Executive Summary

Natural gas plays a key role in our nation's clean energy future. The United States has vast reserves of natural gas that are commercially viable as a result of advances in horizontal drilling and hydraulic fracturing technologies, which enable greater access to gas in rock formations deep underground. These advances have spurred a significant increase in the production of both natural gas and oil across the country.

Responsible development of America's oil and gas resources offers important economic, energy security, and environmental benefits. However, as the use of hydraulic fracturing has increased, so have concerns about its potential human health and environmental impacts, especially for drinking water. In response to public concern, the US House of Representatives requested that the US Environmental Protection Agency (EPA) conduct scientific research to examine the relationship between hydraulic fracturing and drinking water resources (USHR, 2009).

In 2011, the EPA began research under its *Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources.* The purpose of the study is to assess the potential impacts of hydraulic fracturing on drinking water resources, if any, and to identify the driving factors that may affect the severity and frequency of such impacts. Scientists are focusing primarily on hydraulic fracturing of shale formations to extract natural gas, with some study of other oil- and gas-producing formations, including tight sands, and coalbeds. The EPA has designed the scope of the research around five stages of the hydraulic fracturing water cycle. Each stage of the cycle is associated with a primary research question:

- Water acquisition: What are the possible impacts of large volume water withdrawals from ground and surface waters on drinking water resources?
- Chemical mixing: What are the possible impacts of hydraulic fracturing fluid surface spills on or near well pads on drinking water resources?
- Well injection: What are the possible impacts of the injection and fracturing process on drinking water resources?
- Flowback and produced water: What are the possible impacts of flowback and produced water (collectively referred to as "hydraulic fracturing wastewater") surface spills on or near well pads on drinking water resources?
- Wastewater treatment and waste disposal: What are the possible impacts of inadequate treatment of hydraulic fracturing wastewater on drinking water resources?

This report describes 18 research projects underway to answer these research questions and presents the progress made as of September 2012 for each of the projects. Information presented as part of this report cannot be used to draw conclusions about potential impacts to drinking water resources from hydraulic fracturing. The research projects are organized according to five different types of research activities: analysis of existing data, scenario evaluations, laboratory studies, toxicity assessments, and case studies.

Analysis of Existing Data

Data from multiple sources have been obtained for review and analysis. Many of the data come directly from the oil and gas industry and states with high levels of oil and gas activity. Information on the chemicals and practices used in hydraulic fracturing has been collected from nine companies that hydraulically fractured a total of 24,925 wells between September 2009 and October 2010. Additional data on chemicals and water use for hydraulic fracturing are being pulled from over 12,000 well-specific chemical disclosures in FracFocus, a national hydraulic fracturing chemical registry operated by the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission. Well construction and hydraulic fracturing records provided by well operators are being reviewed for 333 oil and gas wells across the United States; data within these records are being scrutinized to assess the effectiveness of current well construction practices at containing gases and liquids before, during, and after hydraulic fracturing.

Data on causes and volumes of spills of hydraulic fracturing fluids and wastewater are being collected and reviewed from state spill databases in Colorado, New Mexico, and Pennsylvania. Similar information is being collected from the National Response Center national database of oil and chemical spills.

In addition, the EPA is reviewing scientific literature relevant to the research questions posed in this study. A *Federal Register* notice was published on November 9, 2012, requesting relevant, peer-reviewed data and published reports, including information on advances in industry practices and technologies. This body of literature will be synthesized with results from the other research projects to create a report of results.

Scenario Evaluations

Computer models are being used to identify conditions that may lead to impacts on drinking water resources from hydraulic fracturing. The EPA has identified hypothetical, but realistic, scenarios pertaining to the water acquisition, well injection, and wastewater treatment and waste disposal stages of the water cycle. Potential impacts to drinking water sources from withdrawing large volumes of water in semi-arid and humid river basins—the Upper Colorado River Basin in the west and the Susquehanna River Basin in the east—are being compared and assessed.

Additionally, complex computer models are being used to explore the possibility of subsurface gas and fluid migration from deep shale formations to overlying aquifers in six different scenarios. These scenarios include poor well construction and hydraulic communication via fractures (natural and created) and nearby existing wells. As a first step, the subsurface migration simulations will examine realistic scenarios to assess the conditions necessary for hydraulic communication rather than the probability of migration occurring.

In a separate research project, concentrations of bromide and radium at public water supply intakes located downstream from wastewater treatment facilities discharging treated hydraulic fracturing wastewater are being estimated using surface water transport models.

Laboratory Studies

Laboratory studies are largely focused on identifying potential impacts of inadequately treating hydraulic fracturing wastewater and discharging it to rivers. Experiments are being designed to test how well common wastewater treatment processes remove selected contaminants from hydraulic fracturing wastewater, including radium and other metals. Other experiments are assessing whether or not hydraulic fracturing wastewater may contribute to the formation of disinfection byproducts during common drinking water treatment processes, with particular focus on the formation of brominated disinfection byproducts, which have significant health concerns at high exposure levels.

Samples of raw hydraulic fracturing wastewater, treated wastewater, and water from rivers receiving treated hydraulic fracturing wastewater have been collected for source apportionment studies. Results from laboratory analyses of these samples are being used to develop a method for determining if treated hydraulic fracturing wastewater is contributing to high chloride and bromide levels at downstream public water supplies.

Finally, existing analytical methods for selected chemicals are being tested, modified, and verified for use in this study and by others, as needed. Methods are being modified in cases where standard methods do not exist for the low-level detection of chemicals of interest or for use in the complex matrices associated with hydraulic fracturing wastewater. Analytical methods are currently being tested and modified for several classes of chemicals, including glycols, acrylamides, ethoxylated alcohols, disinfection byproducts, radionuclides, and inorganic chemicals.

Toxicity Assessments

The EPA has identified chemicals reportedly used in hydraulic fracturing fluids from 2005 to 2011 and chemicals found in flowback and produced water. Appendix A contains tables with over 1,000 of these chemicals identified. Chemical, physical, and toxicological properties are being compiled for chemicals with known chemical structures. Existing models are being used to estimate properties in cases where information is lacking. At this time, the EPA has not made any judgment about the extent of exposure to these chemicals when used in hydraulic fracturing fluids or found in hydraulic fracturing wastewater, or their potential impacts on drinking water resources.

Case Studies

Two rounds of sampling at five case study locations in Colorado, North Dakota, Pennsylvania, and Texas have been completed. In total, water samples have been collected from over 70 domestic water wells, 15 monitoring wells, and 13 surface water sources, among others. This research will help to identify the source of any contamination that may have occurred.

The EPA continues to work with industry partners to begin research activities at potential prospective case study locations, which involve sites where the research will begin before well construction. This will allow the EPA to collect baseline water quality data in the area. Water quality will be monitored for any changes throughout drilling, injection of fracturing fluids, flowback, and production. Samples of flowback and produced water will be used for other parts of the study, such as assessing the efficacy of wastewater treatment processes at removing contaminants in hydraulic fracturing wastewater.

Invigorating the Research Study Through Consultation and Peer Review

The EPA is committed to conducting a study that uses the best available science, independent sources of information, and a transparent, peer-reviewed process that will ensure the validity and accuracy of the results. The agency is working in consultation with other federal agencies, state and interstate regulatory agencies, industry, non-governmental organizations, and others in the private and public sector. In addition to workshops held in 2011, stakeholders and technical experts are being engaged through technical roundtables and workshops, with the first set of roundtables held November 14–16, 2012. These activities will provide the EPA with ongoing access to a broad range of expertise and data, timely and constructive technical feedback, and updates on changes in industry practices and technologies relevant to the study. Technical roundtables and workshops will be followed by webinars for the general public and posting of summaries on the study's website. Increased stakeholder engagement will also allow the EPA to educate and inform the public of the study's goals, design, and progress.

To ensure scientifically defensible results, each research project is subjected to quality assurance and peer review activities. Specific quality assurance activities performed by the EPA make sure that the agency's environmental data are of sufficient quantity and quality to support the data's intended use. Research products, such as papers or reports, will be subjected to both internal and external peer review before publication, which make certain that the data are used appropriately. Published results from the research projects will be synthesized in a report of results that will inform the research questions associated with each stage of the hydraulic fracturing water cycle. The EPA has designated the report of results as a "Highly Influential Scientific Assessment," which will undergo peer review by the EPA's Science Advisory Board, an independent and external federal advisory committee that conducts peer reviews of significant EPA research products and activities. The EPA will seek input from individual members of an *ad hoc* expert panel convened under the auspices of the EPA Science Advisory Board. The EPA will consider feedback from the individual experts in the development of the report of results.

Ultimately, the results of this study are expected to inform the public and provide decision-makers at all levels with high-quality scientific knowledge that can be used in decision-making processes.