

Scoping Materials for Initial Design of EPA Hydraulic Fracturing Research Study

**Scoping Materials for
Initial Design of EPA Research Study on
Potential Relationships Between Hydraulic Fracturing
and Drinking Water Resources**

**U.S. Environmental Protection Agency
Office of Research and Development**

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Note: This document has been developed for discussion only. Its purpose is to elicit ideas and suggestions from the EPA Science Advisory Board and the public. The document does not represent, and should not be construed to represent, any Agency policy or determination.

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Potential Relationships Between Hydraulic Fracturing and Drinking Water Resources

Introduction

Natural gas plays a key role in our nation's clean energy future and the process known as hydraulic fracturing (HF) is one way of accessing that vital resource. HF is used by gas producers to stimulate wells and recover natural gas from sources such as coalbeds and shale gas formations. HF is also used for other applications including oil recovery. Over the past few years, several key technical, economic, and energy policy developments have spurred increased use of HF for gas extraction over a wider diversity of geographic regions and geologic formations. It is projected that shale gas will comprise over 20% of the total US gas supply by 2020¹. Along with the expansion of HF, there have been increasing concerns about its potential impacts on drinking water resources, public health, and environmental impacts in the vicinity of these facilities.

Gas extraction practices that use HF consist of the following activities:

- Site exploration, selection and preparation;
- Equipment mobilization-demobilization;
- Well construction and development;
- Mixing and injecting fracturing fluids;
- Hydraulic fracturing of the formation;
- Produced water and waste management, transport, treatment, and disposal;
- Gas production (infrastructure for storage and transportation); and
- Site closure.

During HF, fracturing fluids are injected into wells under high pressure to generate fractures in underground formations. Fracturing fluids consist primarily of water and additives that serve a variety of purposes such as increasing fluid viscosity, inhibiting corrosion, and limiting bacterial growth. In addition, proppants, primarily sand, are added to keep the fractures open after the pressure is released. The sources of water used during HF activities include surface water and ground water and significant quantities of water can be used (up to 5 million gallons per well), depending on well characteristics (depth, horizontal distance) and the number of times each well is fractured. Practices for managing the produced water vary depending on local constraints and conditions.

¹ Energy Information Administration (2009), *Annual Energy Outlook 2009*. US Department of Energy; Washington, DC. [http://www.eia.doe.gov/oiaf/archive/aeo09/pdf/0383\(2009\).pdf](http://www.eia.doe.gov/oiaf/archive/aeo09/pdf/0383(2009).pdf)

In its Fiscal Year 2010 budget report, the U.S. House of Representatives Appropriation Conference Committee identified the need for a focused study of this topic:

“The conferees urge the Agency to carry out a study on the relationship between hydraulic fracturing and drinking water, using a credible approach that relies on the best available science, as well as independent sources of information. The conferees expect the study to be conducted through a transparent, peer-reviewed process that will ensure the validity and accuracy of the data. The Agency shall consult with other Federal agencies as well as appropriate State and interstate regulatory agencies in carrying out the study, which should be prepared in accordance with the Agency's quality assurance principles.”

The purpose of this document is to describe the initial steps in framing a study consistent with this Congressional mandate. Initial thoughts on the potential scope of the study, research questions, and concepts for stakeholder involvement are presented. EPA's Office of Research and Development (ORD) will lead the development and implementation of the study. It is anticipated that the study will begin during 2010 with initial research products available by the end of 2012.

Approach to Determining the Scope of the Study

The primary objective of the study is to evaluate the potential for HF activities to impact surface and/or underground sources of drinking water and impose public health or environmental risks. Socio-economic factors may also play a role in understanding how to address potential health and environmental concerns. In the initial scoping of the study, potential HF impacts on other water resource functions, such as supporting aquatic ecosystems and recreational activities, will also be considered. To ensure that meaningful results are produced in a timely manner, it is important to clarify the overall scope of the study and define explicit short-term (1-3 years) and long-term (3-5 years) goals.

As an initial scoping framework to identify, categorize, and prioritize research needs, EPA proposes using a Life Cycle Assessment (LCA) approach to identify potential interrelationships between energy, water, the chemicals used during HF, the surrounding environment, and safeguards for public health protection. Information generated through an LCA can help policy makers understand and make decisions about the breadth of issues relating to HF, including cross-media risks and the relationship to the entire natural gas production cycle.

In developing the study design and defining potential research products, a critical consideration is the type of information necessary to inform policy decisions. Research activities may include a combination of field activities, case studies, and laboratory research that lead to the development of methods, models, and tools to characterize and manage risks associated with HF activities.

Framing the Research Questions

To initiate the study design, EPA has defined three major categories that can provide a context for defining research and information needs. Research questions pertaining to each category will be used to help define the scope of the study. As the study design progresses, there will be opportunities for stakeholder input and peer review. The initial research categories are:

- Characterization of the Hydraulic Fracturing Lifecycle
- Potential Relationships to Drinking Water Resources
- Potential Health and Environmental Risks

Characterization of the Hydraulic Fracturing Lifecycle

Understanding the processes used in HF gas production is key to understanding potential impacts. In addition to specific drilling, fracturing and engineering practices, knowledge about the current and anticipated site inventory, associated activities, chemical and water use, and proximity to communities within a given region or locality are key considerations. Chemical and water use, fate and transport, and potential exposure pathways are critical elements of the HF Lifecycle. Geographic water resource constraints and hydrological variations are integral to applying a systems approach to assessing human and environmental impacts.

Examples of Potential Research Questions:

- How are HF operations sited in relation to other injection or extraction activities (e.g., other HF operations or other UIC wells)?
- Can HF sites be mapped to evaluate current and projected development, geographical distribution, relationship to drinking water resources, and proximity to communities, tribal lands and communities that might face socio-economic hardships?
- Do site preparation and well construction activities have potential to impact water resources?
- What criteria should be considered in evaluating the proximity of drinking water resources (underground and surface) and water availability to siting HF activities?
- To what extent may other nearby well penetrations, especially abandoned wells, affect potential impacts from HF activities?

- What tools are needed to define an appropriate area of review surrounding the HF well?
- What tools and analytical methods are needed to characterize HF fluids, produced water, and site-runoff?
- What are the fate and transport properties of HF fluids?
- How can well construction and maintenance practices prevent contamination of water resources?
- What materials and design/construction practices are needed for wells to which HF treatments will be applied?
- What types of monitoring and testing can be used to ensure wells and fractures are placed in appropriate locations to protect Underground Sources of Drinking Water (USDWs) and geologic confining layers?
- What are the most effective methods for well failure mitigation, including methods for assessing well integrity, designing HF treatments, and monitoring during and after HF?
- What safeguards are needed to prevent mechanical integrity failures that could result in leaks of fluids and gases into USDWs that overlie the gas reservoir?
- What are the possible problems and impacts associated with available options for the management and disposal of produced water and do remedial technologies exist?
- What data and information are needed to demonstrate the effectiveness of best management practices (BMPs) for the storage, treatment, and disposal of produced water? What are the constraints on recycling the produced water rather than disposal?
- What tools and analytical methods are needed to characterize emissions from HF and associated gas production operations?
- What data and information are needed to optimize BMPs for vapor emissions during HF operations?

Potential Relationship to Drinking Water Resources

To frame research questions on the potential impacts of the HF lifecycle on drinking water resources (surface and underground sources of drinking water), mechanisms of potential water quality impairment need to be identified in the context of local geology and hydrology. Potential impacts to drinking water resources may be associated with the chemicals and fluids used in the fracturing process, biogeochemical and physical-chemical reactions triggered by HF, leakage from gas-bearing formations, or on-site runoff. Water, waste, and chemical management practices also have potential to impact drinking water resources depending on: the source and quantity of make-up water; on-site activities; and treatment, discharge, and/or reuse approaches for produced water and stormwater. There is also potential for local drinking water resources to be impacted by the withdrawal of water for use during HF. In addition, hydraulic connections between ground and surface waters may result in cross-contamination.

Examples of Potential Research Questions:

- What components of the HF lifecycle could potentially lead to the contamination of drinking water sources and hydraulically connected ground and surface waters?
- What types of field studies could be conducted to evaluate impacts of HF on biogeochemical mobilization of metals, radionuclides, mineral salts, organic contaminants and gases present in gas-bearing formations?
- What is the likelihood that pressurized methane can migrate into USDWs?
- What types of mitigation strategies might be appropriate to prevent the potential release of sequestered metals and radionuclides into USDWs?
- To what extent does surface water withdrawal for HF purposes potentially affect drinking water and/or impact flow regimes in streams and their role in maintaining ecosystem services?
- To what extent does ground water withdrawal for HF purposes affect water levels and the usability of smaller aquifers for water supplies, both through availability of water, and geochemical changes caused by lowered water levels?
- What types of monitoring and modeling tools are needed to determine if there is sufficient capacity available and/or feasible for wastewater treatment or underground injection?
- What treatment technologies are effective for managing HF flowback and/or produced fluids? What are the impacts of these contaminants on wastewater treatment plant facility operations?
- What are the potential options for restoration of impacted aquifers? What are the limitations of current technologies?
- Can potential impacts on downstream water supplies be predicted and prevented?
- How should USDW sampling (location and frequency) and monitoring (constituents) programs be designed to characterize and control potential water quality impacts associated with HF activities?
- What approaches are effective for characterizing and controlling Technically Enhanced Naturally Occurring Radionuclide Materials (TENORM) in Marcellus Shale and other gas-bearing formations?
- What pre-existing conditions or concurrent activities (e.g., other underground injections, abandoned wells, etc.) can increase the likelihood of HF impacting drinking water sources?
- Are there viable fracturing alternatives that may have less potential for impacts to drinking water resources? If so, are they economically viable? What are the tradeoffs?

Potential Health and Environmental Risks

Identification of health risks and environmental concerns related to HF requires an understanding of potential exposure pathways and receptors. HF-related activities may introduce contaminants into water, food, air, soils, and other materials over the HF lifecycle. The potential exposure pathways to be addressed by this study include ingestion, inhalation, dermal exposure through water, air, food, and environmental exposures. It is also important to recognize that interconnections between surface water and ground water resources might affect the magnitude and extent of potential exposures and risks. Addressing potential health and environmental concerns requires consideration of socio-economic factors. Where appropriate, the study design will incorporate community health and environmental concerns.

Examples of Potential Research Questions:

- Are there health risks associated with HF chemicals, fluids, and produced waters, and if so, how can they be characterized?
- What key exposure pathways associated with HF activities may impact human health (e.g. ingestion, inhalation, dermal exposure through water, air, food, and environmental exposures)?
- How can geologic monitoring and modeling methods be used for risk assessment?
- What is the potential to contribute to the spread of invasive or non-native species associated with HF activity?
- What is the potential for livestock, crops, and wildlife to be impacted?
- What are the aquatic life and recreational impacts to receiving streams from treatment facilities that accept fracturing wastes (e.g. total dissolved solids)?
- Which analytes serve as effective indicators of exposure for humans? For ecological populations? What are the relative contributions of multiple pathways to aggregate exposures? What are the contributions of exposures to multiple contaminants to estimates of aggregate risk?
- What are the socioeconomic considerations that communities bring to perceptions of environmental impacts?
- What community health and environmental justice issues may be associated with HF activities?
- What are appropriate biological endpoints that could be used to evaluate ecological risks (aquatic, semi-aquatic, terrestrial; surface and subsurface) and establish biomonitoring methods for detecting unacceptable levels of exposure in target populations?
- Are there social/behavioral science research approaches that could be developed to generate increased awareness of the potential environmental benefits and potential risks of HF in the context of community and environmental protection?

Approach for Compiling Background Data and Information

It is important to ensure that information and data used to inform the EPA study are credible and of appropriate quality. EPA is aware of information on hydraulic fracturing from numerous sources including studies supported by EPA, Department of Energy, state associations, industry groups, environmental groups, newspapers, and magazines.

Although these groups have written about hydraulic fracturing, there is a limited body of peer-reviewed literature on the relationship between hydraulic fracturing and drinking water. In analyzing and interpreting existing data to identify gaps and inform the study design, several key points should be considered:

- Geology is site specific and studies done in one area of the country may not be applicable to another area.
- Additives used during hydraulic fracturing may differ depending on the site, making it difficult to compare practices from one site to another.
- Lack of baseline data collected about the site characteristics and surrounding area prior to drilling may make it difficult to assess impacts from existing sites.
- Lack of validated and consistent data on chemicals and their concentrations make it difficult to assess impacts.

Potential Elements of Research Study

The categorical scoping exercise detailed above identified a host of potential questions that should be considered in designing the research study. The data and information needs to answer the questions can be organized to optimize study design. The major components of the study might include chemical characterization and monitoring, modeling, field studies, and technology.

Chemical Characterization and Monitoring

- Determine the potential range of chemical constituents that make up HF fluids.
- Understand how chemicals in the HF fluids might degrade as they interact with geologic formations and the microbes present in the formations.
- Determine the potential for metals, radionuclides, TENORM, organic contaminants or gases to be mobilized from geologic formations.
- Determine the chemical composition of produced water following the introduction of HF fluids.
- Verify and/or develop analytical methods that could be used to test additives, produced water, wastes, and ground and surface waters.
- Identify indicator/surrogate parameters that can be used to indicate exposure.
- Identify potential degradation products of HF chemicals.
- Develop a centralized database for compiling information that could be used as a resource for developing sampling plans.

Modeling

- Develop models or techniques to predict the likelihood of drinking water impacts based upon the available geologic, geochemical, and geophysical data.
- Evaluate key biogeochemical processes that might impact the quality of drinking water supplies.
- Identify tools that can be used to determine the zone of influence of HF fluids and area of review in the subsurface.
- Study the extent to which models for fracture stimulation accurately predict actual fracture geometries in various geologic settings.
- Develop watershed based models to evaluate impacts of water withdrawals and wastewater discharges on water quality and identify critical monitoring locations.

Field studies

- Examine how abandoned wells and geologic features provide conduits for fluid migration.
- Develop sampling programs to test the characteristics of fracturing waters and additives that are stored in holding tanks.
- Conduct effluent sampling at water reclamation facilities that receive HF flowback and/or produced waters.
- Conduct ambient water quality sampling to assess impacts on receiving streams.
- Determine if tracer fluids can be added to injected fluids to quantify subsurface fate and transport.
- Study the effects of fracture stimulations on domestic water supplies and attendant mechanisms in vulnerable hydrogeologic settings.
- Characterize the likelihood, volumes, contaminants (and their concentrations) and environmental impacts associated with normal HF surface operations.
- Evaluate whether HF proximity to abandoned and/or poorly constructed wells, faults, and fractures affects impacts on water, health, and/or ecosystems.
- Evaluate and characterize the potential for community health and environmental justice issues associated with HF activities.
- Develop approaches for sampling of public drinking water supplies and wells that are potentially impacted by HF activities.

Technology

- Assess the state of green chemical design for HF fluids.
- Evaluate the ability of current geophysical tools to verify the 3D location of HF induced fractures to determine if fractures are contained within target zones.
- Identify geophysical tools that allow differentiation between leachate derived from surface pits and potentially deeper sources.
- Determine the effectiveness of existing and emerging treatment technologies for HF flowback and/or produced fluids, residuals and solids produced. Develop cost estimates for practicable treatment technologies.
- Employ a geographic information system (GIS) approach to overlay HF activities with the locations of gas resources, drinking water resources, and other relevant site information.

Initial Approach for Stakeholder Involvement

EPA plans to design the research study with an integral stakeholder process that incorporates public participation concepts identified by the National Research Council.² There will be opportunities for stakeholder involvement throughout the study, starting from its initial planning and design through its implementation and completion. The Agency has crafted an initial set of guiding principles for stakeholder involvement and an initial set of outreach and communication options.

Example guiding principles for stakeholder involvement include:

1. Communicate with the stakeholders in a transparent and open manner.
2. Interact with stakeholders to foster an environment of mutual trust and respect.
3. Take measures to assure inclusive and comprehensive representation of all those who have an interest in the planning and implementation of the HF research program.
4. Treat all participants with respect and conduct any workshops and/or meetings in a fair and orderly manner.
5. Ensure the stakeholder engagement process is accessible and efficient.
6. Endeavor to understand the diversity of views presented by the stakeholders.
7. Provide stakeholders with the timely and understandable information that they need to effectively participate in activities.
8. To the extent possible, the Agency will communicate to its stakeholders, the rationale for decisions pertaining to the study design and other aspects of the effort and how their input was taken into account in decision-making.
9. Engage stakeholders throughout the duration of the research study.
10. Acknowledge that there are regional issues that must be considered and reach out to specifically understand stakeholder views in this context.

Stakeholder engagement is relevant in these phases of the study:

- Review of the research scoping documents
- Defining the scope of study
- Prioritizing research objectives
- Study design
- Research results documents and reports
- Explanation of possible risks and the Agency's risk assessment process.

² National Research Council. (2008). *Public Participation in Environmental Assessment and Decision Making*. Panel on Public Participation in Environmental Assessment and Decision Making, Thomas Dietz and Paul C. Stern, eds. Committee on the Human Dimensions of Global Change. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Potential communication and outreach activities include:

- Publishing Federal Register notices to request comments and information.
- Holding public meetings, listening sessions, and technical workshops to inform stakeholders about key issues related to HF and its relationship to drinking water resources.
- Centralized website so stakeholders can obtain information on study progress.
- Use of multiple forms of communication including web-based materials such as web-casts, podcasts, wikis, and interactive websites.
- Outreach through EPA's regional offices.