No MSDSs were received from BJ Services. Furthermore, the only citation including BJ Services in the EPA study is a personal communication conference call with EPA on April 19, 2002. (U.S. EPA. June, 2004. p. MR-6).

50 American Federation of State, County And Municipal Employees, AFL-CIO. "How To Read A Material Safety Data Sheet." http://www.afscme.org/health/faq-msds.htm

51 ibid.

52 Connecticut Department of Environmental Protection. 2003. "Hazardous Waste Determinations/Knowledge of Process." http://dep.state.ct.us/wst/hazardous/hwd.htm#How%20can%20knowledge%20be%20applied%20to%20determine%20if%20a%20waste%20is%20a%20characteristic%20waste

coworkers compared the reproductive effects of fifteen glycol ethers on mice.[53] They report that pregnant mice treated with five different glycol ethers produced no viable litters. Mice treated with four other glycol ethers showed a reduction in litter viability. The remainder of the glycol ethers tested had no effect on reproduction at the administered concentrations.

Table 5 provides a list of some chemicals that are considered to be glycol ethers.[54] This information was not included in the EPA study.

TABLE 5. GLYCOL ETHERS.

Common Name	Chemical Name
Ethylene glycol monomethyl ether	2-methoxyethanol
Ethylene glycol monomethyl ether acetate	2-methoxyethyl acetate
Ethylene glycol monoethyl ether	2-ethoxyethanol
Ethylene glycol monoethyl ether acetate	2-ethoxyethyl acetate
Ethylene glycol monopropyl ether	2-propoxyethanol
Ethylene glycol monobutyl ether	2-butoxyethanol
Ethylene glycol dimethyl ether	1,2-dimethoxyethane
Ethylene glycol diethyl ether	1,2-diethoxyethane
Diethylene glycol monomethyl ether	2-(2-methoxyethoxy)ethanol
Diethylene glycol monoethyl ether	2-(2-ethoxyethoxy)ethanol
Diethylene glycol monobutyl ether	2-(2-butoxyethoxy)ethanol
Diethylene glycol dimethyl ether	bis(2-methoxyethyl)ether
Diethylene glycol dimethyl ether	bis(2-methoxyethyl)ether

EPA should have identified and evaluated data on the specific glycol ethers present in hydraulic fracturing fluids. Similarly, EPA should have provided detailed chemical and toxicity information on all of the chemicals used in fracturing fluids prior to deciding whether or not the fluids pose a threat to human health.

The failure of EPA to provide comprehensive information on fracturing chemicals is further highlighted by the following example. In Attachment 1 of the EPA study, the Agency mentions that formaldehyde, chromic acetate and hydrochloric acid are constituents of fracturing fluids used in the San Juan basin. A cursory review conducted by OGAP shows that formaldehyde is a known carcinogen;[55] chromic acetate is considered to be an "environmental hazard" in Pennsylvania;[56] and

[53] D.L. Schuler, B.D. Hardin, R.W. Niemeier, G. Booth, K. Hazelden, V. Piccirillo and K. Smith. 1984. "Results of Testing Fifteen Glycol Ethers in a Short-Term *in Vivo* Reproductive Toxicity Assay." *Environmental Health Perspectives*. Volume 57, pp. 141-146.

[54] California Department of Health Services, Hazard Evaluation System and Information Service. "Glycol Ethers." http://www.dhs.ca.gov/ohb/HESIS/glycols.htm

[55] International Agency for Research on Cancer. 2004. "Formaldehyde, 2-Butoxyethanol and 1-*tert*-Butoxy-2-propanol," *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans.* Volume 88, pp. 2-9. http://www-cie.iarc.fr/htdocs/monographs/vol88/formal.html

[56] In Pennsylvania, "Hazardous substances which are considered environmental hazards because of their particular or extreme properties pose a danger if released into the environment are contained in an Environmental Hazard List." (Pennsylvania Code. Title XIII. *Workers Right-to-Know-Act*. Chapter 323. Hazardous Substance List. See appendix A for a list of hazardous substances, including acetic acid, chromium 3+ salt, also known as chromic acetate.) http://www.pacode.com/secure/data/034/chapter323/chap323toc.html

hydrochloric acid is highly corrosive. Neither formaldehyde nor chromic acetate is mentioned in the chapter of the EPA study that lists and discusses health impacts associated with hydraulic fracturing fluids (i.e., Chapter 4).

Given the limited data that EPA collected from hydraulic fracturing companies, and the fact that certain chemicals known to be in fracturing fluids are not discussed in the main body of the report, it is clear that EPA does not present a thorough analysis of hydraulic fracturing fluid constituents that are being used across the country. Without knowing exactly what is being injected, it is clearly premature of EPA to conclude that hydraulic fracturing fluids do not pose a threat to USDWs.

2.3.2 EPA fails to thoroughly investigate the toxicity and health effects related to hydraulic fracturing fluid chemicals.

EPA presents little information on the toxicity and human health effects related to hydraulic fracturing fluids. In Chapter 4 of the study, EPA states that:

> *Most of the literature pertaining to fracturing fluids relates to the fluids' operational efficiency rather than their potential environmental or human health impacts.*[57]

It is surprising that EPA makes this statement, since the Agency did not specifically look for literature on the effects of fracturing fluid chemicals on human health. According to EPA:

> ***The search terms used by the Agency did not include health-related terms*** *because the study's goals did not include conducting a human-health risk assessment or conducting a new investigation into the toxicity of any of the components of hydraulic fracturing fluids.*[58] [emphasis added]

As mentioned in the above quotation, EPA did not conduct any new investigations into the toxicity of any of the components of hydraulic fracturing fluids.[59] Surprisingly, it appears that EPA did not even review any scientific literature related to various fracturing fluid chemicals other than what was included in MSDSs.[60] Not one toxicological study is referenced in EPA's study.

While MSDSs do contain some information on chemical toxicity and health hazards, "Many MSDSs are inaccurate or incomplete. . . MSDSs often leave out chronic health information, such as whether a chemical causes cancer or birth defects."[61]

For example, Halliburton provided EPA with an MSDS for its hydraulic fracturing crosslinker fluid.[62] The MSDS lists boric acid, ethylene glycol and monethanolamine as each making up 10-30% of the fracturing fluid. In the toxicological information, the MSDS states that:

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[57] U.S. EPA. June, 2004. p. 4-1.

[58] U.S. EPA. June, 2004. Appendix: Public comment and response summary for HF CBM Study. p. 8.

[59] U.S. EPA. June, 2004. Appendix: Public comment and response summary for HF CBM Study. p. 8.

[60] U.S. EPA. June, 2004. p. 4-1.

[61] American Federation of State, County And Municipal Employees. "How To Read A Material Safety Data Sheet." http://www.afscme.org/health/faq-msds.htm

[62] Halliburton Energy Services. 2001. Material Safety Data Sheet for BC-140. Provided to EPA by Stan Willis, Senior Technical Professional. August 15, 2001. (Obtained from EPA by OGAP through a *Freedom of Information Act* Request No. HQ-RIN-00044-05.)

Prolonged or repeated exposure may cause kidney damage. Prolonged or repeated exposure may cause liver, heart, blood and brain damage. Prolonged or repeated exposure may cause reproductive system damage. Prolonged or repeated exposure may cause embryo and fetus toxicity.

Yet under the header "Toxicity Tests," the Halliburton MSDS states that the oral, dermal and inhalation toxicities, as well as carcinogenicity, genotoxicity and reproductive/developmental toxicity for the fracturing fluid product <u>have not been determined</u>.[63] It is impossible, therefore, to determine at what chemical concentration, and over what time period, effects such as kidney damage or embryo toxicity will develop.

A review of MSDSs received by EPA show that for many hydraulic fracturing fluids no human or animal toxicity tests (assessing acute and chronic toxicity, immunotoxicity, carcinogenicity, genotoxicity, endocrine disruption, and developmental and reproductive effects) have been conducted.[64] Thus, there is no way to predict at what concentrations these chemicals may begin to cause health effects.

Knowing the concentrations at which specific hydraulic fracturing chemicals begin to elicit health effects in humans is critical information, especially if these chemicals are being injected into or near to public water sources. Without this information EPA cannot know for sure that the chemicals injected into USDWs are at levels that are safe for humans.

The goal of the EPA study was "to assess the potential for contamination of USDWs due to the injection of hydraulic fracturing fluids."[65] By not using health-related search terms, EPA failed to thoroughly investigate the toxicity and potential health effects related to fracturing fluids and fracturing fluid components. Without this information, an accurate assessment of the contamination potential of fracturing fluids cannot be made. Furthermore, it is not reasonable or prudent to conclude that chemicals of unknown toxicity can be injected safely into USDWs; yet, that is what EPA concludes.

2.3.3 The effect of chemical interactions on groundwater is not addressed by EPA.

When chemicals are mixed together chemical reactions may take place that increase or decrease the toxicity of the individual chemicals.[66] Other federal departments, such as the Agency for Toxic Substances and Disease Registry, are concerned about the interactive effects of mixtures of chemicals.[67] Given that hydraulic fracturing

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[63] ibid.

[63] ibid.

[64] OGAP received copies of 26 MSDSs that EPA received from Halliburton Energy Services (1 MSDS), Schlumberger Limited (13 MSDSs) and Hercules Incorporated (12 MSDSs). (Obtained from EPA through *Freedom of Information Act Request* No. HQ-RIN-0004-05.)

[65] U.S. EPA. June, 2004. p. 1-1.

[66] According to a National Academy of Science (NAS) report, "...organisms are usually exposed not to single chemicals but to chemical mixtures, the components of which may interact in unexpected ways. We need to better understand and predict additive, synergistic, or antagonistic interactions between chemicals." NAS. 2000. *Opportunities for Environmental Applications of Marine Biotechnology.* p. 113. http://books.nap.edu/books/0309071887/html/113.html#pagetop

[67] Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. 2001. *Guidance Manual for the Assessment of Joint Toxic Action of Chemical Mixtures.* Draft for Public Comment.

fluids are mixtures of various chemicals, it is surprising that the EPA study does not address the potential for toxic interactions between those chemicals.

Also, the study does not examine the potential for injected chemicals to react with naturally occurring compounds or elements present in the coal formations. Trace elements such as arsenic, mercury, lead, selenium, cadmium and others are known to exist in coals (see section 2.3.4 below); and organic compounds, such as polycyclic aromatic hydrocarbons (PAHs), are associated with coal formations.[68] It is possible that injected chemicals could react with naturally occurring compounds and elements in additive or synergistic ways, with the result being that previously potable groundwater becomes too toxic to be used as drinking water.

For example, the solvent ethylene glycol monobutyl ether (2-butoxyethanol) is sometimes used in foamed hydraulic fracturing gels.[69] The same chemical is also widely used as a solvent for mineral oils, which makes it an excellent candidate for releasing naturally occurring hydrocarbons found in coal.[70] Similarly, ethanol, another constituent used in hydraulic fracturing fluids, has been shown to leach PAHs, many of which are known carcinogens, from coal tars.[71]

Furthermore, it has been shown that certain water-soluble compounds (e.g., dihydroxyphenols, thiocyanate, disulfides and hydroxypyridines) derived from coal are powerful goitrogens, which are substances that can lead to thyroid disorders.[72] There is no discussion in the EPA study on whether or not injected fracturing chemicals (or the creation of more extensive fracture systems) could increase the bioavailability or toxicity of these compounds.

Instead of thoroughly examining the potential consequences of injecting mixtures of hydraulic fracturing chemicals into the underground environment, the study simply dismisses the fact that these chemicals could have any harmful effects.[73] Clearly, EPA needs to gather more information on <u>all</u> chemical constituents in hydraulic fracturing fluids; on the toxicity of individual chemicals and mixtures of chemicals in hydraulic fracturing fluids; and on baseline concentrations of chemical constituents present in groundwater prior to injecting hydraulic fracturing fluids. Baseline data should include:

> *. . .the entire scope of trace elements from alkaline to acid based derivatives in both their dissolved and suspended form. In addition, the entire scope of polyaromatic hydrocarbons (both parent and alkylated forms) in the*

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68 S.P. McElmurry, and T.C. Voice. 2004. "Screening methodology for coal-derived organic contaminants in water." *International Journal of Environmental and Analytical Chemistry.* Vol. 84, No. 4. pp. 266-287.

69 Schlumberger. 2001. *Material Safety Data Sheet for Foaming Agent F104.* Obtained by OGAP through a Freedom of Information Request to EPA.

70 Theo Colborn, (PhD). Professor, Zoology Department, University of Florida; Adjunct Graduate Faculty, Texas A&M. Oct. 22, 2002. Letter to the Bureau of Land Management and U.S. Forest Service, Re: An Analysis of Possible Increases in Exposure to Toxic Chemicals in Delta County, Colorado Water Resources as the Result of Gunnison Energy's Proposed Coal Bed Methane Extraction Activity. p.1. (Hereafter referred to as Theo Colborn. Oct. 22, 2002.)

71 P.H. Lee, S.K. Ong, J. Golchin and G.L. Nelson. 2001. "Use of solvents to enhance PAH biodegradation of coal tar-contaminated soils." *Water Research.* V. 35, No.16. pp. 3941-3949.

72 R.H Lindsay, J.B. Hill, E. Gaitan, R.C. Cooksey and R.L. Jolley. 1992. "Antithyroid effects of coal-derived pollutants." *Journal of Toxicology and Environmental Health.* Vol. 37, No. 4. pp. 467-481.

73 "EPA expects fate and transport considerations would minimize the possibility that chemicals included in fracturing fluids would adversely affect USDWs." (U.S. EPA. June, 2004. p. 4-19).

underground coal bed water should be quantified prior to any activity. . . Information such as this will allow for determining if the fracturing liquid releases additional toxic components.[74]

Without this information, there can be no scientific basis for determining whether or not hydraulic fracturing fluids injected into USDWs pose a threat to human health.

2.3.4 The hazards associated with acid fracturing are not addressed by EPA.

Acids are often injected into oil, gas or coalbed methane wells to increase production. Simply put, the acids dissolve the rock and enlarge the pores in the formation, which enhances flow of oil, gas or water to the well. This treatment is referred to as acidizing. Acid fracturing is similar to acidizing, except the acids (e.g., hydrochloric, hydrofluoric or formic acids) are injected into underground formations under extremely high pressures, which causes the formations to fracture.

Acids are corrosive, and thus are harmful to human health. The EPA study does not demonstrate the fate and transformation of injected acids, nor does it discuss whether or not these acids pose a threat to human health. Additionally, the role that acids play in the leaching of metals and radioactive elements from coals is not addressed in the EPA study.

The phenomenon of metal leaching is well known in the mining industry.[75] Indeed, acidic drainage/metal leaching is recognized as the "largest environmental liability facing the mining industry."[76] As acidity increases, metals and other elements are liberated from their host rocks, and become mobile. The U.S. Geological Survey (USGS) has reported that extremes of acidity or alkalinity can enhance the solubility of radioactive elements such as uranium and thorium.[77]

According to the West Virginia Geological and Economic Survey, coals in West Virginia contain more than 50 trace elements, including the highly toxic elements of arsenic, mercury, lead, and selenium.[78] According to the USGS, coals from other areas also contain elements that are of environmental concern such as cadmium, cobalt, chromium, nickel and uranium.[79] In some coals, concentrations of metals are so high that they are purposely leached from coals to lower the metal content before the coals are burned in a power plant.[80]

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[74] Theo Colborn. Oct. 22, 2002.

[75] Western Pennsylvania Coalition for Abandoned Mine Reclamation. Abandoned Mine Reclamation Clearinghouse. "Acid Mine Drainage Basics," http://www.amrclearinghouse.org/Sub/AMDbasics/ZZoverview.htm

[76] Natural Resources Canada. CANMET Mining and Mineral Sciences Laboratories. "Mine Environment Neutral Drainage." http://www.nrcan.gc.ca/mms/canmet-mtb/mmsl-lmsm/mend/default_e.htm

[77] U.S. Geological Survey. 1997. "Radioactive Elements in Coal and Fly Ash: Abundance, Forms and Environmental Significance." USGS Fact Sheet FS-163-97.

[78] West Virginia Geological and Economic Survey. "Trace Elements in West Virginia Coals." http://www.wvgs.wvnet.edu/www/datastat/te/

[79] U.S. Geological Survey. May, 2002. "Characterization and Modes of Occurrence of Elements in Feed Coal and Fly Ash—An Integrated Approach." USGS Fact Sheet-038-02.

[80] David J. Akers. *A Method For Chemically Removing Mercury From Coal.* CQ Inc., Howard University, and Fossil Fuel Sciences. http://www.cq-inc.com/page3D.html

In its study on hydraulic fracturing, EPA does not present any information on whether or not metals and other elements are mobilized when acids are injected into oil- or gas-bearing formations. EPA has, however, included this information in other reports. As shown in Table 6, which comes from an EPA document, a number of metals and elements have been detected at high levels in fluids from wells that have undergone acidizing treatments.[81] The concentration of thallium in Table 6 exceeds EPA's Maximum Contaminant Level (MCL) for drinking water (2.0 μg/l); and other metals are close to the acceptable levels in drinking water (e.g., antimony and lead).

TABLE 6. ANALYSIS OF FLUIDS FROM AN ACIDIZING WELL TREATMENT.

Analyte	Concentration (μg/l)	Analyte	Concentration (μg/l)
Aluminum	53.1	Magnesium	162
Antimony	< 3.9	Molybdenum	< 0.96
Arsenic	< 1.9	Nickel	52.9
Barium	12.6	Selenium	< 2.9
Beryllium	< 0.1	Silver	< 0.7
Boron	31.9	Sodium	1,640
Cadmium	0.4	**Thallium**	**5.0**
Calcium	35.3	Tin	6.6.6
Chromium	19	Titanium	0.68
Cobalt	< 1.9	Vanadium	36.1
Copper	3.0	Yttrium	0.19
Iron	572	Zinc	28.5
Lead	< 9.82		

Considering that EPA has data showing that acidizing can release metals at concentrations that pose a risk to human health, it is surprising that there is no mention in EPA's report about the potential for USDWs to become contaminated with metals and radioactive elements released during acid fracturing of coals. This is an issue that was overlooked by EPA, and one that merits further investigation.

2.3.5 EPA fails to discuss the toxicity of hydraulic fracturing fluid wastes.

Hydraulic fracturing fluids are injected into underground formations, and a portion is pumped back to the surface (see Section 3 on fracturing fluid recovery). The recovered fracturing fluids are a waste product. In its study, EPA does not provide any information on the toxicity of these wastes; and only includes limited data on fracturing fluid waste disposal practices in the various states.

The toxicity of fracturing fluids wastes is a relevant issue for two reasons: 1) The toxicity of waste products can provide information on hazards associated with fluids trapped underground; and 2) Disposal practices, themselves, may create health hazards.

First, when fracturing fluids are injected underground they mix with groundwater and any naturally occurring compounds or elements (e.g., metals) present in the coal formation. Not all fracturing fluids are removed. If the wastes brought to the surface were to be characterized (e.g., analyzed for toxicity or hazardous constituents), this information could provide valuable insight into the potential for the "wastes" that are

[81] U.S. EPA. 1993. *Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Offshore Subcategory of the Oil and Gas Extraction Point Source Category.* Office of Water. EPA 821-R-93-003. Cited in U.S. EPA. Region 4. 2003. *Ocean Discharge Criteria Evaluation For The National Pollutant Discharge Elimination System General Permit For The Eastern Gulf Of Mexico Outer Continental Shelf.* DRAFT.

trapped underground to contaminate underground sources of drinking water. Unfortunately, EPA does not provide any information on the toxicity of hydraulic fracturing wastes.

Second, the handling and storage of hydraulic fracturing fluid wastes may present a health hazard to workers and people living in close proximity to fractured wells. In Chapter 4, EPA shows photos with the caption:

> *Fluid that is extracted from the well is sprayed through a diffuser and stored in a lined trench until it is disposed of off-site or discharged.*[82]

Some chemicals in fracturing fluids contain volatile components (i.e., components that can move from the liquid wastes into the air). Spraying fracturing fluid wastes through a diffuser and storing the wastes in pits or trenches may generate airborne contaminants at levels that affect human health. EPA did not study this issue.

Nearby soils could become contaminated by the sprayed wastes, and some contaminants could be carried by rainwater into streams. Also, surface waters and groundwater could be contaminated if fracturing wastes seep through inadequately lined pits or if the pits overflow. EPA does not explore these issues.

As for off-site disposal, in Attachment 2 of the final report EPA states that in Alabama, "environmental regulations restrict local disposal of used fracturing fluids, and fracturing fluids are transported to regulated disposal sites."[83] Similarly, in Attachment 6 of the EPA study it is reported that in Virginia fracturing fluid wastes are collected in lined pits[84] or tanks and then transported off-site for disposal.[85]

<u>EPA does not explain</u> why Alabama and Virginia do not allow hydraulic fracturing fluid wastes to be disposed of on-site. This information would help to inform EPA and the public about the nature off hydraulic fracturing wastes. If information were to come to light showing that Alabama and Virginia transfer the wastes offsite because the wastes have hazardous characteristics, it would seriously call into question whether or not the same substances (i.e., essentially fracturing fluids plus groundwater) are safe enough to inject directly into USDWs, as EPA contends.

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[82] U.S. EPA. June, 2004. p. 4-26.

[83] A. M. Hunt, D. and Steele. 1991. "Coalbed methane development in the Northern and Central Appalachian Basins – past, present and future." *The 1991 Coalbed Methane Symposium*. University of Alabama/Tuscaloosa, May 13-16, 1991.

[84] EPA did not report whether or not all states require the use of lined pits as temporary collection vessels prior to off-site transportation. Pits, whether lined or unlined, can leak (but lined pits have the potential to greatly reduce soil and water contamination associated with oil and gas wastes). In New Mexico alone, between the mid-1980s and 2003, the New Mexico Environmental Bureau recorded more than 6,700 cases of pits causing soil and water contamination, with at least 557 of those cases resulting in groundwater contamination. (Letter from Roger C. Anderson, Environmental Bureau Chief, New Mexico Energy, Minerals and Natural Resources Department, to Jennifer Goldman, OGAP. Oct. 23, 2003.) Thus, lined pits should be the minimum requirement for the storage of these potentially toxic waste products. Under no circumstances should unlined pits be allowed, and steel tanks would be the preferred option.

[85] U.S. EPA. June, 2004. p. A6-6.

3. Fracturing Fluid Recovery: incomplete

When hydraulic fracturing fluids are injected underground, a portion of the fluids remains trapped in the coal and adjacent formations. As outlined below, EPA has very little data on how much fracturing fluid remains stranded underground. Furthermore, EPA fails to discuss the long-term impacts related to the stranded fluids. Without this information it is extremely premature for EPA to conclude that hydraulic fracturing fluids do not pose a threat to USDWs.

3.1 EPA study lacks data on the recovery of injected fracturing fluids

3.1.1 EPA relies on flowback results from a single CBM well to assess how much fracturing fluid remains stranded in coal formations.

Part of EPA's reason for concluding that fracturing fluids do not pose a threat to USDWs is based on the fact that only a portion of the hydraulic fracturing fluids injected underground remain there—the rest is pumped back to the well and is recovered. This is referred to as "flowback." For example, in Chapter 4 of the final study, EPA states that:

> *In situations when diesel fuel is used in fracturing fluids, a number of factors would decrease the concentration and/or availability of BTEX. These factors include fluid recovery during flowback, adsorption, dilution and dispersion, and potentially biodegradation of constituents. For example, Palmer et al. (1991a) documented that only about one-third of fracturing fluid that is injected is expected to remain in the formation. EPA expects fate and transport considerations would minimize the possibility that chemicals included in fracturing fluids would adversely affect USDWs.*[86]

As outlined in Section 3.2 of this review, EPA does not provide any empirical data to prove that adsorption, dilution and dispersion significantly reduce the concentration of benzene or other chemicals. Thus, the flowback issue must play a major role in providing EPA with the certainty to conclude that these chemicals do not pose a threat to groundwater.

Yet, EPA provides very little information on flowback from coalbed methane wells. In the final study, EPA continually references the results of a single study by Palmer and co-workers.[87] According to EPA:

> *Palmer (1991a) observed that for fracture stimulations in multi-layered coal formations,* ***61 percent of stimulation fluids were recovered during*** *a 19-day production* ***sampling of a coalbed methane well*** *in the Black Warrior Basin. He further* ***estimated that from 68 percent to possibly as much as 82 percent would eventually be recovered.***[88] [emphasis added]

[86] U.S. EPA. June, 2004. p. 4-19.

[87] I.D. Palmer, R.T. Fryar, K.A. Tumino, and R. Puri. 1991. "Comparison between gel fracture and water-fracture stimulations in the Black Warrior basin," *Proc. 1991 Coalbed Methane Symposium.* University of Alabama/Tuscaloosa. pp. 233-242.

[88] U.S. EPA. June, 2004. p. 3-23.

A single study, reporting flowback results from one well in one coal seam in one CBM basin cannot possibly reflect the variation that will be experienced in the different coal formations from which CBM is extracted. This caveat should have been applied by EPA wherever the 61% or 68-82% flowback numbers were used.

Reviewers of the draft EPA study cautioned EPA on this point. For example, Carl Smith of the U.S. Department of Energy commented that:

> *Regarding 61 % fluid recovery from a CBM well in Alabama. Such a fluid recovery percentage should not be indiscriminately applied to over 14,000 CBM wells. The context of such a notation should be clearly expressed.*[89]

In a study by Willberg and coworkers, the authors state that:

> *. . . our understanding of the fundamental physical and chemical processes governing fluid recovery from hydraulic fractures is immature. Fracture clean-up is a complex problem, and many parameters – fluid system, job design, flowback procedure, and reservoir conditions – can influence polymer and fluid recovery efficiencies. Often specific products and methods that work well in one reservoir have little effect in other situations.*[90]

With so many factors affecting fracturing fluid recovery, it is reasonable to assume that there will be a wide range in fluid recovery efficiencies. Literature cited by EPA in the draft version of its study confirms this assumption. These studies, conducted in non-CBM basins, found that between 25% and 61% of certain hydraulic fracturing fluids flowed back to the well.[91] It seems highly likely that there would be a similar range in flowback values for CBM basins or reservoirs.

The possibility of vastly different volumes of fluid being trapped was not, however, clearly expressed by EPA. Instead, EPA used the data from the Palmer study to make sweeping statements about the recovery of injected fluids. In Chapter 4 of the report EPA states: "the predicted recovery of injected BTEX is between 68 and 82 percent."[92] These numbers clearly come from the Palmer study, yet no information is provided to

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[89] Letter from Carl Smith, U.S. Department of Energy, Office of Fossil Fuels, to EPA. (Water Docket ID No. W-01-09-11), Nov. 2, 2002. Document No. OW-2001-0002-0141.

[90] D.M. Willberg, R.J. Card, L.K. Britt, M. Samuel, K.W. England, K.E. Cawiezel, H. Krus. 1997. "Determination of the Effect of Formation Water of Fracture Fluid Cleanup Through Field Testing in the East Texas Cotton Valley." *Proceedings-SPE Annual Technical Conference and Exhibition*, October 5-8, 1997. Publication by Society of Petroleum Engineers, SPE #38620. pp. 531-543.

[91] "Palmer and others (1991a) found that only **61 percent** of fracturing fluids were recovered during a 19-day production sampling of a coalbed well in the Black Warrior basin, Alabama. Samuel et al. (1997) report that several studies relating to guar-based polymer gels document flow-back recovery rates of approximately **30-45%.** The paper did not discuss the duration over which flow-back recovery rates were measured. Willberg et al. (1997) report that polymer recovery rates during flowback averaged **29-41%** of the amount pumped into the fracture. The results from this study were derived from tests performed on 10 wells over periods of four or five days (Willberg et al., 1997). Willberg et al. (1998) report that polymer returns at conservative flow back rates averaged **25-37%** of the amount pumped into the fracture, while returns at aggressive flow back rates averaged **37-55%.** The results from this study were derived from tests performed on 15 wells over periods of two days at aggressive flow back rates and five days at conservative flow back rates." (U.S. EPA. August 2002. p. 3-10.) Also, in a study by Mukherjee and co-workers (cited on p. A-18 of the draft EPA study), the authors observed that between **35% and 45%** of fracturing fluids were recovered from layered formations (i.e., 55-65% remained in the ground. This study is not mentioned in the final EPA study's discussion of flowback (Chapter 3), nor is it listed in the Master Reference List for the EPA final study. The only Mukhergee study listed was one from 1993. (Reference for the deleted study is: Mukhergee, H., Paoli, B.F., McDonald, T. and Cartaya, H. 1995. "Successful control of fracture height growth by placement of an artificial barrier." *SPE Production and Facilities*, 10(2):89-95.)

[92] U.S. EPA. June, 2004. p. 4-16.

caution the reader that this number is only truly applicable to one CBM well in Alabama.

In light of the lack of flowback data from CBM wells, EPA needs to gather more data before the Agency can conclude with any degree of confidence that flowback and other mechanisms significantly reduce the hazards associated with the injection of hydraulic fracturing fluids. Flowback data need to be collected from all CBM basins to gain greater understanding of the volumes of fluids that are remaining in the various coal formations.

EPA would not have to search very hard to find Information on flowback from CBM wells. Popa et al. (2003) report that many companies possess oil or gas-field databases that contain large amounts of information related to hydraulic fracturing.[93] For example, the Patina Oil and Gas fracturing database consists of 42 parameters including: Flowback Volume; Stimulation Sand Volume; Stimulation Fluid Volume; Refrac Sand Volume; Refrac Fluid Volume; and others. Unfortunately, EPA's study methodology did not include the collection or scrutiny of these data.

Instead of relying on a single published study on fracturing fluid flowback, which cannot possibly provide a solid scientific basis for concluding anything about fracturing fluid recovery, EPA needs to enter Phase II of its study and begin to collect and analyze actual field data.

3.1.2 EPA provides no data on the amount of individual hydraulic fracturing chemicals trapped in coal formations, even though it has been shown that chemicals do not flow back at equal rates.

The typical method for measuring flowback is to measure the "load water recovery," which is a measurement of the fluids pumped out of a well following a hydraulic fracturing treatment. One of the studies cited by EPA indicates that load water recovery does not accurately reflect the recovery of all hydraulic fracturing fluid chemicals. For example, if the measured fluid volume coming out of the well is 60% of what went in, it <u>does not mean that 60% of the injected fluids have been removed</u>. This flowback value may include water that originated from the formation itself.[94]

Willberg and coworkers observed that certain chemicals in hydraulic fracturing fluids were preferentially left behind in a non-CBM formation. They performed analyses of the load water recovered, and found that on average (based on sampling from 10 wells), only 35% of hydraulic fracturing polymer was recovered, compared with a 52% return of injected water.[95]

A similar phenomenon occurs in coal beds. Studies have shown that in some cases fracturing fluid gels are strongly trapped in formations. EPA cites a researcher who

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93 A. Popa, S. Mohaghegh, D. Shahab, R. Gaskari and S. Ameri. May, 2003. "Identification of Contaminated Data in Hydraulic Fracturing Databases: Application to the Codell Formation in the DJ Basin." Paper presented at the *Society of Petroleum Engineers (SPE) Western Regional/AAPG Pacific Section Joint Meeting* (Long Beach, California). SPE 83446.

94 According to Willberg et al. (1997): It is obvious . . . that water production is not a good indicator of actual fracture cleanup. Polymer analysis of the samples is required to quantify the recovery of residual fracturing fluid. (D.M. Willberg, R.J. Card, L.K. Britt, M. Samuel, K.W. England, K.E. Cawiezel, H. Krus. 1997. "Determination of the Effect of Formation Water of Fracture Fluid Cleanup Through Field Testing in the East Texas Cotton Valley." **<u>In</u>** Proceedings-SPE Annual Technical Conference and Exhibition, October 5-8, 1997. Publication by Society of Petroleum Engineers, SPE #38620. pp. 531-543.)

95 ibid.

directly observed (in a mined-through study) the existence of gel clumps within many coal bed fractures—in one instance, the observed concentration of gel in a fracture was 15 times the injected concentration.[96] Other researchers have conducted laboratory studies that have shown that gels injected into coal beds damage the formation by causing swelling of coal pores (known as the coal matrix) and by plugging natural fractures in coal beds (known as cleats); and they found that this sorption is highly irreversible.[97] Field studies have confirmed these observations.[98]

In the final study, EPA states that trapped gels may present a source of gel constituents to flowing groundwater.[99] Also, according to the EPA report some gel constituents are toxic to humans.[100] Consequently, trapped gels may be supplying toxic constituents to USDWs.

For many chemicals used in hydraulic fracturing operations, estimates of flowback are not available. In a document cited in the draft EPA study (but removed from the final version), Puri and coworkers reported that no accounting of the recovery of friction reducer chemicals has ever been made.[101] Clearly, EPA needs to gather additional information on the flowback rates of the various chemicals before determining that the trapped chemicals do not pose a threat to groundwater quality.

This type of chemical accounting should be routinely conducted by industry, as it is in the best interest of companies to analyze fluid and polymer returns. According to one researcher, analyzing flowback constituents is the only method to quantify fracture clean-up, which is in turn essential for improving well stimulation.[102] By not conducting these analyses, and correcting their practices based on the results, companies may be damaging the coal formations, and forever limiting the amount of gas that can be extracted. This issue was not addressed in the EPA study.

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[96] U.S. EPA. June, 2004. p. 4-15. Steidl, P.F. 1991. "Inspection of induced fractures intercepted by mining in the Warrior basin, Alabama." *Proceedings 1991 Coalbed Methane Symposium*. University of Alabama/Tuscaloosa. pp. 181-191.

[97] R. Puri, G.E. King, and I.D. Palmer. (Amoco Production Co.). 1991. "Damage to Coal Permeability During Hydraulic Fracturing." Paper presented at the *Rocky Mountain Regional Meeting and Low-Permeability Reservoirs Symposium,* Denver, CO, April 15-17, 1991. Society of Petroleum Engineers, SPE 21813. Also, P.J. Reucroft and K.B. Patel. 1983. "Surface Area and Swellability of Coal," *Fuel.* Vol. 62, p. 279-284. (Cited in Puri et. Al, 1991).

[98] Research in two basins (Warrior and San Juan) has shown that wells fractured with water produce more gas than those fractured with gels because the gel damages the coal formations and reduces the ability of the gas to flow. (I.D. Palmer, R.T. Fryar, K.A. Tumino, and R. Puri. 1991 "Comparison between gel fracture and water-fracture stimulations in the Black Warrior basin," *Proceedings 1991 Coalbed Methane Symposium.* University of Alabama/Tuscaloosa. pp. 233-242.)

[99] U.S. EPA. June, 2004. p. 4-15.

[100] See Table 4-2, in Section 2.3.1 of this review.

[101] R. Puri, G.E. King, and I.D. Palmer. (Amoco Production Co.). 1991. "Damage to Coal Permeability During Hydraulic Fracturing." Paper presented at the Rocky Mountain Regional Meeting and Low-Permeability Reservoirs Symposium, Denver, CO, April 15-17, 1991. Society of Petroleum Engineers, SPE 21813.

Another study, which was removed from the final EPA study, indicated there could be a separation of chemicals based on their weight or phase (i.e., gas versus liquid) when a branching of the flow path occurs (e.g., when a natural fracture is encountered. (R.M. Stahl and P.E. Clark. 1991, "Fluid Loss During the Fracturing of Coalbed Methane Wells," *Proceedings of the 1991 Coalbed Methane Symposium*. University of Alabama/Tuscaloosa, May 13-16, 1991).

[102] D.M. Willberg, R.J. Card, L.K. Britt, M. Samuel, K.W. England, K.E. Cawiezel, H. Krus. 1997. "Determination of the Effect of Formation Water of Fracture Fluid Cleanup Through Field Testing in the East Texas Cotton Valley." *Proceedings-SPE Annual Technical Conference and Exhibition*, October 5-8, 1997. Publication by Society of Petroleum Engineers, SPE #38620. pp. 531-543.

3.1.3 EPA does not provide any evidence to prove that concentrations of hydraulic fracturing fluid chemicals stranded in USDWs are safe.

EPA acknowledges that some hydraulic fracturing fluid constituents, in their pure form, are toxic to humans.[103] Also, the EPA study provides evidence that a portion of injected hydraulic fracturing fluids remains trapped in the fractured formations.[104] What remains unknown, however, is whether or not the concentrations of these trapped chemicals (i.e., the residual concentrations) are high enough to significantly degrade water quality and threaten human health.

- The EPA study fails to provide any evidence that the residual concentrations of chemicals in USDWs do not pose a threat to human health.
- The EPA study does not present <u>any</u> sampling data on residual concentrations of potentially toxic substances left in USDWs following hydraulic fracturing events.
- The study does not provide <u>any</u> groundwater sampling data on concentrations of hydraulic fracturing chemicals that find their way into adjacent groundwater-bearing formations after hydraulic fracturing occurs.
- The study does not reveal <u>any</u> EPA or state agency requirements for companies to conduct routine monitoring of groundwater during and after hydraulic fracturing operations.

EPA spends a great deal of effort providing theoretical explanations (see Section 3.2) as to why chemicals injected into coal formations do not pose a threat to groundwater quality. Theories, however, cannot substitute for the fact that <u>no studies have been conducted to determine actual concentrations of fracturing fluids in USDWs</u>.

Without these data there is no way to know for sure how great a threat is posed by the introduction of these substances into or near to USDWs. Thus, it is possible that many wells have been or are being affected, but citizens and state/federal agencies do not know it because contaminant monitoring programs have not be undertaken.

3.1.4 Information suggests that residual concentrations of fracturing fluids have been found in USDWs. EPA removed this information from the final study.

In the draft version of the EPA study, the attachment on the San Juan Basin contained the following sentence:

> *A few water samples from the Fruitland aquifer show possible evidence of residual contamination from previous fracturing treatments, suggesting that fracturing fluids might not always be fully recovered.*[105]

This was a passing comment, and no details were provided on which fracturing fluid constituents were found or the concentrations of those constituents. This critical information did not appear in the final version of the study, and no substantiation was given as to why the sentence was removed.

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[103] U.S. EPA. June, 2004. p. 4-9. Table 4-1.

[104] ibid. p. 3-11.

[105] U.S. EPA. August, 2002. A1-8.

The information is important because it may show that fracturing fluids have been detected in USDWs such as the Fruitland aquifer. If it has happened in the Fruitland aquifer, it is highly possible that it is happening in other areas as well. Clearly, more sampling to determine residual fracturing fluid is needed.

3.2 EPA uses a theoretical, best-case scenario, without any supporting data, to conclude that stranded fracturing fluids will not harm USDWs

EPA discusses a number of mechanisms that may cause fracturing fluids to remain trapped in underground formations:

1. Due to the high pressures used to fracture the formations, a portion of fluids may be transported beyond the "capture zone," which is the portion of the aquifer that contributes water to the well. Fluids that move beyond the capture zone generally are not recovered during the flowback process.[106]
2. Some fracturing fluid gels do not flow with groundwater during production pumping, and remain in the subsurface unrecovered.[107]
3. Fracturing fluids can be "lost" (i.e., remain in the subsurface unrecovered) due to "leakoff" into connected fractures and the pores of porous rocks.[108]
4. Movement and entrapment of fluids beyond the propped fractures may occur, due to narrowing of the fractures when injection ceases. This fluid likely cannot be recovered during normal flowback operations.[109]

EPA then argues that the processes of dilution, dispersion, adsorption and perhaps biodegradation will adequately decrease the levels of any chemicals that do not flow back to the well. For a number of reasons, EPA's analysis of the dilution, dispersion, adsorption and biodegradation is inadequate.

3.2.1 There are factors that counteract the effectiveness of dilution, dispersion, adsorption and biodegration processes.

EPA spends very little time addressing factors that may counteract the ability of dilution, dispersion, adsorption and biodegradation to reduce the concentrations of hydraulic fracturing chemicals that are stranded in underground formations. The only factors that EPA mentions are:

- Some adsorbed chemicals could desorb from coals and become mobile, and certain chemicals in trapped gels could be released from the gels, even though the gels themselves remain stranded.[110] (Thus, it is possible that the concentrations of chemicals may be higher than EPA predicts.)
- EPA mentions that the levels of oxygen in coal beds are likely to vary based on depth of coal bed from the surface. EPA then references a single study, which found that, "benzene in an anaerobic [no oxygen] environment indicates a range from no degradation to relatively slow degradation."[111] (Thus, the only biodegradation study cited by EPA suggests that due to lack of oxygen benzene will not degrade in some coal bed formations.)

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106 U.S. EPA. June, 2004. p. 4-15.

107 ibid. p. 3-13.

108 ibid.

109 ibid.

110 U.S. EPA. June, 2004. p. 4-15.

111 ibid. p. 4-17.

EPA does not mention the possibility that some byproducts of biodegradation could be more toxic than the originally injected chemicals. Not only may these byproducts be toxic to humans, they may also be toxic to the microbial organisms that biodegrade fracturing fluid chemicals. For example, according to the ASTDR, "Degradation of aromatic hydrocarbons, such as toluene, can yield phenolic and benzoic acid intermediates. Various microbial populations may be inhibited by compounds such as phenol and toluene, particularly at high concentrations."[112]

Additionally, EPA does not mention the fact that the presence of some heavy metals and elements, such as lead, zinc, copper, chromium, nickel, and cadmium, can reduce biodegradation rates. This is a relevant issue, since many coal formations contain these elements.[113] (See Section 2.3.4.)

The fate of chemicals injected into underground formations is complex, and EPA has not considered the full range of factors that can affect chemical concentrations, or the relative importance of the various processes in controlling the concentrations of chemicals in groundwater.

3.2.2 EPA fails to conduct scientific studies or modeling to determine residual chemical concentrations.

In the absence of scientific studies it is difficult to quantify the decrease in chemicals due to dilution, dispersion, adsorption and biodegradation. According to the California Department of Conservation, Division of Oil and Gas:

> *Groundwater recharge and movement can dilute a contaminant and, given enough time, spread it over large areas for a significant distance from the actual source point. . . Many studies have addressed this problem, but they basically concur that* ***precise conclusions cannot be made without adequate monitoring programs****.*[114] [emphasis included]

EPA, as well, admits that, "Although adsorption in coalbeds is likely, **quantification of adsorption is difficult in the absence of laboratory or site-specific studies.**"[115] [emphasis included] EPA does not, however, attempt to quantify the decrease in fracturing chemical concentrations, nor does the Agency provide any empirical data (e.g., from laboratory studies, computer models or direct field measurements) on the magnitude of the dilution, dispersion or adsorption of any hydraulic fracturing fluid constituents. Yet, despite the lack of actual data, "EPA expects fate and transport considerations would minimize the possibility that chemicals included in fracturing fluids would adversely affect USDWs."[116]

Realistically, in the absence of empirical data EPA is simply proposing a best-case scenario, whereby chemicals may be: 1) diluted by regional groundwater flows, thus

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[112] Agency for Toxic Substances and Disease Registry. 1999. *Toxicological Profile for Total Petroleum Hydrocarbons.* p. 75. http://www.atsdr.cdc.gov/toxprofiles/tp123.html

[113] ibid.

[114] D.C. Mitchell. 1989. *The Effects of Oilfield Operations on Underground Sources of Drinking Water in Kern County.* California Department of Conservation, Division of Oil and Gas. Publication No. TR36. p.4. In the report, the author cites 13 studies to this effect.

[115] U.S. EPA. June, 2004. p. 4-15.

[116] U.S. EPA. June, 2004. p. 4-17.

decreasing their concentrations in groundwater; 2) dispersed or diffused throughout the aquifer, thus lowering the concentration in any one place; 3) adsorbed or attached to the coals and not mobilized by groundwater flows; and 4) biodegraded by microbes (without producing toxic by-products).

In this best-case scenario, EPA assumes that dilution, dispersion, adsorption and biodegradation will effectively decrease chemical concentrations if 18-32% of the fluids remain trapped underground, as predicted by Palmer. But what if 50% or more of the fluids remain stranded in the coal formations? Will dilution, dispersion, adsorption and biodegradation still reduce chemicals to safe levels?

Clearly, EPA needs to validate their theory by establishing a monitoring program to sample groundwater, over time, for chemicals known to be constituents of hydraulic fracturing fluids; or at least attempting to model the physical and chemical fate of chemicals injected underground. In other words, EPA needs to conduct Phase II of its study, and incorporate these types of analyses into the Phase II study design.

3.3 EPA fails to examine long-term impact of fluids stranded in CBM formations

3.3.1 EPA does not know what effect groundwater recharge will have on the fracturing fluids that accumulate in dewatered coal formations.

EPA's best-case scenario implies that if 18-32% of the fluids remain underground, that dilution, dispersion, adsorption and perhaps biodegradation will reduce the concentration of the chemicals such that they won't pose a threat to USDWs. This best-case scenario fails to consider a longer-term view of the chemical fate and transport of these fluids.

This is an especially important issue on a regional level, where the pumping of groundwater during CBM production lowers groundwater tables (sometimes by hundreds of feet). In some areas, thousands of CBM wells have been or will be hydraulically fractured, and some will be fractured several times over the course of production. (See Section 3.3.2.) Thus, cumulatively, there could be large volumes of trapped hydraulic fracturing fluids that may become mobilized as groundwater tables return to pre-development levels.

The issue of long-term mobilization of stranded hydraulic fracturing fluids is potential concern in the San Juan Basin, where hydraulic fracturing is occurring and is likely to increase in coal beds that are USDWs.

CASE STUDY: How much fracturing fluid is stranded in Northern San Juan Basin (NSJB) coals? What are the consequences of this?

The primary coal formation utilized for coalbed methane production in the Northern San Juan Basin (NSJB) is the Fruitland Coal Formation, parts of which are considered underground sources of drinking water.[117]

It has been reported that the hydraulic fracturing of one CBM well in the San Juan Basin uses between 55,000 to 300,000 gallons of stimulation and fracturing fluids.[118] For each fractured well in the San Juan Basin, it is possible that between 9,900 and 96,000 gallons of fracturing fluids are remaining underground per fractured well.[119]

According to EPA, about 2,550 wells were operating in the San Juan Basin in 2001, and about half of those wells were fractured using conventional hydraulic fracturing methods.[120] Consequently, between 12 million and 122 million gallons of fracturing fluids are likely stranded in San Juan Basin coals.[121]

The Bureau of Land Management and U.S. Forest Service predict that CBM development in the NSJB will increase drawdown of shallow groundwater resources, and that drawdown will likely cause water wells to go dry.[122] Eventually, the Fruitland aquifer system should be restored to pre-development levels and domestic wells should once again be able to provide a supply of drinking water.[123] As this occurs, will the rise in groundwater cause a mobilization of millions of gallons of stranded fracturing fluids?

In the draft EPA study, the discussion on the San Juan Basin (SJB) included the following quotations:

> *A few water samples from the Fruitland aquifer show possible evidence of residual contamination from previous fracturing treatments, suggesting that fracturing fluids might not always be fully recovered.*[124]
>
> *. . .fracturing fluids in coal can penetrate into the surrounding formations. . . when fracturing ceases and production resumes, these chemicals may not be entirely pumped back out of the coalbed methane well, and . . . therefore might be available to migrate through the aquifer.*[125]

Thus, it was recognized that stranded fluids might be able to migrate through the Fruitland aquifer in the San Juan Basin. Consequently, on a regional level it is possible that drinking water wells could become contaminated with hydraulic fracturing fluid chemicals as groundwater levels rise in the Fruitland formation.

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117 U.S. EPA. June, 2004. p. A1-4.

118 I.D. Palmer, S.W. Lambert and J.L. Spitler. 1993. "Coalbed methane well completions and stimulations." *AAPG Studies in Geology 38.* Chapter 14, pp. 303-341.

119 Using Palmer's flowback numbers, between 68 and 82% of fluids may be recovered over the lifetime of the well, which means that between 18% and 32% of injected fracturing fluids remain stranded underground. **Calculation:** Minimum value is 18% of 55,000 gallons injected = 9,900 gallons stranded. Maximum value is 32% of 300,000 gallons injected = 96,000 gallons stranded.

120 U.S. EPA. June, 2004. pp. A1-5, A1-6.

121 **Calculation:** Minimum value is 9,900 gallons of hydraulic fracturing fluid stranded per well multipled by 1,225 wells (1/2 of 2,550 wells) = 12,622,500 gallons stranded. Maximum value is 96,000 gallons * 1,225 wells = 122,400,000 gallons stranded in the San Juan Basin.

More than one hydrogeologist commenting on the draft EPA study raised concerns about the potential long-term implications of residual fracturing fluid mobilization with EPA.[126] The following quotation comes from Wayne Van Voast, senior hydrogeologist with the Montana Bureau of Mines and Geology:

> *The study does not consider the fate of fracture-fluid residuals after decommission of the wells. When hydrostatic pressures recover sufficiently, the residuals will become mobilized in the Powder River Basin's fresh-water regimen that we have already demonstrated to be an active flow system. Twenty or fifty years from now these aquifers will be far more important than they are today, and to have left them contaminated with residuals from hydrofracturing would only be seen as a stupid and costly mistake. It can only be concluded that hydrofracturing in the Powder River Basin must be done only with fresh water, or not at all.* ***If the EPA will properly address this issue, they will look beyond the period of gas production; they will assign hydrological expertise to the inquiry; and they will acknowledge the dynamic ground-water flow in these aquifers.***[127] [emphasis added]

The concerns expressed by Van Voast and others were not addressed in the final study, or in EPA's response to public comments.

3.3.2 EPA does not seriously address the issue of residual fracturing fluids left when wells are fractured more than once; or the effect of infilling as CBM basins mature.

EPA cites numerous scientific papers as reporting that many coalbed methane wells are fractured more than once.[128] The final EPA study does not, however, address how multiple fracturing operations affect the amount of fracturing fluids stranded in the formation.

During CBM development, groundwater (known as produced water) is pumped from the coal formation to reduce the pressure that is holding the methane to the coal. This pumping of groundwater is one of the mechanisms that EPA mentions as a means of reducing the amount of fracturing fluid that remains in the formation. According to EPA, "The recovery process typically lasts approximately 10-20 years. During that time, groundwater within the production well's capture zone flows toward the production well."[129]

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122 U.S. Dept. of Interior, Bureau of Land Management; U.S. Dept. of Agriculture, Forest Service. June, 2004. *Northern San Juan Basin Coal Bed Methane Project Draft Environmental Impact Statement.* Volume I. p. 3-69.

123 ibid. p. 3-78.

124 U.S. EPA. August, 2002. Attachment 1 "San Juan Basin." p. A1-9.

125 ibid. p. A1-7 and A1-8.

126 E.g., Letter from Dr. John Bredehoeft, hydrogeological consultant and 32-year-veteran of the U.S. Geological Survey to Joan Harrigan-Farrelly, Chief, Underground Injection Control, Prevention Program, EPA. May15, 2003. Water Docket ID No. W-01-09-11. http://www.ogap.org/2003ExpertComments-Fracing.htm

127 Letter from Wayne Van Voast, Montana Bureau of Mines and Geology to EPA. Oct. 16, 2002. Water Docket ID No. W-01-09-11. Document No. OW-2001-0002-0111.

128 According to these studies, wells may be refractured in an effort to re-connect the well bore to the production zones, or to overcome plugging or other well problems. Also, where coal seams are thin and vertically separated by up to hundreds of feet of intervening rock, operators may perform several fracture treatments within a single well to produce methane in an economically viable fashion. (U.S. EPA. June, 2004. p. 3-5.)

129 U.S. EPA. June, 2004. p. 4-16.

If wells are fractured later in a well's life, however, it is likely that there will not be as much groundwater flow in the vicinity of the well (since CBM produced water decreases over the life of the well). Thus, groundwater will not transport as much of the injected fluid back to the production well, and a greater portion of the chemicals will remain stranded. It is possible that these chemicals will not be mobilized by groundwater until regional groundwater level returns to pre-development levels.

Another issue that is not considered by EPA is the effect of adding hundreds or thousands of additional wells in CBM basins. Typically, as CBM regions mature, coalbed methane wells are developed at a higher density (i.e., CBM fields are downspaced or infilled). As infilling occurs more fracturing fluids are going to be stranded in the same formations, some of which are USDWs. So perhaps the fracturing fluids are not yet at a concentration that is causing noticeable harm, but with the addition of hundreds or thousands of wells in an area, the concentrations may begin to cause harmful effects.

Without data on the amount of fluids trapped underground, the concentrations of hydraulic fracturing fluid chemicals in groundwater, knowledge of the toxicity of the fracturing fluids constituents, and a clear understanding of the fate and transport of these fluids through USDWs, it is extremely premature for EPA to conclude that the fracturing of hundreds or thousands of wells will have no impact on USDWs. Unfortunately, with EPA's decision to halt the study of potential contamination caused by hydraulic fracturing, there is no regulatory body that will be monitoring contaminant concentrations over time.

3.4 EPA does not discuss the toxicity of produced water that contains residual fracturing fluids

According to information in the EPA study, a portion of hydraulic fracturing fluids flow back to the well over a relatively short timeframe (on the order of weeks). Of the chemicals that remain underground, a portion will be removed along with produced water.[130] The latter process may last from 10 to 20 years.[131]

If toxic chemicals are being removed along with produced water, it is likely that the concentrations will be relatively low, but, sustained over numerous years. EPA does not discuss the ramifications of hydraulic fracturing chemicals that are removed along with produced water.

In a white paper on produced water, the Argonne National Laboratory reports that several chemicals used during hydraulic fracturing (i.e., biocides, corrosion inhibitors, breakers, organic components such as benzene and naphthalene) may present a source of toxicity in produced waters, and that "some of these treatment chemicals can be lethal at levels as low as 0.1 parts per million."[132] (EPA does not cite

[130] Produced water is groundwater that is pumped from the coal formation in order to release hydrostatic pressure in the formation. Reduction of this pressure allows the methane to flow to the well.

[131] U.S. EPA. June, 2004. p. 4-16.

[132] J.A. Veil, M.G. Puder, D. Elcock and R.J. Redweik Jr. 2004. *A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas and Coalbed Methane.* Prepared for U.S. Department of Energy by Argonne National Laboratory. pp. 7,8.

this paper.) As well, hydraulic fracturing treatments that use acid may increase the concentration of metals in produced water. (See Section 2.3.4, above.)

No measurements of the concentrations of fracturing fluid chemicals or associated contaminants in produced water are provided in the EPA study. This is important information, as the toxicity of produced water could provide insight into the toxicity of groundwater that may be used as drinking water; and the disposal of produced water has potential environmental and human health implications.

In some states, produced water may be disposed of in streams. Low levels of chemicals that are introduced into aquatic environments over long periods of time may produce chronic effects in aquatic organisms. Some chemicals accumulate in sediments; some bioaccumulate (i.e., build up) in the tissues of organisms; and some biomagnify (i.e., organisms higher on the food chain accumulate toxic chemicals from the organisms that they feed on). The Argonne National Laboratory reports that:

> *In areas where CBM produced waters have dissolved constituents that are greater than those in the receiving waters, stream water quality impacts are possible.*[133]

In other states, surface disposal of produced water is allowed. According to the Argonne National Laboratory:

> *Surface discharges of CBM produced water can cause the infiltration of produced water contaminants to drinking water supplies or sub-irrigation supplies.*[134]

Produced water may also be injected underground. Thus, it may be that the hydraulic fracturing fluids are removed from the coal formation in the produced water, only to return underground via injection wells. According to a 1989 study by the U.S. General Accounting Office, there have been numerous cases of contamination from oil and gas produced water injection wells. In several cases, produced water has contaminated drinking water supplies by entering USDWs through abandoned oil and gas wells; or through leaks in the injection casing.[135]

EPA does not address any of these issues in its study. These issues, however, are relevant to those who live in oil and gas development areas that utilize hydraulic fracturing as a stimulation method.

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133 ibid. p. 13.

134 ibid.

135 United States General Accounting Office. July, 1989. *Drinking Water – Safeguards Are Not Preventing Contamination From Injected Oil and Gas Wastes*. Report to the Chairman, Environment, Energy and Natural Resources Subcommittee, House of Representatives. GAO/RCED-89-97. p. 26

4. Fracture Behavior: unpredictable

In Chapter 3 of the final study, EPA explains the importance of examining fracture behavior:[136]

> *Fracture behavior is of interest because it contributes to an understanding of the potential impact of fracturing fluid injection on USDWs. . . the following scenarios are of potential concern:*
>
> - *The hydraulically induced fracture may extend from the target formation into a USDW.*
> - *The hydraulically induced fracture may connect with natural (existing) fracture systems and/or porous and permeable formations, which may facilitate the movement of fracturing fluids into a USDW.*

As outlined below, the best available data (i.e., direct observations) show that in some basins fractures can and do extend out of coalbeds, creating pathways for chemicals to move into adjacent aquifers. Fractures, however, behave differently in different basins – so these data cannot be applied to all CBM basins. What is clear from the EPA study is that fracture behavior is poorly understood, primarily because operators do not perform the more expensive tests that would provide them with reliable fracture data.

4.1 Fractures and fracturing fluid can move out of target formations

4.1.1 The EPA presents data that show that hydraulic fracturing fluids follow natural fracture systems in the coal, and that the fluids are able to move out of coal beds into adjacent formations.

EPA cites several "mined-through studies"[137] conducted in Pennsylvania, Alabama, West Virginia, Illinois, Virginia, Utah, and Australia.[138] These studies provide unique information because they allow the direct measurement of hydraulically induced fractures in coal seams and surrounding strata, and allow observation of the movement of proppant and fracturing fluid through induced and natural fractures (e.g., fluorescent paint can be injected with the fracturing fluid to allow mapping of fluid movement).

Mined-through studies have demonstrated that hydraulic fractures can connect with natural fracture systems, and that fracturing fluids can move into formations other than the targeted coal formation. These studies do not necessarily reflect what might happen in all coalbed methane basins (no mined-through studies have been conducted in the San Juan and Powder River Basins), but they provide the best information presented in the EPA study. The following quotations are from EPA's study:

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136 U.S. EPA. June, 2004. pp. 3-5, 3-6.

137 Mined-through studies involve the mining of subsurface coal seams that have been previously hydraulically fractured. This allows direct access to fractures for measurement. (U.S. EPA. June, 2004. p. 3-16.)

138 "Twenty-two coalbeds were hydraulically fractured, subsequently mined-through, and investigated several months to several years later in Pennsylvania, Alabama, West Virginia, Illinois, Virginia, and Utah (Diamond 1987a and b; Diamond and Oyler 1987). Similar studies have been conducted by Jeffrey et al. (1993) in Queensland Steidl (1991a; 1991b; 1993) in the Black Warrior Basin, Alabama." (U.S. EPA. June, 2004. p. 3-16.)

- *Importantly, in several locations in the Diamond (1987a and b) study sites, fluorescent paint was injected along with the hydraulic fracturing fluids and the paint was found in natural fractures from 200 to slightly more than 600 feet beyond the sand-filled ("propped") portions of hydraulically induced or enlarged fractures.* ***This suggests that the induced/enlarged fractures link into the existing fracture network system and that hydraulic fracturing fluids can move beyond, and sometimes significantly beyond, the propped, sand-filled portions of hydraulically induced fractures****.*[139] [emphasis added]

- *Diamond and Oyler (1987) also noted that this* ***opportunistic enlarging of preexisting fractures appears to account for those cases where hydraulic fractures propagate from the targeted coalbeds into overlying rock****.*[140] [emphasis added]

- ***Jeffrey et al. (1993) found that most of the proppant in three of their four treatments was found in the roof rock*** *[the rock overlying the coal in the mined areas]. Thus, mined-through studies in Australia and in six states in the United States found that* ***hydraulic fracturing fluids penetrated into, and, when shales were very thin, through strata surrounding coalbeds in 50 percent of stimulations in the United States*** *and 75 percent of the stimulations in Australia.*[141] [emphasis added]

- ***Penetration into layers above the coal was observed in more than 80 percent of the fractures intercepted by mines underground in the Black Warrior Basin.*** *Some fractures continued completely through very thin shales.*[142] [emphasis added]

As mentioned above, information in these studies comes from direct observation of fractures, and thus, is the best available information on fracture behavior. These studies demonstrate that fluids can enter USDWs if the sources are located adjacent to the coal formations being fractured.

In the draft version of EPA's study, the Agency admitted that "Hydraulic fractures can, and sometimes do, extend "out of zone"; indeed, fracture excursions out of zone are an area of interest in the energy industry."[143] The Agency removed this statement from the final study.

4.1.2 It is suspected that hydraulic fracturing has created connections between coal seams and adjacent aquifers in the Raton Basin.

In Chapter 7 of the study, EPA states that hydraulic fracturing:

> *. . .may have increased or have the potential to increase the communication between coal seams and adjacent formations in some instances. For example, in the Raton Basin, some fracturing treatments resulted in higher than expected withdrawal rates for production water. Those increases, according to literature*

139 U.S. EPA. June, 2004. p. 3-8.

140 ibid.

141 U.S. EPA. June, 2004. p. 3-17.

142 ibid. p. 2-4.

143 U.S. EPA. August, 2002. p. 6-8.

*published by the Colorado Geologic Survey, **may be due to well stimulations creating a connection between targeted coal seams and an adjacent sandstone aquifer.***[144] [emphasis added]

4.1.3 Fracturing fluids have been observed leaving coal formations and entering sandstones in the San Juan Basin.

It is unclear whether EPA, during its literature review, came across a study conducted by the Gas Research Institute (GRI), Phillips Petroleum Co. and Amax Oil and Gas Inc. (hereafter referred to as the GRI et al. study) related to hydraulic fracturing in the San Juan coalbed methane basin. No mention of the study is made in the draft or final EPA study. The absence of the GRI et al. study calls into question the thoroughness of EPA's literature review.

The GRI et al. study provides additional information to support the mined-through study findings, i.e., that fracturing fluids enter formations adjacent to coal formations. The authors of the GRI et al. study report that:

> *. . .over one-half the injected fluid volume was displaced below the coal intervals [into a sandstone strata] during fracturing. . . drillstem test results had indicated that the sandstone was of low permeability."*[145]

This study is important for a number of reasons. First, it reveals that the companies' predictions of fluid movement based on permeability of sandstone were wrong – the fluids entered the sandstone despite the fact that drillstem tests indicated the sandstone was of low permeability. This highlights the uncertainty with hydraulic fracturing injection. Oil and gas operators may think they know what is going to happen to fluids when injected underground, but in reality fracturing fluids may behave quite differently than predicted.

Second, the GRI et al. study provides additional proof that fracturing fluid is not always confined by sandstone formations. The ramifications of this could be quite significant, considering that many coal seams in the San Juan Basin are bounded by sandstone, and in other coalbed methane basins sandstone and coals are interbedded.[146]

This study from the San Juan Basin, when combined with the data from the mined-through studies from coal mines in several eastern states and Utah, provides irrefutable evidence that hydraulic fracturing fluids are not always confined to the coal beds into which they are injected.

4.1.4 Industry literature warns oil and gas operators that fractures can extend through shales and into water-bearing zones.

In its conclusions, EPA states that "the low permeability of relatively unfractured shale may help to protect USDWs from being affected by hydraulic fracturing fluids in some basins. At some sites, shale may act not only as a hydraulic barrier, but also as a

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[144] U.S. EPA. June, 2004. p. 7-4.

[145] Logan, T.L. "Preliminary results of cooperative research efforts with Phillips Petroleum Company and Amax Oil and Gas Inc., San Juan Basin." *Quarterly Review of Methane from Coal Seams Technology.* April 1994. 11(3&4): 39-49.

[146] U.S. EPA. June, 2004. pp. 3-7, 3-8.

barrier to fracture height growth."[147] EPA does not provide an analysis of how many CBM basins have shale of high enough quality to act as a hydraulic barrier.

Interestingly, when oil and gas operators communicate among themselves, they admit that risks exist with hydraulic fracturing, even when shale is present. In 2003, the Petroleum Technology Transfer Council produced a manual for independent oil and gas operators. In the section discussing "unexpected increases in water production," the author cautions operators that shale may not prevent the movement of fractures and fluids. The manual states that:

> *Even if natural barriers, such as dense shale layers, separate the different fluid zones and a good cement job exists, shales can heave and fracture near the wellbore. . .**often, this type of failure is associated with stimulation attempts. Fractures break through the shale layer, or acids dissolve channels through it**. . .*
>
> ***An improperly designed or poorly performed stimulation treatment can allow a hydraulic fracture to enter a water zone**. If the stimulation is performed on a producing well, an out-of-zone fracture can allow early breakthrough of water. . . many operators tag the tail end of their proppant with radioactive tracer, so if the well does not respond as anticipated, they can log the well to determine where the fracture went.*[148] [emphasis added]

Industry is willing to admit that hydraulic fracturing stimulations can penetrate into water-bearing formations. Yet EPA, without having the hydraulic fracturing experience that industry possesses, is downplaying the same risks.

4.1.5 Movement of fluids into USDWs is not allowed under any other UIC programs.

As mentioned above, the movement of hydraulic fracturing fluids out of the targeted coal zones is problematic in that contaminants can be transferred from one formation to another. It is especially problematic if a formation adjacent to a fractured coal bed is an underground source of drinking water.

The seriousness of this issue is addressed under some of EPA's Underground Injection Control regulations. When hazardous and nonhazardous substances are injected underground (via Class I wells), operators are not allowed to inject directly into a USDW. More importantly, operators must <u>prove that injection occurs below all USDWs</u> in the vicinity, <u>and that there is a confining layer between the injection zone and any USDW</u>, to prevent upward movement of injected materials.[149] (See Section 5.4.1 for a more in-depth discussion of this issue.)

Instead of applying similar safeguards to protect drinking water supplies from potentially hazardous fracturing fluids, and instead of addressing the fact that fracturing fluids can and do move out of coal beds into USDWs, EPA simply assumes

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147 U.S. EPA. June, 2004. p. 7-4.

148 Rodney R. Reynolds. 2003. *Produced Water and Associated Issues -- Manual for the independent operator.* Prepared for the South Midcontinent Region of the Petroleum Technology Transfer Council (PTTC) and Oklahoma Geological Survey (OK Geological Survey Open-file Report 6-2003). http://www.pttc.org/pwm/pw_stoc.htm#toc2

149 U.S. Environmental Protection Agency. 2001. *Class I Underground Injection Control Program: Study of the Risks Associated with Class I Underground Injection Wells.* EPA 8160-R-01-007. p. 18.

that the migration of fluids will not harm USDWs.[150] EPA is being extremely negligent in its responsibility to protect the safety of underground drinking water supplies.

4.2 Fracture behavior is poorly understood

From the information provided in Chapter 3 of the EPA study, it is obvious that fracture behavior is not well understood. Industry groups have also admitted the need to gain a greater understanding of fracture behavior associated with coalbed methane development. In 2002, the Gas Technology Institute and New Mexico Tech held focus groups with natural gas producers across the country. The San Juan Basin focus group reported that:

> *The unpredictability of hydraulic fracture response in coalbed methane wells leads to a need for diagnostics to improve the understanding of CBM well completions.*[151]

In a 2003 report, the hydraulic fracturing company Schlumberger, wrote that:

> *. . .complex stress profiles and coal fracture systems make hydraulic fracture propagation in and around coals difficult to simulate.*[152]

EPA agrees that fracture propagation is difficult to simulate. In the final report, EPA does not include vertical fracture height data that was in the draft version of the study because EPA decided that fracture simulations based on computer models were unreliable. (See Section 5.2.1 for more information.)

Based on the lack of data presented by EPA, the reader is left with very little understanding of fracture behavior, other than the fact that it is not predictable and it varies greatly from one geological setting to the next. The dearth of information raises the question: <u>If EPA and hydraulic fracturing companies do not fully understand fracture behavior, how can they pretend to know what is happening to injected fracturing fluids?</u>

4.2.1 EPA does not provide reliable data on fracture height and length – because techniques for measuring fractures, although available, are not widely used.

EPA acknowledges the importance of understanding fracture height in the statement:

> *Because fractures can possibly connect with or even extend into USDWs, fracture height is relevant to the issue of whether hydraulic fracturing fluids can affect USDWs.*[153]

Despite the stated importance of understanding the extent to which fractures penetrate formations above and below coal beds, <u>no actual measured fracture heights are reported in the EPA study</u>.

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[150] U.S. EPA. June, 2004. p. 7-5.

[151] Engler, T., and Perry, K. "Creating a Roadmap for Unconventional Gas R&D," *GasTIPs*. (U.S. Department of Energy, Strategic Center for Natural Gas, and Gas Technology Institute). Fall, 2002.

[152] Anderson, J., Simpson, M., Basinski, P., Beaton, A., Boyer, C., Bulat, D., Ray, S., Reinheimer, D., Schlachter, G., Colson, L., Olsen, T., John, Z., Khan, R., Low, N., Ryan, B., Schoderbek, D. August, 2003. "Producing Natural Gas from Coal." *Oilfield Review.* (Published by Schlumberger) http://www.slb.com/oilfield/index.cfm?id=id1614236

[153] U.S. EPA. June, 2004. p. 3-15.

EPA makes general statements about fracture height based on data from mined-through studies conducted in several U.S. coal basins. Unfortunately, the vertical measurements in the mined-through studies did not measure how far the fractures extended into the overlying formations, so total vertical fracture height was not reported.[154]

EPA spends five pages discussing the various ways in which fractures can be measured, and states in the summary of Chapter 3 that:

> *. . .a significant amount of diagnostic research has been conducted in the last decade enabling industry to develop a practical, applied understanding of general fracture behavior as it relates to methane production. . . reliable fracture height and length can be measured accurately by microseismic monitoring and tiltmeters (Warpinksi, 2001).*[155]

If a significant amount of diagnostic research has been conducted in the last decade, and reliable microseismic and tiltmeter technologies can measure fracture height and length, why does EPA not present data from this research? One sentence in Chapter 3, is a possible explanation as to why no data are presented by EPA:

> *. . .fracture diagnostic techniques can provide important data . . . however, for coalbed methane wells, where costs must be minimized to maintain profitability, the best fracture diagnostic techniques are rarely used.*[156]

EPA does not provide reliable data on fracture height in coal beds,[157] and thus, the Agency fails to prove that vertical fractures created during hydraulic fracturing are not a concern. Based on the lack of fracture data presented in the EPA report, the Agency's conclusions should have been that there is a dearth of information on coalbed methane fracture behavior; and that there is not enough information to conclude that fluids will remain confined to the fractured coal beds. Yet instead of requiring more studies to provide reliable information, EPA chooses to downplay the importance of this issue.

4.2.2 Almost all of the statements regarding fracture behavior in the EPA study do not hold true for all situations.

Another point that becomes clear from reading Chapter 3 of the EPA study is that geology is an extremely important control on fracture behavior. Consequently, what occurs in one CBM basin may not hold true for the entire basin, and most likely does not apply to other CBM basins.

Below are some quotations from the EPA study that outline the unpredictability of fracture behavior and fluid movement in coal beds and surrounding geological formations:

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[154] ibid. p. 3-17.

[155] ibid. p. 3-23.

[156] ibid. p. 3-20.

[157] One of the peer reviewers for the EPA study, Norm Warpinski, expressed concerns about the fracture data in a letter to EPA. In the letter he states: "**the information on fracture height in this report is unreliable** and I would not want a future regulator to use such information to proclaim rules on how far CBM fractures should be from a USDW." [emphasis added] (Comments on Docket No. W-01-09-II Hydraulic Fracturing of Coalbed Methane Wells Report. October 21, 2002.) http://docket.epa.gov/edkpub/do/EDKStaffAttachDownloadPDF?objectId=090007d4800f3c29

- *The low permeability of relatively unfractured shale* ***may*** *help to protect USDWs from being affected by hydraulic fracturing fluids in some basins.* ***If*** *sufficiently thick and relatively unfractured shales are present, they* ***ma****y act as a barrier not only to fracture height growth, but also to fluid movement. The degree to which any formation overlying targeted coalbeds will act as a hydraulic barrier* ***will depend on site-specific factors****. The lithology of coalbeds and surrounding formations is variable in the basins where coalbed methane is produced. Although common, the idealized coal cycle (with shales overlying coalbeds)* ***is not always present*** *in all coal basins or necessarily in all parts of any basin.*[158] [emphasis added]

- ***Although Holditch (1993) states*** *that fracture heights can grow where the coal seam is bounded above or below by sandstone,* ***Warpinski (2001) states*** *that highly layered formations or very permeable strata, such as some sandstones, can act to inhibit fracture growth.*[159] [emphasis added]

- *Differences in fracture behavior* ***may also be due in part*** *to very small (but influential) layers or irregularities that exist in the rocks as part of the sedimentation process that created them. Therefore, a valid measurement of* ***rock properties relevant to fracture behavior at one location may not adequately represent the properties of similar rock at another location****. . . For example, the presence of a shallow clay layer as thin as 10 millimeters at the upper contact of a coal seam can cause a vertically propagating, shallow hydraulic fracture to "turn" horizontal and fail to penetrate the next overlying coal seam. . .* ***In other cases****, hydraulic fractures may penetrate into or even, as shown in the case of some thin shales, completely through overlying shale layers . . .Warpinski et al. (1982) found that even microscopically thin ash beds can influence hydraulic fracture propagation.*[160] [emphasis added]

- ***Aspects of fracture behavior****, such as fracture dimensions (height, length, and width),* ***are affected by the different fracturing approaches*** *taken by the operator during a hydraulic fracturing event. Generally, the larger the volume of fracturing fluids injected, the larger the potential fracture dimensions. Fluid* ***injection rates and viscosity can also affect fracture dimensions****. . . Gelled water treatments may result in the widest and longest fractures, but this occurrence* ***cannot be concluded with certainty*** *from the mined-through studies.*[161] [emphasis added]

Based on this information, it is clear that fracture behavior is highly variable. This highlights the importance of conducting fracture diagnostic tests throughout all CBM basins, rather than relying on assumptions about how fractures are going to behave. As mentioned above, EPA removed information on vertical fracture heights because of lack of reliable data (i.e., based on something other than computer models). Until more reliable data on fracture behavior become available, EPA cannot substantiate its claim that hydraulic fracturing does not pose a threat to USDWs.

[158] ibid. p. 3-7.
[159] ibid. p. 3-8.
[160] ibid. p. 3-8.
[161] ibid. p. 3-10.

5. Critique of EPA's Study and Analyses

There are many problems with the EPA study and how the Agency came to its conclusion that hydraulic fracturing poses little or no risk to drinking water. Problems ranging from lack of data to inconsistent application of environmental safeguards are discussed below.

5.1 Data gaps plague EPA study

A thorough read of EPA's study reveals that there is little empirical data on which to base a conclusion that hydraulic fracturing chemicals do not pose a threat to USDWs. Data problems mentioned in this report are summarized in Table 7, below.

TABLE 7. DATA CONCERNS WITH THE EPA HYDRAULIC FRACTURING STUDY.

Issue of concern	Problems with the data	Where in this report to find more information
Hydraulic fracturing fluids	Lack of comprehensive data on the array of chemical constituents in hydraulic fracturing fluids	Section 2.3.1
	Lack of acute and chronic toxicity data, as well as immunotoxicity, carcinogenicity, genotoxicity, endocrine disruption and developmental and reproductive data for individual hydraulic fracturing chemical constituents	Section 2.3.2
	No toxicity data for mixtures of hydraulic fracturing chemicals	Sections 2.3.2 and 2.3.3
	No information on hazards associated with acid fracturing	Section 2.3.4
	No information on toxicity of hydraulic fracturing wastes	Section 2.2.5
Fracturing fluid recovery	Only one study on the volume of fluid that flows back to CBM wells	Section 3.1.1
	No data on the preferential trapping of certain chemicals in coals	Section 3.1.2
	No data on the concentrations of fracturing chemicals left in coals (i.e., residual chemicals)	Section 3.1.3
	No empirical data on the fate and transport of chemicals that are stranded in coal formations	Section 3.2
	No data on the effect of groundwater recharge on contaminant concentrations	Sections 3.3.1 and 3.3.2
	No data on the concentration of hydraulic fracturing chemicals recovered in produced water	Section 3.3.3
Fracture behavior	Fracture behavior data are not relevant for all situations	Section 4.2.2
	No data on vertical fracture heights	Section 5.2.1

In the final study, EPA, itself, acknowledges deficiencies in the existing research.

> *Most of the literature pertaining to fracturing fluids relates to the fluids' operational efficiency rather than their potential environmental or human health impacts.* ***There is very little documented research on the environmental impacts that result from the injection and migration of these fluids into subsurface formations, soils, and USDWs.***[162] [emphasis added]

An absence of scientific data on the impact of hydraulic fracturing on the environment does not equate with an absence of threat to the environment and human health. It simply means that industry, academics and government researchers have not asked the right research questions to determine the impacts of hydraulic fracturing. It is very obvious, after reading the EPA study, that Phase II of the study is necessary to fill in data gaps, and to conduct a more realistic analysis of the threats posed by hydraulic fracturing.

5.2 EPA selectively includes and excludes information that does not have scientific studies or data to back it up

The following examples highlight the inconsistency of EPA's data analysis approach. EPA gives vastly different emphasis and weight to information that does not have scientific studies to back it up. Interestingly, the data that are included or highlighted tend to support EPA's findings, while the data that are excluded or downplayed counter EPA's conclusions.

5.2.1 Vertical fracture data — EXCLUDED.

When formations are hydraulically fractured, the fractures extend both horizontally and vertically away from the well bore. If a formation being fractured is located below or above a drinking water aquifer the vertical extent of the fracture becomes critical in assessing whether or not fracturing fluids will contaminate the USDW.

In the draft version of EPA's study, EPA reports that:

> *<u>Vertical fracture heights in Alabama basins have been measured in excess of 500 feet. . . and fracture heights of 300 feet are considered typical</u> (Holditch et al., 1989; Lambert et al., 1989; Ely et al., 1990; Saulsberry et al., 1990; Palmer and Sparks, 1990; Spafford, 1991; Palmer et al., 1991 and 1993; Spafford et al., 1993; Gas Research Institute, 1995).*[163] [emphasis added]

No data on actual vertical fracture height appear in final version of EPA's study. In its response to public comments, EPA states that the reference to vertical fractures extending more than 500 feet was removed because it reflected "modeled estimates, rather than direct measurements."[164]

In Chapter 3 of the study, EPA states the importance of understanding fracture height:

162 ibid. p. 4-1.

163 U.S. EPA. August 2002. Chapter 5, "Summary of Basins," p. 5-3; and Attachment 2, "Black Warrior Basin," p. A2-6.

164 U.S. EPA. June 2004. "Public Comment and Response Summary for Hydraulic Fracturing CBM Study." p. 21.

Because fractures can possibly connect with or even extend into USDWs, fracture height is relevant to the issue of whether hydraulic fracturing fluids can affect USDWs.[165]

The fact that there are no data on vertical fractures other than modeled simulations might prompt some scientists to conclude that more research into vertical fracture length should be conducted before concluding anything about the risks posed by hydraulic fracturing. The lack of vertical fracture information, despite EPA's stated importance of it, does not, however, stop the Agency from concluding that hydraulic fracturing does not pose a threat to USDWs.

5.2.2 Sandstone as an inhibitor of fracture growth — INCLUDED.

In Chapter 3, EPA writes:

> ***Although Holditch*** *(1993)* ***state****s that fracture heights can grow where the coal seam is bounded above or below by sandstone,* ***Warpinski*** *(2001)* ***states*** *that highly layered formations or very permeable strata, such as some sandstones, can act to inhibit fracture growth.*[166] [emphasis added]

The way this paragraph is written diminishes the earlier (1993 versus 2001) findings of Holditch, and leads the reader to believe that in cases where sandstone layers bound coal formations the fractures will not extend into the sandstone. An examination of the references reveals that the citation "Warpinski (2001)" is a personal communication between EPA and Norm Warpinski of Sandia National Laboratory, one of the peer reviewers for the EPA study. No scientific studies are provided to support Warpinski's statement.

The Holditch reference, on the other hand, is based on a literature review of hydraulic fracturing of coalbed methane wells, in addition to the author's first-hand experiences.[167] EPA should have either provided data to substantiate Warpinski's claim that sandstones can inhibit fracture growth, or not have included the comment.

5.2.3 Theoretical assumptions used to prove that benzene from diesel-based fracturing fluids is not hazardous — INCLUDED.

In stark contrast to removing vertical fracture information because it was not based on direct measurements, EPA forms some conclusions based entirely on theoretical assumptions. If EPA does not consider it proper to use information based on theoretical models to estimate vertical fracture height, how can EPA even begin to justify using theoretical fate and transport assumptions to conclude that benzene and other substances injected into USDWs will degrade/dilute/transform to the point of not posing any risk to drinking water quality? (See the discussion in Section 3.2.) The consequences, if carcinogenic benzene and other chemicals do not behave according to EPA's assumptions, may be deadly.

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165 U.S. EPA. June, 2004. p. 3-15.

166 U.S. EPA. June, 2004. p. 3-7, 3-8.

167 S.A. Holditch. 1993. "Completion methods in coal-seam reservoirs," *Journal of Petroleum Technology.* Vol. 4, No. 3 (March 1993), p. 275.

5.2.4 Calculations showing that numerous chemicals are injected into USDWs at concentrations that pose a threat to human health — EXCLUDED.

As discussed in Section 2.1.3, in the draft version of the study EPA includes calculations (based on data from hydraulic fracturing companies) that show that nine chemicals including benzene are injected at concentrations that exceed federal or state water quality standards. Counter to EPA's conclusions, these calculations indicate that hydraulic fracturing does degrade the quality of USDWs, and does present a threat to human health. The calculations for eight of the chemicals do not appear in the final study.

5.2.5 Information showing that hydraulic fracturing fluids are disposed of as hazardous wastes health — EXCLUDED.

EPA solicited and received Material Safety Data Sheets (MSDSs) from hydraulic fracturing companies. The MSDSs from Schlumberger reveal that the company recommends that some fracturing fluids be disposed of at permitted hazardous waste facilities. These same fracturing fluids are allowed to be injected directly into USDWs. Although EPA had the MSDS information on waste disposal considerations, it was not included in the final study. (See Section 2.1.2.)

5.2.6 "Proven hydraulic fracturing case" in West Virginia — EXCLUDED

EPA states that the study "found no confirmed cases that are linked to fracturing fluid injection into CBM wells or subsequent underground movement of fracturing fluids."[168]

Yet in documents received by OGAP, it appears that there was at least one confirmed case of a water well being affected by a hydraulic fracturing operation. In a meeting held in November, 2001, before the draft version of the EPA's hydraulic fracturing study was released, the peer review panel discussed the issue of citizen complaints related to hydraulic fracturing. In the notes from this meeting, it was written that peer review panelist Peter Clark, "hypothesized that **the proven hydraulic fracturing case in West Virginia** might be related to poor or broken casing."[169] [emphasis added]

OGAP has two concerns with this statement: First, neither the draft nor the final EPA study mentions this "proven hydraulic fracturing case." Second, if the contamination was related to poor or broken casing, as hypothesized by Peter Clark, this raises the issue of the potential impact that the mini-seismic events created by hydraulic fracturing have on the competency of well casings. Can hydraulic fracturing operations induce cracks in well casing or casing cement? If they can, and gases or fluids escape through the leaky casing and contaminate USDWs, the hydraulic fracturing job is still responsible for the contamination.

This is definitely an issue that EPA should have investigated, and one that the Agency should address in Phase II of its hydraulic fracturing study.

[168] U.S. EPA. June, 2004. p. ES-1.

[169] Nov. 15, 2001. *Summary of 10/31/01 Expert Panel Meeting on the Hydraulic Fracturing Study.* Dallas, Texas. p. 12. (This document was received by OGAP from EPA through *Freedom of Information Act* Request No. HQ-RIN-00044-05.)

5.3 Lack of confirmed contamination cases does not prove that harm has not occurred or will not occur

In the study, EPA appears to use the lack of confirmed cases of contamination as proof that the injection of hydraulic fracturing fluids into coalbed methane wells poses little or no threat to USDWs, and that further investigation of the issue is not warranted.[170]

Absence of confirmed cases of contamination cannot be construed as proof that there has been no effect on underground drinking water supplies; or that there won't be effects in the future. As outlined below, there are many reasons why hydraulic fracturing fluids may not have been or may not be detected in drinking water.

5.3.1 Groundwater contamination is difficult to detect.

Contamination of groundwater is not easy to detect because it occurs underground, out of sight. "There are no obvious warning signals such as fish kills, discoloration, or stench that typically are early indicators of surface water pollution. . . many commonly found contaminants are both colorless and odorless and occur in low concentrations."[171]

For example, benzene is a constituent of hydraulic fracturing fluids that contain diesel oil. According to the Oregon Department of Human Services, "Levels of concern in drinking water are far below the levels at which the benzene could be smelled or tasted in the water."[172] [emphasis added] Thus, if hydraulic fracturing contaminates drinking water with benzene, people drinking the water would not necessarily have the ability to detect the contamination. Unfortunately for those people, it may be years after a hydraulic fracturing event that the effects will be felt (e.g., a child develops leukemia).[173] By that time, it would be very difficult to prove that hydraulic fracturing was associated with the health disorder.

The difficulties in detecting groundwater pollution are highlighted in a 1989 report produced by the U.S. General Accounting Office ("GAO"), which is now known as the Government Accountability Office. The GAO investigated contamination from Class II injection wells (used for the disposal of oil and gas wastes). In its report entitled *Drinking Water – Safeguards are not Preventing Contamination from Injected Oil and Gas Wastes*, the GAO describes 23 confirmed and four probable cases of contamination. The GAO cautions that:

> *Contamination is difficult to detect. . . about half the known and suspected cases were discovered only after contamination had become obvious to the*

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[170] U.S. EPA. June, 2004. p. ES-16.

[171] V. Pye and J. Kelley. 1984. "The Extent of Groundwater Contamination in the U.S." in *Groundwater Contamination.* Geophysics Study Committee, National Research Council. p. 23.

[172] Benzene can be detected by taste/odor at levels of 0.4 to 2.0 ppm. (Oregon Department of Human Services, Environmental Toxicology Section. "Benzene." Technical Bulletin, October 1992. p. 2.) The Maximum Contaminant Level established by EPA is 5 ppb.

[173] "Public health concerns arise because some contaminants are individually linked to cancers, liver and kidney damage, and damage to the central nervous system. They also arise because information is not available about the health impacts of many other individual contaminants, or of mixtures of contaminants as typically found in groundwater. Uncertainties about human health impacts are likely to persist because impacts are difficult to study; for example, **impacts may not be observable until long after exposure**." [emphasis added] (U.S. Congress, Office of Technology Assessment. October 1984. *Protecting the Nation Groundwater From Contamination.* Washington, DC. OTA-O-233. p. 5.)

people affected, for example, when their well water became too salty to drink, their crops were ruined, or when they could see water flowing at the surface of old wells. Neither EPA nor the states routinely require groundwater monitoring for Class II wells.[174]

5.3.2 Standard water quality tests may not detect all hydraulic fracturing chemicals.

According to the U.S. Congress Office of Technology Assessment:

> *Techniques for analyzing groundwater quality samples are biased in terms of which of the contaminants present they detect, and **some contaminants cannot be readily measured at low but potentially harmful levels using routinely available methods**.*[175] [emphasis added]

For example, glycol ethers are potentially toxic chemicals that are present in some hydraulic fracturing foamed gels.[176] According to the Agency for Toxic Substances and Disease Registry:

> *Routine analyses for the glycol ethers in water… are often not completed because frequently used general-purpose GC/MS methods designed to measure priority pollutants do not readily detect these compounds.*[177]

5.3.3 Water quality data can be difficult to analyze and interpret.

As mentioned in Section 2.3.3, hydraulic fracturing fluids are mixtures of chemicals, and there is the possibility that fracturing chemicals will react with naturally occurring compounds in coals to produce new compounds. Analysis of water quality data is especially difficult if trace levels or mixtures of contaminants are present or if contaminants have been chemically and biologically transformed into substances different than those expected.[178]

If chemicals are detected in a water sample at trace levels that do not pose a threat to human health, regulators may assume that there is not a problem. But the movement of chemicals in water is complex. Levels may be low because a contaminant plume is just beginning to move into the drinking water supply when the sample is taken. Thus, it is important to sample over a period of time, so that trends, such as an increase in chemical concentrations, can be detected.

5.3.4 Contamination cases are not necessarily reported to regulators.

The GAO, in the report mentioned in Section 5.3.1, states that:

> *There may be more instances of contamination because not all occurrences are detected nor are all known cases necessarily reported. **According to EPA***

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174 United States General Accounting Office. July, 1989. *Drinking Water – Safeguards Are Not Preventing Contamination From Injected Oil and Gas Wastes*. Report to the Chairman, Environment, Energy and Natural Resources Subcommittee, House of Representatives. GAO/RCED-89-97.

175 U.S. Congress, Office of Technology Assessment. Oct. 1984. *Protecting the Nation's Groundwater From Contamination.* Washington, DC. OTA-O-233. p.10.

176 Schlumberger. 2001. Material Safety Data Sheet for Foaming Agent F104.

177 Agency for Toxic Substances and Disease Registry. (1998) *Toxicological Profile of 2-Butoxethanol and 2-Butoxyethanol Acetate.* http://www.atsdr.cdc.gov/toxprofiles/tp118.html

178 U.S. Congress, Office of Technology Assessment. Oct. 1984. *Protecting the Nation's Groundwater From Contamination.* (Washington, DC). OTA-O-233. p.10.

*officials and a state official, **individuals whose drinking water is affected may choose to deal directly with the well operator and never inform the regulatory authority.***[179] [emphasis added]

5.3.5 Regulators may not adequately follow up on citizen complaints.

From the information included in EPA's study, it appears that several agencies have not performed due diligence when following up on citizen complaints related to hydraulic fracturing.[180] In Chapter 6, EPA reports that:

> *An individual reported that her drinking water well had become filled with methane gas, causing it to hiss. . .the tap water became cloudy, oily, and had a strong, unpleasant odor. In addition, the tap water left behind an oily film and contained fine particles. The drinking water well owner had her well tested by a private consultant, who confirmed the presence of methane. **The Alabama OGB** tested this drinking water well, but **only looked for naturally occurring contaminants. EPA also sampled and tested this drinking water well, but not until 6 months after the event**. No mention is made of the analytical results obtained from the drinking water well by these agencies.*[181] [emphasis added]

Clearly, the Alabama Oil and Gas Board (OGB) did not even look for hydraulic fracturing chemicals, so there is no way to know whether or not hydraulic fracturing fluids contaminated this well. Moreover, neither the Alabama OGB nor EPA provided the analytical results from the water quality tests to be included in the EPA study. So again, there is no way of knowing whether or not hydraulic fracturing chemicals were present in the water.

Another example cited in the EPA study described how shortly after a fracturing event, an Alabama citizen's water contained globs of black, jelly-like grease and smelled of petroleum. The citizen reported that her neighbors also said their water smelled like petroleum. This occurred in 1989. On June 26, 1990, EPA collected samples from the complainant's drinking water well. The results indicated that no purgeable or extractable organic compounds were detected.[182] The slow Agency response to complaint makes it difficult to determine if there was a connection between the hydraulic fracturing and the water quality impacts experienced by this citizen.

In the interviews conducted for the EPA study, Virginia organizations told EPA that the Virginia Division of Mineral Resources (VDMR) had received more than 100 complaints related to adverse effects from hydraulic fracturing coalbed methane wells, but that the division intentionally classified and filed them as complaints about long wall coal mining. The citizens contend that this was to conceal the existence of

179 United States General Accounting Office. July, 1989. *Drinking Water – Safeguards Are Not Preventing Contamination From Injected Oil and Gas Wastes.* Report to the Chairman, Environment, Energy and Natural Resources Subcommittee, House of Representatives. GAO/RCED-89-97.

180 Natural Resources Defense Council. January, 2002. "Hydraulic Fracturing of Coalbed Methane Wells: A Threat to Drinking Water." http://www.ogap.org/resources/200201_NRDC_HydrFrac_CBM.htm

181 U.S. EPA. June, 2004. p. 6-11.

182 ibid. pp. 6-10, 6-11.

impacts by coalbed methane development in southwest Virginia.[183] The final study does not mention this issue, so it is unclear whether or not the EPA tried to uncover these complaints.

During interviews with EPA, most of the residents said that their complaints to the state usually resulted in investigations without resolution. Some residents mentioned that the gas companies were providing them with potable water to compensate for the contamination or loss of their drinking water wells.[184] It appears, then, that the companies were admitting some responsibility for water well contamination due to their activities (otherwise, they would not have to replace the drinking water), yet the state agencies refused to admit that the two were connected.

The above examples show that some regulatory agencies either do not collect reliable water quality data, or did not provide the data to EPA. Without the water quality data related to the potentially contaminated wells, it is impossible to conclude with any degree of certainty that hydraulic fracturing was unrelated to the changes in water quality experienced by citizens.

5.3.6 There is no regulatory requirement for companies to test for hydraulic fracturing chemicals in groundwater.

Neither EPA nor the states require routine groundwater monitoring to specifically look for hydraulic fracturing chemicals in groundwater. If no one is seriously looking for these chemicals in drinking water, it is not surprising that none have been found.

Detailed groundwater monitoring programs are needed to determine the concentrations and movement of hydraulic fracturing chemicals that are injected into or close to drinking water sources. These programs must include sampling of drinking water wells in the vicinity of fractured wells over a period of time, in order to detect trends in water chemistry. Only by conducting this sort of monitoring will it be possible to know whether or not there have been any impacts to underground sources of drinking water.

5.4 EPA is not being consistent in its level of protection of groundwater or human and ecosystem health

EPA has stated that some fracturing fluid constituents are harmful to human health. Yet these chemicals are being injected directly into underground sources of drinking water. As outlined below, other industries are allowed to inject toxic and hazardous substances underground, but almost never directly into USDWs. Furthermore, EPA has taken steps to reduce the toxicity of oil and gas industry chemicals discharged into the ocean, yet the Agency continues to allow hydraulic fracturing fluids to be injected into drinking water sources at levels that exceed drinking water standards. (See Section 2.1.3.) Clearly, EPA is not applying consistent standards across the board.

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[183] Public comments submitted by Sheila McClanahan on behalf of the Buchanan Citizens Action Group to EPA for the August 24, 2000 public hearing about EPA's proposed study of hydraulic fracturing of coalbed methane wells as well as telephone conversations with other concerned citizens from Buchanan and Dickenson Counties.

[184] It should be noted that the supply of drinking water is not adequate compensation. Many of these residents are still using well water to bathe, and it is well known that many chemicals can enter one's body through the skin or inhalation of water vapor.

5.4.1 Other industries are not allowed to inject wastes directly into USDWs.

Underground water supplies provide about 50% of public drinking water in the United States (95% in rural areas),[185] and these supplies are vulnerable to contamination.[186] In 1974 the *Safe Drinking Water Act* was passed, which authorized EPA to regulate underground injection wells in order to protect drinking water sources. Recognizing that cleanup was not always possible, Part C of the *Safe Drinking Water Act* stressed prevention of contamination to ensure safe drinking water supplies.[187]

The prevention of contamination was further emphasized in 1984, when legislation was passed that banned injection well disposal of hazardous waste unless operators could demonstrate that the waste would not migrate for as long as it remained hazardous. The legislators who required EPA to strengthen the *Underground Injection Control* (UIC) program did so despite the fact that there were "few confirmed cases of drinking water contamination from hazardous waste injection wells."[188] Those legislators had enough wisdom to recognize that without adequate safeguards over the disposal of hazardous wastes, USDWs could become contaminated.[189]

Table 8 outlines the requirements that exist for Class I UIC wells (which allow the disposal of hazardous and nonhazardous substances). As shown in the table, extra precautions have been built in to prevent hazardous and nonhazardous wastes from contacting USDWs. For example, injection must occur beneath the lowermost USDWs, and there must be a confining layer between the injection zone and any USDW.[190] These safeguards are not in place for hydraulic fracturing operations.

Other notable Class I UIC requirements that exist for Class I wells are the area of review (AOR)[191] and well construction requirements. The AOR requires operators to identify wells (e.g., abandoned oil and gas wells) that penetrate the injection or confining zone, and determine whether they could serve as pathways for migration of injected wastes. The construction requirements ensure that fluids do not escape from the injection well itself. These safeguards are not in place for oil and gas wells that are hydraulically fractured. Two EPA peer review panelists flagged this as an issue of concern for hydraulically fractured wells,[192] yet the EPA study fails to address the

185 U.S. General Accounting Office. August 1987. *Hazardous Waste – Controls Over Inject Well Disposal Operations Protect Drinking Water.* Report to the Chairman, Environment, Energy and Natural Resources Subcommittee, Committee on Government Operations, House of Representatives. GAO/RCED-87-170. p.8.

186 United States General Accounting Office. June, 2003. *Deep Injection Wells.* Report to the Honorable Lynn C. Woolsey, House of Representatives. GAO-03-761. p. 4.

187 U.S. General Accounting Office. August 1989. *Drinking Water – Safeguards Are Not Preventing Contamination from Oil and Gas Wastes.* Report to the Chairman, Environment, Energy and Natural Resources Subcommittee, House of Representatives. GAO/RCED-89-97. p. 11.

188 U.S. General Accounting Office. August 1987. *Hazardous Waste – Controls Over Inject Well Disposal Operations Protect Drinking Water.* Report to the Chairman, Environment, Energy and Natural Resources Subcommittee, Committee on Government Operations, House of Representatives. GAO/RCED-87-170. p.4.

189 ibid. p. 2.

190 In the regulations, "the lowermost formation that is a USDW" is the lowermost formation that contains, within one-quarter mile of the injection well, a USDW.

191 Area of Review (AOR): The AOR is a radius around the well within which injection can affect a USDW. This radius for nonhazardous wells is at least 1/4 mile. For hazardous wells, the AOR is at least 2 miles. Several states require and AOR larger than the federal regulations.

192 "[Peter Clark] indicated that the report did not discuss well casings and their potential link to contamination (i.e., a poor cementing job could lead to contamination)." "[Norm Warpinski] indicated that direct well to well communication is a mechanism that may impact USDWs. He indicated that this potential exists in the Powder River Basin and San Juan Basins.

possibility that poorly constructed wells or abandoned wells in the vicinity could provide conduits for fracturing fluids to contaminate USDWs.

TABLE 8. REQUIREMENTS FOR CLASS I (HAZARDOUS AND NONHAZARDOUS) UIC WELLS.[193]

Location	• Hazardous and nonhazardous wastes must be injected beneath the lowermost USDW; and between the injection zone and the USDW there must be a relatively non-permeable layer of rock, known as the confining zone, to prevent fluids from moving vertically into the USDW. • Wells injecting hazardous waste must be located in geologically stable (i.e., low risk of earthquakes) areas that are free of natural (e.g., transmissive fractures or faults) or artificial (e.g., abandoned wells) pathways through which injected fluids could travel to drinking water sources. • Operators must identify all wells within the "area of review" that penetrate the injection or confining zone, determine whether they could serve as pathways for migration of wastewaters, and take any corrective action necessary to prevent migration.
Construction	• The design of the casing, tubing, and packer must be based on the depth of the well; the chemical and physical characteristics of the injected fluids; injection and annular pressure; the rate, temperature, and volume of injected fluid. • During well construction, operators conduct deviation checks at sufficiently frequent intervals to ensure that there are no diverging holes that would allow vertical migration of fluids. Other logs and tests (e.g., resistivity or temperature logs) also may be required during construction.
Operation	• Class I wells must be operated so that injection pressures will not initiate new fractures or propagate existing fractures in the injection or confining zones.
Monitoring	• Operators of Class I wells must continuously monitor the characteristics of the injected wastewater, annular pressure, and containment of wastes within the injection zone. The wells must be equipped with recording devices that automatically sound alarms and shut down the well whenever operating parameters exceed permitted ranges. Operators also must periodically test the well's mechanical integrity.
No Migration	• Class I operators seeking to inject hazardous waste must demonstrate, via a no-migration petition (using sophisticated models), that the hazardous constituents of their wastes will not migrate from the disposal site for as long as they remain hazardous; or that the wastes will decompose or otherwise be attenuated to nonhazardous levels before they migrate from the injection zone.

Under the UIC regulations, Class III and Class IV wells are allowed to inject hazardous substances into or above USDWs. But Class IV wells have been banned under the UIC program because they directly threaten public health.[194] And Class III (solution mining) wells that are located in USDWs must install monitoring wells to detect any excursion of injection fluids, process by-products, or formation fluids beyond the mined area.[195] There is no such requirement for chemicals injected into USDWs during the hydraulic fracturing process.

This may be associated with poor well construction such as poor cementing or casing leakage." (Nov. 15, 2001. *Summary of 10/31/01 Expert Panel Meeting on the Hydraulic Fracturing Study.* Dallas, Texas. pp. 3 and 5. This document was received by OGAP from EPA through *Freedom of Information Act* Request No. HQ-RIN-00044-05.)

[193] The following stipulations come from: U.S. Environmental Protection Agency. 2001. *Class I Underground Injection Control Program: Study of the Risks Associated with Class I Underground Injection Wells*. EPA 8160-R-01-007.

[194] Environmental Protection Agency. *Classes of Injection Wells*. http://www.epa.gov/safewater/uic/classes.html

[195] 40 CFR Ch. I. §146.32. *Criteria and Standards Applicable to Class III Wells.* "Construction Standards." http://www.access.gpo.gov/nara/cfr/waisidx_02/40cfr146_02.html

As mentioned in Section 2.1.2 of this report, MSDSs for many hydraulic fracturing fluids recommend or require that these fluids be disposed of at hazardous waste facilities. Under the UIC program hazardous wastes cannot be injected directly into or above USDWs. Furthermore, even if hazardous wastes are diluted with water so that the hazardous characteristics of the fluids are removed, the wastes are still subject to Class I nonhazardous well requirements, i.e., they cannot be injected into USDWs.[196]

Unlike the extra precautions taken with the injection of hazardous and nonhazardous wastes, EPA has not taken a precautionary approach with the underground injection of hydraulic fracturing fluids. Despite the fact that hydraulic fracturing involves the underground injection of known hazardous substances, EPA has not developed any regulations with respect to underground injection of hydraulic fracturing fluids. The only state that has hydraulic fracturing regulations is Alabama.[197]

5.4.2 Other industries cannot exceed Maximum Contaminant Levels at the point-of-injection.

As mentioned in Section 2.3.1 of this report, the data included in EPA's draft study suggest that numerous chemicals in hydraulic fracturing fluids are likely to exceed the Maximum Contaminant Levels (MCLs) when they are injected into USDWs. Other industries are not allowed to exceed MCLs at the point-of-injection. According to the Underground Injection Control regulations:

> *Exceeding an MCL at the point injected fluids enter a USDW would be cause for the Director to determine if the prohibition of fluid movement has been violated. This is an especially critical issue for injection wells disposing of non-hazardous waste directly into a USDW. Operators of such wells could be required to obtain an injection well permit, modify the injection procedure to reduce contaminant levels, or cease injection and close the well.*[198]

5.4.3 EPA prohibits the discharge of some fracturing fluid chemicals into the ocean, and requires toxicity tests before others can be discharged.

One final example of how EPA has demanded more of others in order to protect the environment is by requiring the offshore oil and gas industry to minimize the discharge of contaminants. Oil and gas operators are prohibited from discharging "priority pollutants," such as benzene and several other chemical constituents of diesel-based fracturing fluids, into the ocean.[199] Priority pollutants are listed under

[196] U.S. Environmental Protection Agency. 2001. *Class I Underground Injection Control Program: Study of the Risks Associated with Class I Underground Injection Wells.* EPA 8160-R-01-007. pp. 17-18. and 40 CFR Ch. I. §146.11. *Criteria and Standards Applicable to Class I Nonhazardous Wells.* http://www.access.gpo.gov/nara/cfr/waisidx_02/40cfr146_02.html

[197] Some of the notable stipulations (paraphrased) in the Alabama Regulation include: 1) The proposed fracturing operation shall not occur in a USDW unless the operator certifies in writing that the mixture of fracturing fluids does not exceed the maximum contaminant levels in 40 C.F. R. § 141 Subparts B and G; and 2) Impervious strata, such as shale, must overlie the uppermost coal bed to be fractured, and the strata must be of sufficient thickness and consistency to serve as a barrier to the upward movement of fluids. Otherwise, a fracturing proposal will be denied. (*Rules and Regulations of the State OGB of Alabama Governing CBM Gas Operations.* 400-3-8-.03. "Protection of USDWs during the Hydraulic Fracturing of Coal Beds.") http://www.ogb.state.al.us/HTMLS/OGBRULES/OGB_Rules_Table_of_Contents.htm#400-3

[198] U.S. EPA. December, 2002. *Technical Program Overview: Underground Injection Control Regulations.* Office of Water. 4606 EPA 816-R-02-025.

[199] "For well treatment fluids, completion fluids, and workover fluids, the discharge of priority pollutants is prohibited except in trace amounts. Information on the specific chemical composition of any additives containing priority pollutants shall be recorded."

the *Clean Water Act*.[200] Additionally, companies must periodically perform toxicity tests on produced water, and the water samples "shall be representative of produced water discharges when scale inhibitors, corrosion inhibitors, biocides, paraffin inhibitors, well completion fluids, workover fluids, and/or treatment fluids are used in operations."[201] Hydraulic fracturing fluids are considered "treatment fluids."

Furthermore, according to the U.S. Minerals Management Service web site:

> *In 1993, the EPA published limitation guidelines on [offshore] oil and gas discharges; these guidelines are based on Best Available Technology. This means that if a technology exists that can limit the discharge and/or its contaminants,* ***even if no environmental effect has been shown to occur,*** *the oil or gas operator must use this technology or a compatible one*.[202] [emphasis added]

It is clear that EPA has the history of requiring industries to improve their practices in order to decrease the risk to ecological and public health, even in the absence of widespread contamination or any environmental effect. Yet, in the case of hydraulic fracturing, the Agency is continuing to allow the injection of potentially toxic substances into underground sources of drinking water. Clearly, EPA is not being consistent in applying a precautionary approach to safeguarding the nation's environment.

[200] *Clean Water Act*. Section 307 and 40 CFR 401.15. For a list of priority pollutants, visit: EPA Water Quality Standards Database. Priority Pollutants. http://oaspub.epa.gov/wqsdatabase/wqsi_epa_criteria.rep_parameter

[201] Environmental Protection Agency, Region 6. Gulf of Mexico OCS General Permit NPDES No. GMG290000. p. 8. http://www.epa.gov/region6/offshore

[202] Minerals Management Service. "Offshore Discharges From Oil and Gas Development Operations – Frequently Asked Questions." http://www.gomr.mms.gov/homepg/offshore/egom/factshee.html

6. Discussion: non-toxic alternatives exist

One obvious approach to decreasing the contamination threat posed by hydraulic fracturing fluids is to move to non-toxic fracturing fluids and additives. As explained below, some non-toxic alternatives already exist. Furthermore, non-toxic fracturing fluids are not only good for the environment, they are also wise from an economic standpoint.

6.1 Non-toxic hydraulic fracturing fluids are being developed, and some already exist

In Appendix A of the EPA final study, the Department of Energy (DOE) states that:

> *. . .research is being conducted in developing "green additives" to use in hydraulic fracturing, especially in shallow formations like coal seam reservoirs. It costs a lot of money to handle additives and dispose of fracturing fluids that are either left over after the treatment or produced back from the well bore. The development of new, green additives will be a new technology that will benefit all parties.*[203]

If the hydraulic fracturing additives and wastes are expensive to handle, it is almost certainly because they have hazardous qualities. Yet, EPA does not mention this issue in its discussion of hydraulic fracturing fluids. Moreover, in the main text there is no mention of DOE's comments on the benefits of developing "green additives, and no information on the "green additives" themselves.

The development of non-toxic or "green" fracturing fluids is not in its infancy. The offshore oil and gas industry has had to develop fluids that are non-toxic to marine organisms in order to be allowed to discharge the fluids into the ocean.[204] According to the Schlumberger web site:

> *Meeting stringent environmental guidelines in both the U.K. North Sea and the Gulf of Mexico, the new Schlumberger GreenSlurry system delivers consistent, earth-friendly performance. This slurry system, developed for use in all types of fracturing and gravel-packing operations in environmentally sensitive regions, features a unique carrier fluid. . . the earth-friendly GreenSlurry system does not adversely affect marine life.*[205]

One assumes that Schlumberger had to formulate new fluids because standard fracturing fluids were toxic to marine organisms. What remains unknown is whether or not standard fracturing fluid mixtures are toxic to humans. Remarkably, though, in the absence of this information EPA is willing to allow these fluids to be injected directly into underground sources of drinking water.

As mentioned in Section 5.4.3, EPA has a history of requiring industries to improve their practices in order to decrease the risks to ecological health. EPA should be applying this Best Available Technology standard to on-shore operations by requiring the use of non-toxic fracturing fluids. Not only will this enhance the protection of

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[203] U.S. EPA. June, 2004. Appendix A-13.

[204] Schlumberger. "Green Slurry: Earth-friendly GreenSlurry system for uniform marine performance."

[205] http://www.oilfield.slb.com/content/services/stimulation/fracturing/greenslurry.asp

USDWs, it will also benefit companies by reducing the costs associated with the handling and disposal of toxic fracturing fluids.

6.2 Several studies show that water is an effective fracturing fluid, and that it is more economic and less destructive than gel-based fluid

It has become commonplace to fracture coal formations with cross-linked gels, which can carry large concentrations of the proppants used to hold open fractures. According to Palmer and coworkers:

> *The history of hydraulic fracturing has been a search for viscous fracturing fluids which would carry higher concentrations of proppant, and place them in the formation so that more of the productive pay height is propped. However,* ***the use of such viscous fluids, especially cross-linked gels, always damages the formation permeability to some extent.***[206] [emphasis added]

Gels damage coal permeability because the gels become sorbed to the coals, which causes a swelling in the coal matrix. Even slight swelling can reduce substantially coal cleat porosity and permeability.[207] Plugging of the coal pores with residual gel is also responsible for some loss of permeability. When formation permeability is damaged, gas production is impaired. Impairment appears to be permanent, as laboratory studies have found that neither reverse water flushing nor injection of acid removes the permeability damage.[208]

EPA has suggested that fracturing with liquid carbon dioxide (CO_2) is one approach for avoiding formation damage.[209] Although this practice is being used in some jurisdictions, there are still many unknowns related to CO_2 fracturing. According to recent studies, the injection of CO_2 into coalbeds has been found to decrease the permeability of the coal cleat system surrounding the injection area.[210] Furthermore, in non-ideal[211] coals seams the swelling might also induce stresses on overlying and underlying rock strata that could cause faulting and create migration pathways out of the coal seam.[212]

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206 I.D. Palmer, R.T. Fryar, K.A. Tumino and R. Puri. 1991. "Comparison between gel fracture and water-fracture stimulations in the Black Warrior basin," *Proceedings 1991 Coalbed Methane Symposium.* University of Alabama/Tuscaloosa. p. 233.

207 ibid. p. 237.

208 R. Puri, G.E. King, I.D. Palmer. (Amoco Production Co.) 1991. "Damage to Coal Permeability During Hydraulic Fracturing." Paper presented at the *Rocky Mountain Regional Meeting and Low-Permeability Reservoirs Symposium,* Denver, CO, April 15-17, 1991. Society of Petroleum Engineers, SPE 21813. p. 112. And I.D. Palmer, R.T. Fryar, K.A. Tumino and R. Puri. 1991. p. 237.

209 U.S. Environmental Protection Agency. 2002. *Fracturing Technologies for Improving CMM/CBM Production.* Coalbed Methane Outreach Program. EPA 68-W-00-094. http://www.epa.gov/coalbed/clibrary/creports.htm

210 P.A. Fokker and L.G.H. van der Meer. 2002. "The injectivity of coalbed CO_2 Injection wells. *Proceedings of the Sixth International Conference on Greenhouse Gas Control Technologies.* J1-1; and Reeves, S. 2002. "Coal-Seq Project Update: Field Studies of ECBM Recovery/CO_2 Sequestration in Coal Seams." *Proceedings of the Sixth International Conference on Greenhouse Gas Control Technologies.* J1-1. Cited in Voormeij, D. and Simandl, G. 2002. "Geological and Mineral CO_2 Sequestration Options: A Technical Review." *Geological Fieldwork 2002.* Paper 2003-1. p. 268.

211 Non ideal coal seams are thin, of low permeability and highly faulted.

212 J. Gale, and D. Davidson. 2003. "Transmission of CO_2: Safety and Economic Considerations," *Proceedings of the Sixth International Conference on Greenhouse Gas Control Technologies.* Vol. 1, p. 517-522. Cited in K. Damen, A. Faaij and W. Turkenburg. 2003. *Health, Safety and Environmental Risks of Underground CO_2 Sequestration.* Prepared for the Advisory Council for Research on Spatial Planning, Nature and Environment of the Netherlands. p. 8. http://www.chem.uu.nl/nws/www/publica/e2003-30.pdf

The migration of CO_2 may, in turn, have impacts on groundwater quality. According to Holloway:

> *Even small CO_2 leaks may possibly cause significant deterioration in the quality of potable groundwater. An increase in CO_2 concentration might cause a decrease in pH to a level of 4-5, which might cause calcium dissolution, increase in the hardness of water and change in the concentration of trace elements.*[213]

Consequently, while CO_2 may not be as damaging as gels to coal formations, CO_2 fracturing may not be the best non-toxic fracturing alternative.

It is possible to use water as the proppant carrier. Unlike gel fracturing, this procedure, known as water fracturing, does not cause extensive damage to coal permeability. Water fracturing does, however, have its disadvantages, e.g., fractures may not be as long as gel fractures, and water fracturing tends to prop fewer coal seams than gels.[214]

Several hydraulic fracturing companies use additives (e.g., friction reducing polymers, biocides, etc.) in their water fracturing treatment of coals. In a laboratory study using San Juan basin coal core samples, Puri and coworkers found that even small quantities of friction reducing chemicals reduced the permeability of coal; and that the damage was irreversible. They concluded that:

> *Due to the possibility of extensive damage to coal permeability, it is recommended that all possible effort be made to* ***avoid contacting the coal seam with fluids containing polymers, surfactants, biocides, friction reducers, or any other liquid chemicals****.*[215] [emphasis added]

EPA held a meeting of the hydraulic fracturing study peer review panel in November, 2001. During the meeting, it was suggested that the section introducing hydraulic fracturing practices mention that:

> *. . .**hydraulic fracturing can be performed using water without additives**, or with a gas (such as nitrogen), or with liquid carbon dioxide.*[216] [emphasis added]

Several studies have compared water fracturing (with no additives) and gel fracturing, and have concluded that water fracturing results in higher gas production and reduced costs. While these results may not necessarily be transferable to all CBM basins, the results are compelling enough to encourage further investigation of water fracturing without additives.

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213 S. Holloway. 1996. "The Underground Disposal of Carbon Dioxide." Final report JOULE II, Proj. No. CT92-0031. British Geological Survey, Nottingham. Cited in Damen, A. Faaij and W. Turkenburg. 2003. *Health, Safety and Environmental Risks of Underground CO_2 Sequestration.* Prepared for the Advisory Council for Research on Spatial Planning, Nature and Environment of the Netherlands. p. 9. http://www.chem.uu.nl/nws/www/publica/e2003-30.pdf

214 I.D. Palmer, R.T. Fryar, K.A. Tumino and R. Puri. 1991. "Comparison between gel fracture and water-fracture stimulations in the Black Warrior basin," *Proceedings 1991 Coalbed Methane Symposium*. University of Alabama/Tuscaloosa. p. 237.

215 Puri, R., King, G.E., Palmer, I.D. Amoco Production Co. 1991. "Damage to Coal Permeability During Hydraulic Fracturing." Paper presented at the *Rocky Mountain Regional Meeting and Low-Permeability Reservoirs Symposium, Denver, CO, April 15-17, 1991*. Society of Petroleum Engineers, SPE 21813.

216 Environmental Protection Agency. Nov. 15, 2001. *Summary of 10/31/01 Expert Panel Meeting on the Hydraulic Fracturing Study.* Dallas, Texas. p. 6. (This document was received by OGAP from EPA through *Freedom of Information Act* Request No. HQ-RIN-00044-05).

A comparison of gas production from water versus gel fractures in the Oak Grove Field of the Warrior Basin was conducted by Amoco Production Company. Thirteen wells were gel fractured and 10 were water fractured. Water fractures outperformed gel fractures by producing approximately 115 thousand cubic feet (Mcf) of gas per day versus 80 Mcf per day, respectively. Moreover, water fractures cost less than gel fractures ($28,000 per well versus $50,000 per well, respectively).[217]

Amoco conducted a similar field project in the San Juan Basin, and reported that, "Early results from San Juan basin water fractures indicate that they outperform gel fractures there also (by 2-3 times in the northern part of the basin), and again they are only half as expensive."[218]

A study conducted by Gas Research Institute, Resource Enterprise, Inc., Phillips Petroleum Co. and Amax Oil and Gas Inc. showed that hydraulic fracturing using Fruitland formation water was more effective than gel treatment in stimulating flow from recompleted wells in the northern portion of the San Juan Basin.[219]

TABLE 9. COMPARISON OF GEL VS. WATER FRACTURING TREATMENTS.

Company	Fracturing Fluid	Completion Cost	Average gas production rate (Mcf/day)	Location
Phillips Petroleum Co. and Amax Oil and Gas Inc.	Borate Cross-linked Gel Water	$85,750	1,392	San Juan Basin
Phillips Petroleum Co. and Amax Oil and Gas Inc.	Formation water	$67,855	1,445	San Juan Basin
Amoco	Water	1/2 cost of gel fractured well	2 to 3 times the gas production	Northern San Juan Basin
Amoco	Cross-linked gel	$50,000	115	Warrior Basin
Amoco	Water	$28,000	80	Warrior Basin

From the available data, it appears that water fracturing, even without the use of additives, is not only cost effective, but also less damaging to the coal formations. The industry should be moving toward safer practices, either using water fracturing without additives, or using water with non-toxic additives.

217 ibid. p. 238.

218 ibid. p. 237.

219 T.L. Logan. 1994. "Preliminary results of cooperative research efforts with Phillips Petroleum Company and Amax Oil and Gas Inc., San Juan Basin." *Quarterly Review of Methane from Coal Seams Technology.* April 1994. 11(3&4): 39-49.

7. Conclusions

OGAP's review of the final version of EPA's study Evaluation of Impacts to Underground Sources of Drinking Water by Hydraulic Fracturing of Coalbed Methane Reservoirs has led to three main conclusions:

1. The EPA study presents information that shows that hydraulic fracturing poses a threat to USDWs.
2. EPA has prematurely concluded that hydraulic fracturing does not pose a threat to drinking water and human health.
3. Based on EPA's own criteria, there is a need to conduct Phase II of the EPA study.

1. **The EPA study presents information that shows that hydraulic fracturing poses a threat to USDWs.**

   This conclusion is based on the following facts:

   - Underground sources of drinking water (USDW) are present in portions of 10 of the 11 coalbed methane basins in the U.S.
   - Hydraulic fracturing fluids are allowed to be injected directly into USDWs.
   - Some of the chemicals present in hydraulic fracturing fluids can lead to serious health problems, ranging from eye and respiratory disorders to cancer.
   - Many hydraulic fracturing fluids chemicals in their pure form are toxic to humans.
   - In the final version of the study, EPA only calculated the point-of-injection concentration for one fracturing fluid: diesel. EPA's calculations show that when diesel is injected it can introduce the carcinogen benzene into USDWs at levels that are 880 times the acceptable level in drinking water.
   - All but three hydraulic fracturing companies are allowed to inject diesel into USDWs (three companies have signed an agreement with EPA to stop injecting diesel into USDWs).
   - Hydraulic fracturing can enlarge or create connections between coal formations and adjacent formations (which may be USDWs).
   - Fracturing fluids have been observed moving out of fractured coal formations and into adjacent formations.

2. **EPA has prematurely concluded that hydraulic fracturing does not pose a threat to drinking water and human health.**

   This conclusion is based on two issues. First, there are many gaps in the data presented by EPA:

   - EPA does not know the identity of all hydraulic fracturing fluid chemicals.
   - Toxicological data do not exist for many fracturing fluids or their individual chemical components.
   - While it is known that the pure form of many fracturing chemicals produce health effects, EPA does not present data on the toxicity of these chemicals when they are diluted. Thus, EPA does not prove that diluted chemicals are safe to inject into USDWs.
   - No information is presented on the potential for increased toxicity when fracturing fluid chemicals are mixed together (or when they react with naturally occurring substances in coal formations).

- EPA relies on a single study to determine the quantity of injected fluid that remains stranded in coal formations.
- No scientific evidence is provided to show that fracturing fluids stranded in or injected into USDWs do not pose a threat to human health.
- EPA does not know to what extent regional groundwater recharge will mobilize stranded fracturing fluid chemicals.
- EPA does not prove that vertical fractures do not present a conduit for hydraulic fracturing fluids into USDWs (because no direct measurements of vertical fractures are presented).
- Techniques to measure fractures are not widely used by CBM producers (because they are expensive), so fracture behavior is not well understood.

Second, the EPA study fails to inform readers that:

- The draft version of EPA's study showed that a number of chemicals in fracturing fluids (benzene, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, fluorenes, phenanthrenes, aromatics, ethylene glycol and methanol) may be injected into USDWs at concentrations that exceed national or state drinking water standards. This information was removed from the final EPA study.
- Groundwater contamination is difficult to detect, so people may not realize that hydraulic fracturing fluids have contaminated their water (and thus, not report it).
- Standard water quality tests may not detect all hydraulic fracturing fluid chemicals, or may not detect chemicals at concentrations that are harmful to human health.
- At least one fracturing fluid company recommends that numerous fracturing fluids be disposed of at hazardous waste facilities.
- No other industry is allowed to inject hazardous wastes –unchecked– directly into USDWs; and even hazardous wastes that have been diluted to remove the hazardous characteristics cannot be injected directly into USDWs.
- Oil and gas operators cannot inject standard hydraulic fracturing fluids directly into the ocean, but have had to develop fluids that are non-toxic to marine organisms.
- Non-toxic hydraulic fracturing alternatives, such as fracturing with plain water, exist, and often save oil and gas operators money.

3. **Based on EPA's own criteria, there is a need to conduct Phase II of the EPA study.**

As shown above, the weight of evidence strongly suggests that hydraulic fracturing poses a threat to drinking water. Based on this, and the fact that there are many gaps in understanding of hydraulic fracturing that need to be addressed, it is OGAP's final conclusion that EPA should be continuing with Phase II of its hydraulic fracturing study.

In the study methodology,[220] EPA determined that it would not continue into Phase II of the study if the investigation found:

- That no hazardous constituents were used in fracturing fluids,
- Hydraulic fracturing did not increase the hydraulic connection between previously isolated formations, and
- Reported incidents of water quality degradation could be attributed to other, more plausible causes.

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[220] U.S. EPA. June, 2004. p. 2-2.

EPA's findings absolutely support the need to continue to Phase II of the study for the following reasons:

There are hazardous constituents in fracturing fluids

EPA presents information showing that many fracturing fluids, in their pure (undiluted) form are hazardous to human health. EPA does not present any empirical data to prove that the injection of these known toxic hydraulic fracturing fluids into USDWs is safe. In fact, the draft version of EPAs study showed that a number of chemicals in fracturing fluids are injected into USDWs at concentrations that exceed national or state drinking water standards.[221] This information was not included in the final study.

Furthermore, information included in MSDSs from hydraulic fracturing companies reveal that some fracturing fluids should be disposed of at permitted hazardous waste facilities. This further suggests that the fluids have some hazardous characteristics. Although EPA had this information, it was not included in the final study.

There is sufficient information in the data gathered by EPA to prove that fracturing fluids do contain hazardous constituents.

Hydraulic fracturing may increase hydraulic connection between previously isolated formations. What is more serious, however, is that hydraulic fracturing occurs in USDWs.

In the draft study, EPA clearly stated that "Hydraulic fractures can, and sometimes do, extend "out of zone"; indeed, fracture excursions out of zone are an area of interest in the energy industry."[222] The Agency removed this statement from the final study.

Even without this strong statement, the information presented in the final study shows that hydraulic connection between formations may be increased due to hydraulic fracturing. In Chapter 5, EPA states that:

> *The literature also indicates that hydraulic fracturing **may have increased or have the potential to increase the communication between coal seams and adjacent aquifers** in two of the basins: the Powder River and Raton Basins.*
>
> *. . . in the Pittsburgh Coal Group in Pennsylvania. . .production wells operating down to approximately 450 feet **could potentially be hydraulically connected to the USDW**.*[223] [emphasis added]

Also, EPA cites studies, based on direct observations of fractures, showing that hydraulically induced fractures frequently connect with and enlarge natural fractures that extend into adjacent formations. In many of these studies the injected fracturing fluid moved beyond the coal formation and into adjacent formations, and sometimes completely through thin formations such as shale.

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221 As shown in Section 2 of this report, numerous hazardous constituents are present in hydraulic fracturing fluids. These include benzene, naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, fluorenes, phenanthrenes, aromatics, ethylene glycol and methanol. In the draft version of the EPA study, the agency calculated that all of these chemicals would exceed a water quality standard at the point-of-injection.

222 U.S. EPA. August, 2002. p. 6-8.

223 U.S. EPA. June, 2004. p. 5-8.

This is extremely important, because an enlargement of natural fractures in adjacent formations may enhance the movement of fluids or gas from coals into the adjacent formations. For example, what may have been a slow movement of small quantities of methane gas and aromatic hydrocarbons (e.g., benzene) could turn into a significant movement of gas into an adjacent formation. The increased flow could be enough to cause a significant deterioration of water quality.

This could be a problem in the San Juan Basin, where:

> *The history of documented gas seeps and methane occurrence in water wells indicates that* ***natural fractures probably serve as conduits*** *in parts of the basin where coal formations are near or at the surface and in the interior of the basin, where the coal formations are deeper. These* ***conduits may enable hydraulic fracturing fluids to travel from targeted coalbeds to shallow aquifers.***[224] [emphasis added]

Any enlargement of these natural fractures could exacerbate the migration of methane, as well as serve as conduits for hydraulic fracturing fluids.

It should be noted that in some hydraulic fracturing locations hydraulic connection is not the important issue. Rather, the issue of concern is that fracturing is occurring or may occur <u>directly in</u> USDWs. EPA found that:

> *The majority of coalbed methane development and hydraulic fracturing in the northern portion of the San Juan Basin takes place within a USDW.*[225]
>
> *. . .between 700 and 1,000 coalbed methane wells have been fracture-stimulated directly in the USDW of Area 1* [Fruitland Coal Formation of the San Juan Basin].[226]
>
> *. . .coalbed methane extraction wells in the Arkoma Basin could be coincident with potential USDWs in Arkansas.*[227]

Given that EPA found literature showing that hydraulic fracturing may have increased or have the potential to increase hydraulic connection between formations, and given that some fracturing actually takes place directly within USDWs, there is enough information to create concern about contamination of USDWs from hydraulic fracturing (either from the fracturing fluids themselves, or the migration of methane and other gases into USDWs).

Reported incidents of water quality degradation may have other plausible causes, but that does not prove that hydraulic fracturing did not cause the contamination.

Chapter 6 of the EPA study addresses citizen complaints related to hydraulic fracturing and water contamination. In many cases, local, state and federal agency response to public complaints about water well contamination by hydraulic fracturing has been inadequate. In some cases tests were not done until months

[224] ibid. p. 2-2.
[225] ibid. p. 5-2.
[226] ibid. p. A1-7.
[227] ibid. p. 5-10.

after the hydraulic fracturing event; in other cases, the water quality tests did not specifically look for hydraulic fracturing fluid chemicals.

These facts weaken any assertion by EPA that there is no relationship between hydraulic fracturing and the contamination of these water wells.

EPA concludes the chapter by saying:

> *. . .the body of reported problems considered collectively suggest that water quality (and quantity) problems might be associated with some of the production activities common to coalbed methane extraction. These activities include surface discharge of fracturing and production fluids, aquifer/formation dewatering, water withdrawal from production wells, methane migration through conduits created by drilling and fracturing practices, or any combination of these.*

EPA does not acknowledge that hydraulic fracturing has influenced groundwater quality. EPA does acknowledge, however, that fracturing may create conduits for the migration of methane. This should be of concern to EPA, as some components of fracturing fluids may partition into the gas phase and migrate with methane, through natural fractures, into groundwater or surface water and soils. Additionally, as the regional groundwater table return to pre-development levels, stranded hydraulic fracturing fluids could become mobilized and migrate through these fractures into groundwater.

Even if EPA discounts all of the complaints related to hydraulic fracturing, it should be noted that an absence of confirmed cases of contamination cannot be construed as proof that there has been no effect on underground drinking water supplies (or that there won't be effects in the future). As outlined in Section 5.3 there are many reasons why hydraulic fracturing fluids may not have been detected in drinking water: groundwater contamination is difficult to detect; standard water quality tests may not detect all hydraulic fracturing chemicals; water quality data can be difficult to analyze and interpret; contamination cases are not necessarily reported to regulators; regulators may not adequately follow up on citizen complaints; and there is no requirement for companies to test for hydraulic fracturing chemicals.

Using EPA's own criteria, the information included in the study confirms the need to conduct further study of the potential impacts of hydraulic fracturing on USDWs.

8. Recommendations

Approximately half of the water that Americans rely on for drinking comes from underground sources. It is in the public interest to ensure – with a very high degree of certainty – that any substances that are injected underground do not pose a threat to drinking water quality and human health. Given that there are huge gaps in understanding of the toxicity and fate of hydraulic fracturing fluids, it is clear that EPA has more work to do.

OGAP has the following recommendations:

1. **Further study of the effects of hydraulic fracturing on underground sources of drinking water should be conducted.**

   EPA should continue with Phase II of its hydraulic fracturing study to verify the Agency's unsubstantiated assertion that no harm has or will occur from current hydraulic fracturing practices. Further work should include, but not be limited to:

   - Monitoring of groundwater quality in and adjacent to formations where hydraulic fracturing is occurring; and monitoring of water quality in nearby drinking water wells. Water quality sampling should include all potentially toxic, naturally occurring substances in the coals; as well as constituents known to be used to hydraulically fracture oil and gas wells in the vicinity of the monitoring wells.
   - Toxicity tests (e.g., acute and chronic tests on different organisms that are known to be as sensitive as humans to various chemicals) on a variety of mixtures of hydraulic fracturing fluids and additives; as well as tests on individual fracturing constituents.
   - Collection of data to determine the percentage of injected hydraulic fracturing fluids that are recovered (i.e., flow back), and what percentage of fracturing fluids remains trapped underground. The data should be collected for individual hydraulic fracturing fluid components (e.g., ethylene glycol), as well as the fluid mixtures.
   - Fracture diagnostic tests using, at minimum, microseimic monitoring and tiltmeters, to better understand the vertical and horizontal dimensions of fractures, and where the fractures go.
   - Studies to determine the cumulative impact of thousands of hydraulic fracturing operations in various CBM basins. Especially in those basins where groundwater dewatering and subsequent recharge have the possibility of mobilizing stranded hydraulic fracturing fluids.

   Field investigations should be undertaken in each coalbed methane basin, as well as some conventional oil and gas and nonconventional (e.g., tight sands in the Piceance Basin of Colorado) oil and gas basins.

2. **EPA should establish regulations for hydraulic fracturing under the *Safe Drinking Water Act.***

   Safe Drinking Water Act Underground Injection Control regulations should be developed not only for the hydraulic fracturing of CBM wells, but for hydraulic fracturing of all types of oil and gas wells. Any regulations developed should utilize safeguards similar to Class I UIC wells, which:

. . .have redundant safety systems and several protective layers to reduce the likelihood of failure. In the unlikely event that a well should fail, the geology of the injection and confining zones serve as a final check on movement of wastewaters to USDWs.[228]

Additionally, the EPA UIC hazardous waste injection program requires companies to report all chemicals that are being used, as well as provide laboratory test data showing the chemical transformations that are likely to occur over time.[229] These same stipulations should apply to companies injecting hydraulic fracturing fluids underground. Regulations should also include construction and operation standards, and monitoring requirements.

3. **Hydraulic fracturing <u>should not</u> be exempted from the *Safe Drinking Water Act*.**

   Approximately half of the water that Americans rely on for drinking water comes from underground sources. It is in the public interest to ensure – with a very high degree of certainty – that any substances that are injected underground do not pose a threat to drinking water quality and human health. The EPA study does not provide adequate scientific proof that hydraulic fracturing does not pose a threat to drinking water. In fact, the EPA study shows that substances that are disposed of as hazardous wastes are being injected into or close to USDWs. Exempting hydraulic fracturing from the *Safe Drinking Water Act* could result in long-term threats to public health, as well as contamination liability for oil and gas companies, the federal and state governments, and American taxpayers.

4. **Until they can be proven safe, all potentially toxic substances should be eliminated from fracturing fluids.**

   No chemicals or chemical mixtures should be injected during any hydraulic fracturing operation until companies can scientifically prove that fracturing fluid constituents and mixtures will not be injected at concentrations that pose a short-term or long-term threat to human health. Non-toxic alternatives, such as fracturing with plain water, exist. And recently, three companies agreed to stop using diesel when fracturing coalbeds that are USDWs, which shows that it is possible to remove toxic chemicals and still hydraulically fracture formations. The removal of diesel should be required by all hydraulic fracturing companies.

5. **Public accountability mechanisms should be put in place.**

   First, despite the fact that three companies have voluntarily agreed to stop injecting diesel into USDWs during hydraulic fracturing operations, the public has not received adequate information on what this actually means on the ground. Neither the MOA nor the EPA study provide information on how many hydraulic fracturing companies are still allowed to inject diesel directly into USDWs (nor the names of these companies); how many fracturing jobs the companies perform per year; and where these fracturing operations are taking place.

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228 U.S. Environmental Protection Agency. 2001. *Class I Underground Injection Control Program: Study of the Risks Associated with Class I Underground Injection Wells.* EPA 8160-R-01-007. p. xiii.

229 40 CFR. Chapter 1. Part 148. *Hazardous Waste Restrictions.* §148.21. "Information to be submitted in support of petitions." http://www.access.gpo.gov/nara/cfr/waisidx_02/40cfr148_02.html

Additionally, the MOA states that, "If necessary, the Companies may use replacement components for hydraulic fracturing fluids that will not endanger USDWs." Yet, there is nothing in the MOA that requires companies to provide EPA with data showing that fracturing fluids do not endanger USDWs.

This is the type of information that EPA should be collecting from companies, so that the Agency can track what substances are being injected, where injection is occurring, and where the safety of USDWs may be threatened. The Agency would then be able to make this information available to the public.

Finally, as mentioned above, there are many chemicals in hydraulic fracturing fluids and additives that are potentially toxic. Yet it is extremely difficult for the public to obtain information on the chemicals being injected during hydraulic fracturing operations. The EPA, or the agencies that have primacy over the UIC program, should obtain more information about fracturing operations and the chemicals that are being injected during these operations. For example, agencies could create regulations requiring that companies submit MSDS sheets that include the chemical names and quantities of <u>all</u> chemicals used during hydraulic fracturing operations. All of the information collected by agencies should be available to citizens.

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