Chapter 2
Study Methodology

The purpose of this chapter is to outline EPA's approach for completing Phase I of the study. The methodology describes the development of the study, the information collection and review process that EPA used, and the internal and external review process for the report.

2.1 Overview of the Study Methods

EPA developed the study methodology for Phase I to assist the Agency in determining whether hydraulic fracturing of coalbed methane wells poses a threat to Underground Sources of Drinking Water (USDWs). On July 25, 2000, EPA published a *Federal Register* notice (Volume 65, Number 143, [Page 45774-45775]) requesting comment on a conceptual study design in order to receive stakeholder input on how an EPA study should be structured. EPA received more than 80 sets of comments from industry, state oil and gas agencies, environmental groups, and individual citizens. A summary of comments can be viewed on EPA's web site at http://www.epa.gov/safewater/uic/cbmstudy.

In response to these comments, EPA revised its study approach. Most significantly, EPA decided to carry out the study in discrete phases to help define the scope and eliminate unnecessary events based on the results of the preliminary phases. Also, as recommended by commenters, EPA compiled accounts of personal experiences with regard to coalbed methane impacts on drinking water wells. These experiences are discussed in Chapter 6.

EPA identified two mechanisms by which hydraulic fracturing of coalbed methane wells could potentially impact USDWs:

1. Direct injection of hydraulic fracturing fluids into a USDW in which the coalbed is located; and
2. Creation of a hydraulic communication between the target coalbed formation and an adjacent USDW.

EPA designed the study to collect information on key factors that influence the likelihood that contamination could occur through either of these mechanisms. More specifically, EPA collected information on:

1. hydraulic fracturing practices;
2. hydraulic fracturing fluids and additives to determine whether these substances contain hazardous constituents;
3. the hydrogeology of the coalbed methane basins including the identification of coal seams that are located within USDWs; and

4. information regarding water quality incidents that are potentially associated with hydraulic fracturing.

EPA anticipated that sufficient information would be available to evaluate Mechanism #1 (direct injection) because the main considerations are the location of the coal formations relative to USDWs and the chemical constituents in hydraulic fracturing fluids. The Agency further anticipated that documenting USDW impacts via Mechanism #2 (creation of hydraulic communication) would be more difficult because the more detailed, site specific, geological information and data for specific fracturing events that are required to definitively document such a hydraulic communication are not readily available.

2.2 Information Sources

EPA obtained available literature and data through:

- literature reviews;
- coordination with the Department of Energy (DOE);
- interviews with hydraulic fracturing companies;
- field visits; and
- responses to EPA's *Federal Register* request (*Federal Register*: July 30, 2001; Volume 66; Number 146; Page 39395-39397) for information from the public on any impacts to ground water believed to be associated with hydraulic fracturing.

The procedure that EPA used to obtain information from each of these sources is discussed in more detail below. A copy of the quality assurance protocol that EPA employed to verify all the sources of data used to write this report is provided as Appendix B.

2.2.1 Literature Reviews

Phase I of the study consists of a review of existing literature and data. The focus of the literature review was to obtain information on the topics listed in Section 2.1 above.

Equivalent amounts of information were not available for each of the coalbed basins in the report. The amount of information available depends on the extent of exploration and production that has taken place in the basin.

EPA conducted an extensive literature search using the Engineering Index and GeoRef on-line reference databases for abstracts from technical articles, books, and proceedings. EPA conducted internet-based searches to locate additional information using relevant web sites located using various search engines, including Google™, Yahoo®, and Alta Vista®. EPA also queried more specialized search engines, such as those provided on state geological survey web sites and by the Gas Technology Institute. All relevant web sites were logged in project books and referenced in this report when cited.

EPA guided these literature searches by subject topics and on the following key words either separately and/or in combination: coal basin, coalbed methane, cross-linked gel, fracturing fluid additives, fracturing fluid technology, fracturing fluid performance, fracturing fluids, ground water, hydraulic fracturing, hydraulic fracture dimension, hydraulic fracture growth, hydrology, linear gel, methane gas production, nitrogen foam, and USDW. All search results were printed, catalogued and surveyed for pertinent journal articles, books and conference proceedings containing information that might meet the specific data needs of this report.

All pertinent articles identified from the Engineering Index and GeoRef on-line reference databases were acquired from the University of Texas (U of T) Library in Austin, Texas, because this library's holdings include an extensive collection of oil and gas-related publications. References from the U of T documents were researched and documents that were relevant to the study were acquired. Only a small fraction of the pertinent articles, specifically articles published for overseas conferences and proprietary articles, were unavailable. All papers collected for the study have been archived by topic.

To verify key information extracted from the literature, relevant organizations such as state regulatory agencies, state geological surveys, natural gas companies, and service companies were contacted by telephone. Telephone logs were used to document all communications. Personal conversations with the employees of the various organizations yielded additional information in the form of reports, figures, and maps, as well as professional experience. These were collected, documented and referenced in conjunction with the literature identified in the literature searches. The majority of the literature pertaining to coalbed methane basins and hydraulic fracturing was written in the early to mid 1990s. According to the Texas Bureau of Economic Geology (TBEG) (personal communication, TBEG Staff, 2000), this intensive period of activity is a function of the emphasis placed on gas exploration by the Section 29 Tax Credit of the Crude Oil Windfall Profit Tax Act of 1980, and research grants to industry, academia, and government agencies. The Section 29 credit does not apply to coal gas wells drilled after December 31, 1992.

2.2.2 Department of Energy

EPA reviewed and incorporated information from DOEs "White Paper" on hydraulic fracturing practices. This paper addresses the following topics:

- Objectives of hydraulic fracturing;
- How candidate wells are selected for hydraulic fracturing;
- How fracture treatments are designed;
- Field operation considerations;
- Physics of fracture formation in coalbeds;
- Fracturing fluids;
- Stimulation techniques used for developing coalbeds; and

- Instrumentation/methods for tracking fractures.

The complete DOE paper is included as Appendix A, and excerpts from this paper are included in Chapter 3 - Characteristics of Coalbed Methane Production and Associated Hydraulic Fracturing Practices.

2.2.3 Interviews

EPA contacted two hydraulic fracturing service companies, Halliburton, Inc. and Schlumberger, Inc., as well as a fracturing fluids producer, Hercules, Inc., to obtain information regarding the content of hydraulic fracturing fluids and additives they use or manufacture. These companies provided EPA with material safety data sheets (MSDSs) for several of the hydraulic fracturing fluids and additives. The MSDSs were reviewed to determine the nature of the constituents in fracturing fluids used for coalbed methane production. These topics are discussed in Chapter 4, Hydraulic Fracturing Fluids.

EPA has also evaluated reports from people and organizations concerned that drinking water supplies were affected by hydraulic fracturing. These reported personal experiences originated from the southern and northern parts of Colorado, New Mexico, Wyoming, Alabama, and Virginia. In response to these reports, EPA conducted telephone interviews with citizens, local authorities, the Bureau of Land Management and EPA Region 8 personnel. EPA has also evaluated state agency responses to any complaints received by both EPA and state agencies and available data to determine if sufficient information exists to understand the source of the alleged water quality contamination.

2.2.4 Field Visits

EPA conducted field visits in three States: Colorado, Kansas, and Virginia. The reasons for these visits included the need to better understand how local coalbed methane production activities may vary from basin to basin, meet with concerned local citizens regarding coalbed methane production, and discuss associated issues with state agencies. A summary of these field visits is provided below.

In August 2000, EPA met with a group of concerned citizens, officials from the Colorado Oil and Gas Conservation Commission, and La Plata County government representatives. EPA witnessed a fracture event, reviewed records including temperature logs of past fracturing events conducted on coalbed methane wells, and performed a reconnaissance of the area allegedly impacted by coalbed methane production.

In August 2001, EPA met with the Virginia Department of Mines, Minerals and Energy, the agency that regulates the coalbed methane production industry in Virginia. The Department provided information regarding the state's regulatory practices regarding

water quality incidents potentially associated with coalbed methane production in the Central Appalachian Valley. The Department submitted water quality incident reports for review by EPA. During this visit, EPA also met with concerned citizens in Virginia. Citizens groups from Buchannan and surrounding counties were invited to meet with EPA and DOE staff to discuss water quality issues believed to be related to local hydraulic fracturing of coalbed methane wells. Notes from the meeting are referenced in Chapter 6.

EPA also organized a field visit with Consol Energy, Inc. and Halliburton to witness a hydraulic fracturing event. A coalbed methane well located in western Virginia was fractured by Halliburton using equipment, fracturing fluids, and techniques typically described in the literature. EPA was able to observe the fracturing process and collect information, including MSDSs from the service company and gas company engineers. The information for this field visit was used to supplement the data on hydraulic fracturing fluids in Chapter 4.

In November 2001, EPA witnessed a fracturing procedure in Wilson County, Kansas to gain a better understanding of the regional geology and hydraulic fracturing practices in that area. In attendance were Colt Energy (the well operator), Consolidated Industrial Services, Inc. (the service company conducting the fracture), and two state agencies, the Kansas Corporation Commission, and the Missouri Department of Natural Resources. MSDSs for fracturing fluids typically used in that area were also provided by the Kansas Corporation Commission.

2.2.5 Federal Register Notice to Identify Reported Incidents

EPA provided an opportunity for the public to submit information on any impacts to ground water believed to be associated with hydraulic fracturing through a request for public comment (*Federal Register*: July 30, 2001; Volume 66; Number 146; Page 39395-39397). EPA also sent copies of the *Federal Register* (FR) notice with a cover letter to county-level public health and/or environmental officials in counties that may be producing coalbed methane. Additionally, letters were sent to stakeholders informing them that FR notice had been published. Responses to the FR notice are available at EPA's water docket (docket number W-01-09; Water Docket (MC 4101); Rm EB 57; U.S. Environmental Protection Agency; 1200 Pennsylvania Avenue, NW.; Washington, DC 20460; phone number: 202-260-3027). A summary of the comments are provided in Chapter 6, Volume I.

2.3 Review Process

This report has benefited from a series of internal and external technical reviews. Information was verified by the contractor through telephone interviews with state and

local officials, as well as through the contractor's own internal quality assurance process. EPA conducted a quality assurance review of the data collection procedures as well as a review of the individual literature sources cited in the report. In addition, more than nine EPA offices reviewed the report. Other federal agencies that reviewed the report included the Department of Energy and the US Geological Survey.

EPA also submitted the report to a scientific peer-review panel consisting of experts from industry, academia, and government agencies. Their task was to review the report and provide comments on the descriptions and conclusions developed by EPA. The panel also provided information about potential additional data sources to supplement those used in the report. Following receipt of comments on the draft report, EPA made the appropriate changes to the document prior to publication and distribution.