

Chapter 7

Conclusions and Recommendations

Under SDWA, EPA's UIC Program is responsible for ensuring that fluids injected into the ground do not endanger USDWs. The goal of the Phase I study was to assess the potential for contamination of USDWs due to the injection of hydraulic fracturing fluids into coalbed methane wells, and to determine, based on these findings, whether further study is warranted.

EPA's approach for evaluating the potential for contamination of USDWs was an extensive information collection and review of empirical and theoretical data. EPA reviewed water quality incidents potentially associated with hydraulic fracturing and evaluated the theoretical potential for hydraulic fracturing to affect the quality of USDWs through one of two mechanisms:

1. Direct injection of fracturing fluids into a USDW in which the coal is located, or injection of fracturing fluids into a coal seam that is already in hydraulic communication with a USDW (e.g., through a natural fracture system).
2. Creation of a hydraulic connection between the coalbed formation and an adjacent USDW.

7.1 Reported Water Quality Incidents

Citizens from Wyoming, Montana, Alabama, Virginia, Colorado, and New Mexico contacted EPA because they were concerned that their water wells were affected by coalbed methane production. The major geographic areas where citizens reported experiencing problems due to coalbed methane development are concentrated in the coal basins with the most coalbed methane activities – the San Juan, Black Warrior, Central Appalachian, and Powder River Basins. This study was initiated, partly, in response to those citizens' concerns. EPA followed-up on letters and telephone calls from citizens and resulting leads to understand specific complaints and citizens' concerns.

EPA published a *Federal Register* notice (66 FR 39396 (USEPA, 2001) requesting information on water quality incidents believed to be associated with hydraulic fracturing of coalbed methane wells. EPA notified over 500 local and/or county agencies in areas with potential coalbed methane production activity to make them aware of the *Federal Register* notice requesting information on coalbed methane-related complaints. The Agency received no information on complaints from these officials.

EPA reviewed responses and follow-up actions conducted by state agencies to address groundwater complaints involving coalbed methane. Hydraulic fracturing is not widely practiced in the Powder River Basin (which includes Wyoming and Montana) and concerned citizens from that area reported surface water and groundwater quantity problems rather than specifying hydraulic fracturing as a problem. Studies of groundwater quality in the San Juan Basin (which includes parts of Colorado and New Mexico) do not address hydraulic fracturing directly. However, problems with groundwater quantity and quality in Colorado may have plausible explanations other than hydraulic fracturing activities. For example, natural fractures, and poorly constructed, sealed, or cemented wells used for various purposes, may provide conduits for methane to move into shallow geologic strata and water wells, or even to surface water (BLM, 1999). The New Mexico Oil Conservation Division reported that citizens began reporting increased levels of methane in their water wells after coalbed methane development began in the San Juan Basin. New Mexico initiated a plugging and abandonment program to seal old, improperly abandoned production wells, which appears to have mitigated the problem (Chavez, 2001).

EPA also obtained individual incident reports from Virginia. None of Virginia's follow-up investigations provided evidence that hydraulic fracturing of coalbed methane wells had caused drinking water well problems. Incidents in Alabama were investigated by the Alabama Oil and Gas Board, the Alabama Department of Environmental Management, and EPA Region IV. Samples from drinking water wells did not test positive for constituents found in fracturing fluids. After reviewing all the available data and incident reports, EPA sees no conclusive evidence that water quality degradation in USDWs is a direct result of injection of hydraulic fracturing fluids into coalbed methane wells and subsequent underground movement of these fluids.

7.2 Fluid Injection Directly into USDWs or into Coal Seams Already In Hydraulic Communication with USDWs

To determine if USDWs are threatened by the direct injection of fracturing fluids into a USDW, EPA: 1) reviewed information on 11 major U.S. coal basins mined for coalbed methane to determine if coal seams lie within USDWs, and 2) identified components of fracturing fluids. EPA also used the information on the 11 major U.S. coal basins as well as information collected on water quality incidents potentially associated with hydraulic fracturing to determine if coal seams are already in hydraulic communication with USDWs. Hydraulic fracturing has been, or is being, performed in every basin reviewed. As summarized in Table 5-1 in Chapter 5, evidence suggests that coalbeds in 10 of the 11 major coal basins in the United States are located at least partially within USDWs. The coalbeds in the Piceance Basin in Colorado, however, are several thousand feet below USDWs, and are unlikely to be in hydraulic communication with USDWs.

Hydraulic fracturing fluids injected into coalbed methane wells consist primarily of water, or inert nontoxic gases, and/or nitrogen foam and guar (a naturally occurring substance derived from plants). According to information gathered from MSDSs, on-site reconnaissance of fracturing jobs, and interviews with service company employees, some hydraulic fracturing fluids may contain constituents of potential concern. Table 4.1 in Chapter 4 lists examples of chemicals found in hydraulic fracturing fluids according to the MSDSs. Constituents of potential concern include the following substances either alone or in combination: bactericides, acids, diesel fuel, solvents, and/or alcohols. Although the largest portion of fracturing fluid constituents is nontoxic (>95% by volume), direct fluid injection into USDWs of some potentially toxic chemicals does take place.

For example, potentially hazardous chemicals are introduced into USDWs when diesel fuel is used in fracturing fluids in operations targeting coal seams that lie within USDWs. Diesel fuel contains constituents of potential concern regulated under SDWA – benzene, toluene, ethylbenzene, and xylenes (i.e., BTEX compounds). However, the threat posed to USDWs by introduction of these chemicals is reduced significantly by coalbed methane production's dependence on the removal of large quantities of groundwater (and injected fracturing fluids) soon after a well has been hydraulically fractured. EPA believes that this groundwater production, combined with the mitigating effects of dilution and dispersion, adsorption, and potentially biodegradation, minimize the possibility that chemicals included in the fracturing fluids would adversely affect USDWs.

Because of the potential for diesel fuel to be introduced into USDWs, EPA requested, and the three major service companies agreed, to eliminate diesel fuel from hydraulic fracturing fluids that are injected directly into USDWs for coalbed methane production. Industry representatives estimate that these three companies perform approximately 95 percent of the hydraulic fracturing projects in the United States. These companies signed an MOA on December 15, 2003 and have indicated to EPA that they no longer use diesel fuel as a hydraulic fracturing fluid additive when injecting into USDWs for coalbed methane production (USEPA, 2003).

7.3 Breach of Confining Layer

The second mechanism by which hydraulic fracturing may affect the quality of USDWs is fracturing through a hydrologic confining layer, and creation of a hydraulic communication between a coal seam and an overlying USDW. If sufficiently thick and relatively unfractured shale is present, however, it may act as a barrier not only to fracture height growth, but also to fluid movement.

A hydraulic fracture will propagate perpendicularly to the minimum principal stress. In some shallow formations, the least principal stress is the overburden stress; thus, the hydraulic fracture will be horizontal. In deeper reservoirs, the least principal stress will likely be horizontal; thus, the hydraulic fracture will be vertical. In general, horizontal fractures are most likely to exist at shallow depths (less than 1,000 feet) (Nielsen and Hansen, 1987 as cited in Appendix A: DOE, Hydraulic Fracturing). Most coal seams currently used for methane production are relatively shallow compared to conventional oil production wells, but still lie deeper than 1,000 feet.

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 published by the Colorado Geologic Survey, may be due to well stimulations creating a connection between targeted coal seams and an adjacent sandstone aquifer (Hemborg, 1998). In the Powder River Basin, concerns over the creation of such a hydraulic connection are cited as one reason why hydraulic fracturing of coalbed methane reservoirs is not widely practiced in the region. Some studies that allow direct observation of fractures (i.e., mined-through studies) also provided evidence that fractures move through interbedded layers, sometimes taking a stair-step pathway through complex fracture systems, and sometimes enter or propagate through geologic strata above the coal (i.e., roof rock) (Diamond, 1987a and b; Diamond and Oyler, 1987; Jeffrey et al., 1993).

Fracture height is important to the issue of whether or not hydraulic fracturing fluids can affect USDWs because shorter fractures are less likely to extend into a USDW or connect with natural fracture systems that may transport fluids to a USDW. The extent of a fracture is controlled by the characteristics of the geologic formation (including the presence of natural fractures), the volume and types of fracturing fluid used, the pumping pressure, and the depth at which the fracturing is being performed. Deep vertical fractures can propagate vertically to shallower depths and develop a horizontal component (Nielsen and Hansen, 1987, as cited in Appendix A: DOE, Hydraulic Fracturing). In these "T-fractures," the presence of coal fines or a zone of stress contrast may cause the fracture to "turn" and develop horizontally, sometimes at the contact of the coalbed and an overlying formation (Jones et al., 1987b; Morales et al., 1990).

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 barrier to fracture height growth. Shale's ability to act as a barrier to fracture height growth is due primarily to the stress contrast between the coalbed and the higher-stress shale (see Appendix A)

Another factor controlling fracture height can be the highly cleated nature of some coalbeds. In some cases, highly cleated coal seams will prevent fractures from growing vertically. When the fracture fluid enters the coal seam, it is contained within the coal

seam's dense system of cleats and the growth of the hydraulic fracture will be limited to the coal seam (see Appendix A).

Mined-through studies indicate many hydraulic fractures that penetrate into, or sometimes through, formations overlying coalbeds can be attributed to the existence of pre-existing natural fractures. However, given the concentrations and flowback of injected fluids, and the mitigating effects of fate and transport processes, EPA does not believe that possible hydraulic connections under these circumstances represent a significant potential threat to USDWs.

7.4 Conclusions

Based on the information collected and reviewed, EPA has concluded that the injection of hydraulic fracturing fluids into coalbed methane wells poses little or no threat to USDWs and does not justify additional study at this time. This decision is consistent with the process outlined in the April, 2001 Final Study Design, in which EPA indicated that it would determine whether further investigation was needed after analyzing the Phase I information. Specifically, 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 were attributed to other, more plausible causes.

Although potentially hazardous chemicals may be introduced into USDWs when fracturing fluids are injected into coal seams that lie within USDWs, the risk posed to USDWs by introduction of these chemicals is reduced significantly by groundwater production and injected fluid recovery, combined with the mitigating effects of dilution and dispersion, adsorption, and potentially biodegradation. Additionally, EPA has reached an agreement with the major service companies to voluntarily eliminate diesel fuel from hydraulic fracturing fluids that are injected directly into USDWs for coalbed methane production.

Often, a high stress contrast between adjacent geologic strata results in a barrier to fracture propagation. This may occur in those coal zones where there is a geologic contact between a coalbed and a thick, higher-stress shale that is not highly fractured. Some studies that allow direct observation of fractures (i.e., mined-through studies) indicate many fractures that penetrate into, or sometimes through, formations overlying coalbeds can be attributed to the existence of pre-existing natural fractures. However, and as noted above, given the concentrations and flowback of injected fluids, and the mitigating effects of dilution and dispersion, fluid entrapment, and potentially biodegradation, EPA does not believe that possible hydraulic connections under these circumstances represent a significant potential threat to USDWs.

EPA also reviewed incidents of drinking water well contamination believed to be associated with hydraulic fracturing and found no confirmed cases that are linked to fracturing fluid injection into coalbed methane wells or subsequent underground movement of fracturing fluids. Although thousands of coalbed methane wells are fractured annually, EPA did not find confirmed evidence that drinking water wells have been contaminated by hydraulic fracturing fluid injection into coalbed methane wells.