Chapter 7
Conclusions and Recommendations

EPA's Underground Injection Control (UIC) Program is charged with protecting public health from threats arising from contamination of underground sources of drinking water (USDWs) resulting from underground injection activities. USDWs are defined such that aquifers are protected for current and potential future use. USDWs may be currently used to supply drinking water, but a far greater number of USDWs consist of low quality ground water, not suitable for drinking without treatment. The goal of EPA's hydraulic fracturing Phase I study was to determine if a threat to public health, as a result of USDW contamination from the narrow practice of hydraulic fracturing, as it relates to coalbed methane (CBM) wells, exists, and if so, is high enough to warrant further study. The threat to public health from USDW contamination was defined by the presence or absence of documented contamination cases stemming from hydraulic fracturing, or a clear immediate contamination threat to drinking water wells.

EPA's approach for evaluating the threat to public health was an extensive information collection and review of empirical and theoretical data. EPA reviewed claimed incidents of drinking water well contamination and found no confirmed cases from CBM hydraulic fracturing, despite the thousands of fracturing events that have been conducted on CBM wells during the past decade.

EPA also evaluated the theoretical potential for hydraulic fracturing to impact drinking water wells. Two potential mechanisms by which hydraulic fracturing may threaten USDWs were evaluated: (1) the injection of fracturing fluids directly into a USDW, and (2) the creation of a hydraulic communication through a confining layer between the target coalbed formation and adjacent USDWs located either above or below. In some cases, constituents of concern are injected into USDWs during the course of normal fracturing operations. However, EPA's determination is that the threat of contamination of drinking water supplies is low. Studies have found no observed breach of confining layers from hydraulically-created fractures, consistent with theoretical understanding of fracturing behavior.

Based on the information collected during this first phase, the potential threats to USDWs posed by hydraulic fracturing of CBM wells do not appear to be substantial and do not justify additional study.

7.1 Reported Water Quality Incidents

Citizens from the States of Wyoming, Montana, Alabama, Virginia, Colorado, and New Mexico contacted EPA because they were concerned that some aspect of CBM production, hydraulic fracturing or otherwise, was causing water quality or quantity problems in their individual water wells. This study was initiated, partly, in response to

those citizens' concerns. EPA followed up with incoming correspondence and resulting leads to understand specific complaints and citizens' concerns.

EPA published a Federal Register (FR) notice requesting information on water quality incidents believed to be associated with CBM production. We contacted over 500 local and/or county agencies in areas with potential CBM production activity to make them aware of the FR notice requesting data on CBM-related complaints. We received no information on complaints from these officials. Therefore, EPA believes that it knows about the major geographic areas where citizens report they are experiencing problems due to CBM development. The concerns are concentrated in the most active basins – the San Juan, Black Warrior, Central Appalachian, and Powder River Basins.

EPA reviewed responses and follow-up actions conducted by state oil and gas agencies to address ground water complaints involving CBM. Hydraulic fracturing is no longer practiced in the Powder River Basin (Wyoming and Montana) and concerned citizens from that area reported surface water and ground water quantity problems rather than specifying hydraulic fracturing as a problem. Studies in the San Juan basin do not address hydraulic fracturing directly, but the COGCC reported that there are other, more plausible explanations for ground water problems in the area. New Mexico reported that citizens began reporting increased levels of methane in their water wells after CBM development began in the San Juan Basin. New Mexico initiated a plugging and abandonment program to seal old, improperly abandoned wells, which mitigated the problem. EPA obtained individual incident reports from Virginia. None of their follow-up investigations provided evidence that hydraulic fracturing of CBM wells had caused drinking water well problems. Incidents in Alabama were investigated by the Alabama Oil and Gas Boards, the Alabama Department of Environmental Management, and EPA Region IV. Monitoring data from drinking water wells did not test positive for constituents found in fracturing fluids. Taken on a case-by-case basis, we see no conclusive evidence that loss of water quality is a direct result of the practice of hydraulic fracturing of CBM wells.

7.2 Fluid Injection Directly into USDWs (Mechanism 1)

To determine if any threat is posed by the first mechanism, direct injection of fracturing fluids into a USDW, EPA 1) reviewed information for eleven major coalbed methane formations currently mined across the country to determine if coal seams lie within USDWs and 2) identified components in fracturing fluids.

As summarized in Table 5-1, evidence suggests 10 of the 11 coal basins reviewed in this study definitely or likely lie entirely or partially within USDWs. (The coals of the Piceance Basin in Colorado lie several thousand feet below the USDW. Hydraulic fracturing of wells in this basin, therefore, should not affect the USDW.) Hydraulic fracturing has been, or is being, performed in every basin reviewed.

Fracturing fluids consist primarily of inert, nontoxic compounds such as water or nitrogen foam and guar (a naturally occurring substance derived from plants). Based on information gathered from material safety data sheets ("MSDS"), on-site reconnaissance of fracturing jobs, and interviews with service company employees, some fracturing fluids contain constituents of concern. EPA identified constituents of concern that be found in fracturing fluids used for CBM wells (Tables 4.1 – 4.3). They include the following substances either alone or in combination: bactericides, acids, diesel fuel, solvents and/or alcohols. Although water or inert, nontoxic gases and/or foams make up the largest portion of fracturing fluids (>95% by volume), direct fluid injection potentially threatens USDWs because of the toxicity of some of the chemicals used. Diesel fuel is the source of most constituents of concern. It is used as an alternative to water in delivery systems for polymer gels.

EPA assessed the level of threat to public health by recording volumes of various components in the fluids typically used for fracturing coalbed methane wells and estimating constituent concentrations within USDWs. Based on that assessment, EPA believes that fluid injection directly into USDWs does not substantially threaten public health because concentration attenuation and ground water flow dynamics in low-porosity formations would limit the movement of high levels of constituents of concern. EPA's information is that the coal seams that are currently candidates to be hydraulically fractured are not used for drinking water. Most state oil and gas agencies require a drinking water well reconnaissance as part of a CBM well permit application, and states should continue to be vigilant in maintaining a minimum distance between drinking water wells and CBM wells. This adds an additional level of protection to further reduce potential threat.

Research indicates that approximately 30% to 40% of fracturing fluids remain in the formation after producing ground water from the CBM production well for three weeks. Volumes of fracturing fluids used in CBM wells typically range from fifty thousand to three hundred thousand gallons of total fluid injected per fracturing event, most of which is an inert, nontoxic solute such as water or nitrogen foam. EPA estimated the volume of formation water within a representative fracture zone of 1,500 feet by 300 feet to be several hundred million gallons of water. Assuming that 60% of the fluids are removed from the formation, concentrations at the edge of the fracture zone would be diluted to one thirtieth of the point of injection concentrations – a significant drop at a relatively short distance from the production well. Any constituent of concern would have to migrate long distances, both vertically and horizontally, before reaching an exposure point.

Methane production requires the removal of ground water; thus, in active coalbed methane wells the lowest pressure is typically in the CBM production well. Ground water will flow in the direction of the lowest pressure. This pressure dynamic should prevent un-recovered fracturing fluids from migrating beyond the influence of the CBM well.

7.3 Breach of Confining Layer (Mechanism 2)

The second mechanism, by which USDWs might potentially be threatened, fracturing through a confining layer and thereby creating hydraulic communication between a coal seam and an overlying USDW, presents a low level of threat.

A hydraulic fracture will propagate perpendicular 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). Most coal seams currently produced for methane are relatively shallow compared to conventional oil production wells, but lie below 1,000 feet.

Hydraulic fracturing appears to have increased communication between coal seams and adjacent formations in some instances. In four of the basins reviewed for this study, Uinta, Powder River, Raton and Washington Basins, there are indications that some fracturing treatments have resulted in higher than expected withdrawal rates of production water. For example, in the Raton Basin, some fracturing treatments resulted in higher than expected flows of production water, most likely due to fractures extending from the coal layers into adjacent sandstone aquifers. Industry experts believe those increases were most likely due to fractures extending from the coal layers into adjacent sandstone aquifers, hence expanding existing conduits through which waters and possibly fracturing fluids can migrate between stratigraphic layers. Mine back studies also provided evidence that fractures move through interbedded layers. This increase in communication does not introduce new pathways for ground water flow, and thus, presents a low threat.

Confining layers typically act as barriers to vertical fracture growth. Studies show that shale formations present barriers to upward fracture growth because of their higher "elasticity" and stress contrast. According to field engineers and hydraulic fracturing experts, fracture energy could potentially propagate through confining units if the volume of fracturing fluids pumped were unusually large or if the confining unit contains natural fractures. However, generally fractures created during hydraulic fracturing events stay within a coal formation rather than moving through a confining layer. In multiple mine back studies, fractures created in coal seams overlain by confining units resulted in a "T" shape, turning at the boundary between the coal and the shale unit.

For instance, because there are no significant barriers to fracture height, vertical fractures in the Black Warrior basin typically penetrate several thin coal beds and hundreds of feet of intervening rocks. Yet mine back studies showed that fractures turned to create a "T" shaped fracture at the shale/coal seam boundaries. Vertical fracture heights in coalbeds have been measured in excess of 500 feet and lengths can reportedly reach up to 1,500 feet. Fracture heights vary widely depending on the basin geology. For instance, in the Central Appalachian basin, fracture heights can be as small as two feet and lengths are

typically in the range of 200 to 300 feet from the well bore. In the Black Warrior basin, fracture heights are typically 300 feet, depending on the number of coal seams targeted and intervening layers. Fracture lengths typically extend to less than 200 feet from the well bore.

Service company engineers use rock mechanics data to design fracture jobs. Modeling for fracture jobs provides good measures of design parameters (amount of fluid, proppant, and pressure that will be necessary to fracture the well). The models are good indicators of the extent of the fracture but are not good at predicting where or how fractures will grow. Previous experience and measurements in a given well field is a better predictor of that type of information.

Real-time monitoring allows some control of fracture growth, but the naturally occurring in-situ stresses dictate the direction of fracture growth, and is, therefore, out of the control of the engineer. Nevertheless, fracture growth studies and experience gained from thousands of catalogued well stimulations indicate that CBM fractures do not typically grow beyond a few hundred feet and do not propagate through confining layers.

7.4 Recommendations

This study is the most thorough effort conducted to review any impacts to public health from hydraulic fracturing. If the threat to public health from hydraulic fracturing of CBM wells was significant, we would expect to find confirmed instances of water well contamination from the practice. Instead, thousands of CBM wells are fractured annually and yet EPA did not identify any drinking water wells with contamination directly and unequivocally attributable to CBM hydraulic fracturing.

Based on the information collected, the threats posed by hydraulic fracturing of CBM wells to USDWs are low and do not justify additional study. A Phase II effort would not likely provide any new information that would redirect the Phase I findings – those being a lack of contamination incidents and low potential for hydraulic fracturing to threaten human health through the contamination of USDWs. Therefore, the apparent threat to public health from hydraulic fracturing is not compelling enough to warrant expending resources on a Phase II effort. Rather, EPA believes that increasingly tight resources would be better placed on higher priority UIC projects.

Although the threat to public health from hydraulic fracturing appears to be low, it may be feasible and prudent for industry to remove any threat whatsoever from injection of fluids. The use of diesel fuel in fracturing fluids by some companies introduces the majority of constituents of concern to USDWs. Water-based alternatives exist and from an environmental perspective, these water-based products are preferable.

Finally, it is important to note that States with primacy for their UIC programs enforce and have the authority to place controls on any injection activities that may threaten USDWs. With the expected increase in CBM production, additional data collection may

become valuable in the future, if development leads to injection of fracturing fluids into USDWs that are simultaneously used as drinking water sources. The Agency is committed to working with states to collect relevant data to monitor this issue.