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EPA-SAB-10-xxx

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: Advisory on EPA's Research Scoping Document Related to Hydraulic Fracturing

Dear Administrator Jackson:

EPA's Office of Research and Development (ORD) has developed a proposed approach for a policy-relevant research program related to hydraulic fracturing. The purpose of this research program is to ensure drinking water protection and address related public health and environmental issues over the lifecycle of hydraulic fracturing, specifically as it pertains to the extraction of oil and gas from geologic formations. ORD developed this approach in response to the U.S. House of Representatives Fiscal Year 2010 Appropriation Conference Committee Directive to EPA that urged the Agency to conduct a study of hydraulic fracturing and its relationship to drinking water.

In response to a request from ORD, the EPA Science Advisory Board (SAB) convened the Environmental Engineering Committee (EEC) with additional members of the SAB to conduct a review of ORD's research scoping document related to hydraulic fracturing. The SAB Committee held a public meeting on April 7-8, 2010, to provide advice to ORD about this research plan and program. Specifically the SAB was asked to comment on the following three areas:

- Scope of the research program;
- Proposed research categories and topic areas, and process for prioritizing research needs given the Congressional request and a desire by the Agency to complete initial research products by the end of calendar year 2012; and
- Design of a stakeholder process that provides for balanced input.

In general, the Committee found ORD's overall approach and scope for the hydraulic fracturing research plan and program appropriate and comprehensive. The Committee, however, also found several areas that can be enhanced and focused, given the limited funding, resources and time associated with this effort. While a more detailed description of the technical

recommendations is contained in the report, the key points and recommendations are highlighted below.

The Committee discussed the hydraulic fracturing topic on two levels: (1) broad, long-term research goals, and (2) more focused, short-term research needs. The Committee identified a hierarchy of issues that should be considered when assessing these needs: hydraulic fracturing potentially affects water resources and drinking water supplies, and has potential to pose human health and environmental risks. Considering the Congressional request and a desire by the Agency to complete initial research products by the end of calendar year 2012, the Committee recommends that initial, short-term research be directed to study sources and pathways of potential impacts of hydraulic fracturing on water resources, especially potential drinking water sources. While current and potential drinking water sources are a recommended starting point/priority for ORD research, investigations should eventually occur on the impact on water resources more generally, and their aquatic ecosystems and ability to support fishing and recreation.

The Committee found that the systems and lifecycle perspectives described in the ORD research plan for study of the environmental impacts of hydraulic fracturing are appropriate. Considering the limited time, funding and resources available for the initial study by ORD, the Committee recommends using a lifecycle framework, without actually performing a formal lifecycle assessment, as an organizing tool that will facilitate identifying the most important research questions to address in the initial study. Questions pertaining to the impacts of the various stages of the hydraulic fracturing lifecycle on drinking water sources will be of primary importance and consistent with the research request from Congress.

The Committee believes ORD should identify knowledge gaps by outlining the hydraulic fracturing lifecycle and considering which components of the lifecycle pose potential risk to water resources and should be included in ORD's research efforts. The Committee recommends that ORD should emphasize human health and environmental concerns that are specific to or significantly influenced by hydraulic fracturing rather than on concerns that are common to all oil and gas production activities. As a priority, the Committee believes ORD should develop a risk-based research prioritization approach that would provide the scientific knowledge necessary for characterizing the risk of human and ecological exposure to hydraulic fracturing fluids and products.

Regarding potential relationships of hydraulic fracturing to drinking water sources, the Committee recommends that ORD carefully compile and review available data and knowledge on hydraulic fracturing and interaction with drinking water sources in peer-reviewed literature, in industry, in professional and non-governmental organizations, and in government agencies at the beginning of the research study. It is important to realize that the open peer-reviewed literature in this field is limited and other literature must be carefully critiqued regarding its limitations and appropriateness for addressing ORD's specific research needs. These efforts will help ensure accurate identification of data and knowledge gaps, maximize use of existing information, and optimize use of limited research funds. Considering the range of potential environmental

impacts associated with hydraulic fracturing and the range of geographic/geologic regions and site-specific conditions in which hydraulic fracturing may be implemented, the Committee recommends that ORD consider performing in-depth case studies at five to ten different locations selected to represent the full range of regional variability of hydraulic fracturing across the nation. In order to define relationships between hydraulic fracturing processes and drinking water resources, the Committee believes that significantly improved data and information are needed on the occurrence, volume, composition, treatability and/or disposal of hydraulic fracturing source fluids, flowback water, and produced water that is co-mingled with the flowback water, and the sources of the constituents (i.e., additive, reaction product, or leaching product) throughout different phases of the hydraulic fracturing lifecycle.

Regarding potential health and environmental risks associated with hydraulic fracturing, the Committee believes that such potential risks can only be assessed after sources and pathways of possible exposure are much better understood. Several activities must occur before such potential risks are assessed, including: a) characterization of the composition and variability of the source fluids, flowback water and produced water that is co-mingled with the flowback water; b) assessment of possible synergistic effects of mixtures of chemicals in fracturing fluids as well as synergistic effects of chemical mixtures interacting with materials in the fractured injection zone; c) evaluation of potential pathways to human and ecosystem exposure under a range of hydraulic fracturing process conditions relative to different geological formations and conditions; d) analysis of the existence and formation of hydraulic fracturing injection and product fluid transport pathways as a result of hydraulic fracturing; and e) identification of the conditions most likely to lead to impact on drinking water sources. Another important factor to assess is the effect of hydraulic fracturing processes on water quantity. Changes in water quantity in groundwater or surface water can have significant influences on human and ecosystem health. Also, potential secondary effects associated with hydraulic fracturing should be considered (e.g., arsenic mobilization in groundwater and aquifers due to enhanced methane transport and resulting changes in redox conditions).

Knowledge of the characteristics of the injected fluids, the reactions that occur in the injection zone, the characteristics of the fluids leaving the injected zone, and the pathways for the fluids leaving the injection zone will be needed for assessing the likelihood of impacts on drinking water sources, exposure of humans and ecosystems to hydraulic fracturing fluids and products, and the associated uncertainties involved in the assessment. The ORD research plan provides several lists of possible specific research questions. The Committee recommends that ORD identify a few overarching, fundamental questions which can then be placed in order of priority before revising the research plan. Examples of such questions would be: what are the fundamental physical and chemical water-related processes for each phase of the hydraulic fracturing lifecycle, and what are the quality and quantity of source fluids, flowback water and produced water co-mingled with the flowback water.

The Committee recommends developing a balanced, collaborative advisory group of stakeholders representing a broad range of perspectives. In addition to providing information to ORD, the stakeholder group would be engaged throughout the research process. ORD's

objectives and process for stakeholder engagement with the research should be carefully designed. One important objective for engagement with stakeholders should be to gain access to and leverage the existing knowledge base on hydraulic fracturing and its environmental impacts. There is a wealth of data and experience in industry, advocacy groups, state agencies, and other groups for ORD to draw upon in the research effort. It will also be important for ORD to engage with other federal agencies to share data, collaborate, leverage expertise, and align research priorities for optimal use of limited resources.

The SAB appreciates the opportunity to provide EPA with advice on this important subject. We look forward to receiving the Agency's response and potential future discussions with the Agency.

Sincerely,

Dr. Deborah L. Swackhamer, Chair
EPA Science Advisory Board

Dr. David A. Dzombak, Chair
SAB Environmental Engineering Committee

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U.S. Environmental Protection Agency
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SAB Environmental Engineering Committee (EEC) Augmented for the Evaluation and Comment on EPA's Proposed Research Approach for Studying the Potential Relationships Between Hydraulic Fracturing and Drinking Water Resources

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A. BACKGROUND ON SCOPING MATERIALS FOR INITIAL DESIGN OF EPA RESEARCH STUDY ON POTENTIAL RELATIONSHIPS BETWEEN HYDRAULIC FRACTURING AND DRINKING WATER RESOURCES

EPA's Office of Research and Development (ORD) prepared the "Scoping Materials for Initial Design of EPA Hydraulic Fracturing Research Study" document, and requested that the Science Advisory Board (SAB) Environmental Engineering Committee (EEC) review this document and generate ideas/suggestions on ORD's proposed approach for developing a policy-relevant research program related to hydraulic fracturing. EPA provided the following charge to the SAB EEC, and asked the EEC to generate ideas, suggestions and comments on the overall approach that will be used to frame the hydraulic fracturing study design and the areas that will be addressed by research. EPA sought specific advice on the development of the scope of the study, the approach to analyze data gaps and research needs, the stakeholder process, and the identification of the critical research questions. EPA also noted that SAB feedback will be used to guide the development of a scientifically sound study to establish the relationship between drinking water resources and hydraulic fracturing as it pertains to the extraction of oil and gas from geologic formations.

B. EPA's CHARGE TO THE COMMITTEE

Background

In its Fiscal Year 2010 Appropriation Conference Committee Directive to EPA, the U.S. House of Representatives urged the Agency to conduct a study of hydraulic fracturing and its relationship to drinking water, specifically:

> *"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."*

Hydraulic fracturing (HF) is a well stimulation technique used by gas producers to explore and produce natural gas from sources such as coalbed methane and shale gas formations. The gas extraction process includes: 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/or disposal; gas production (infrastructure for storage and transportation); and site closure.

EPA's Office of Research and Development (ORD) has developed a proposed approach for developing a policy-relevant study related to hydraulic fracturing. The purpose of the study is to evaluate the relationship between hydraulic fracturing and drinking water. Socio-economic factors may also play a role in understanding how to address potential health and environmental concerns. 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 and long-term goals. In developing the study design and potential research products, it is important to consider the types of information that might be needed to inform policy decisions.

ORD is currently engaged in compiling available information; identifying data gaps and research needs; defining and prioritizing study objectives; and developing a timeline to implement the study. An important part of this effort will be stakeholder involvement.

Specific Request

ORD has requested that the SAB Environmental Engineering Committee (EEC), as augmented for the hydraulic fracturing review, generate ideas/suggestions and comments on the overall approach that will be used to frame the hydraulic fracturing study design and the areas that will be addressed by research. ORD is seeking specific advice on the development of the scope of the study, the approach to analyze data gaps and research needs, the stakeholder process, and the identification of the critical research questions. SAB feedback will be used to guide the development of a scientifically sound study to establish the relationship between drinking water resources and hydraulic fracturing as it pertains to the extraction of oil and gas from geologic formations.

Charge to SAB

1. **Proposed Scope of Study:**

Congress urged EPA to carry out a study on "the relationship between hydraulic fracturing and drinking water." Key to determining the scope of the study is understanding whether or not the scope of the study should be narrowly focused or broadly focused, taking into account water resources and related public health and environmental issues over the lifecycle of hydraulic fracturing.

Charge Question 1: What recommendations does the SAB EEC have regarding this question of scope?

2. **Proposed Research Topics:**

ORD has identified the following proposed research categories relevant to hydraulic fracturing pertaining to extraction of oil and gas from geologic formations and its relationship to drinking water:

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

Charge Question 2A: What recommendations does the SAB EEC have regarding these proposed research categories and the related questions in the scoping paper?

Charge Question 2B: What process does the SAB EEC suggest for prioritizing research needs given the Congressional request and a desire by the Agency to complete initial research products by the end of calendar year 2012?

3. Stakeholder Process:

It will be critical to engage the stakeholder community in the planning process to establish a research program that is reflective of diverse interests and viewpoints.

Charge Question 3: What advice does the SAB EEC offer for designing a stakeholder process that provides for balanced input in developing a sound scientific approach for the overall research strategy?

C. RESPONSE TO THE CHARGE

The EEC of the EPA Science Advisory Board met in April 2010 to deliberate on the three charge questions raised by ORD to address the Scoping Materials document. These questions focused on: (1) scope of the research program; (2A) proposed research categories and topic areas; (2B) process for prioritizing research needs given the Congressional request and a desire by the Agency to complete initial research products by the end of calendar year 2012; and (3) design of a stakeholder process that provides for balanced input.

The EEC reviewed the Scoping Materials document and background materials provided by ORD, and considered public comments and oral statements that were received. The cover letter highlights the outcome of the Committee's deliberations and the recommendations, and the following Response to the Charge Questions provides details regarding these recommendations.

Charge Question 1: What recommendations does the EPA EEC have regarding the question of scope?

The Committee discussed the hydraulic fracturing topic on two levels: (1) broad, long-term research needs/ideals, and (2) more focused, short-term research goals. The Committee identified a hierarchy of issues that should be considered when assessing these needs: hydraulic fracturing potentially affects water resources and drinking water supplies, and has potential to pose human health and environmental risks. Considering the Congressional request and a desire by the Agency to complete initial research products by the end of calendar year 2012, the Committee recommends that initial, short-term research be directed to study sources and pathways of potential impacts of hydraulic fracturing on water resources, especially drinking water sources. While current and potential drinking water sources are a recommended starting point/priority for ORD research, investigations should eventually occur on the impact on water resources more generally, and their aquatic ecosystems and ability to support fishing and recreation.

ORD has interpreted the charge to investigate "the relationship between hydraulic fracturing and drinking water" with a systems perspective, and developed a research plan with a related broad scope. The SAB EEC supports the systems perspective reflected in the ORD research plan. Environmental science has been moving toward analysis that encompasses larger-scale systems, such as at watershed scale, in order to account for the inter-relationships that ultimately determine ecosystem health and hence the health of human communities that depend on these ecosystems. There is now widespread recognition that focusing too narrowly in assessing impacts of activities can lead to incomplete understanding of ecosystem inter-relationships and health.

The use of a lifecycle framework to plan a research study on the potential human health and environmental impacts of hydraulic fracturing is appropriate. However, a formal lifecycle assessment does not necessarily need to be undertaken. It would be useful to outline the hydraulic fracturing lifecycle and think about the components that would be included in a lifecycle assessment to help identify critical knowledge gaps. Considering the time and resources available for the initial study by ORD, the Committee recommends use of a lifecycle framework, without actually performing a lifecycle assessment, to identify the most important research questions to address in the initial study. Questions pertaining to the impacts of the various stages of the hydraulic fracturing lifecycle on drinking water sources will be of primary importance and consistent with the research request from Congress.

Economic analyses such as cost-benefit analysis are not included in the ORD research plan. The Committee supports the omission of such analysis from the ORD research plan for this initial study. There are a number of first-order science issues that need to be addressed first.

The ORD research plan has been formulated in part by the goal of conducting policy-relevant research. While it is difficult to predict which scientific results will be of greatest use to EPA and other government agencies when they establish policies and regulations in the future, the Committee believes that the research plan includes topics that will be relevant to policy formulation.

The Committee believes that ORD should emphasize environmental concerns that are specific to or significantly influenced by hydraulic fracturing rather than on concerns that are common to all oil and gas production activities. For example, management of produced water is a concern of all oil and gas production activities but hydraulic fracturing may influence the quantity and quality of produced water and the ORD research plan should address those influences.

Charge Question 2A: What recommendations does the SAB EEC have regarding these proposed research categories and the related questions in the scoping paper?

Characterization of the Hydraulic Fracturing Lifecycle

The use of a lifecycle framework to plan a research study on the environmental impacts of hydraulic fracturing is appropriate. Lifecycle assessment (LCA) is a formal process for which the International Organization for Standardization developed an international standard, ISO 14040. However, a formal LCA does not necessarily need to be undertaken in this case. It would be useful to outline the hydraulic fracturing lifecycle and think about the components that would be included in a LCA to help identify critical knowledge gaps. A careful compilation and review of data and knowledge available in the peer-reviewed literature, in industry, in professional and non-governmental organizations, and in government agencies should be conducted to ensure accurate identification of data gaps. It is important to realize that the open peer-reviewed literature in this field is limited and other literature must be carefully critiqued regarding its limitations and appropriateness for addressing ORD's specific research needs.

To the extent possible, in order to avoid duplicative research and focus on the Congressional request, the research plan should focus on issues that are uniquely associated with or significantly influenced by hydraulic fracturing, including both conventional and unconventional impacts that could occur at any point in the hydraulic fracturing lifecycle. However, it will be difficult to separate some issues associated with conventional oil and gas production in the evaluation of hydraulic fracturing and movement of chemicals through fissures in interconnected geological formations.

Development of a lifecycle framework for hydraulic fracturing can help EPA ORD prioritize knowledge gaps and decide what to study. In developing the lifecycle framework, ORD must identify appropriate boundaries for the assessment in order to help inform and focus the hydraulic fracturing research planning. An important boundary issue is where to draw the line between hydraulic fracturing-specific questions and questions pertaining to all oil and gas production operations. With definition of such boundaries, LCA can be used to separate conventional, well-understood issues such as impacts of site development, road construction, and trucking, from impacts that are not well understood, such as fate of chemicals in source fluids, flowback water and produced water that is co-mingled with the flowback water in storage ponds. LCA will be useful in identifying cumulative risks from both conventional and unconventional practices throughout the hydraulic fracturing lifecycle. Boundary definition should also be

guided by considering the types of comparisons that EPA or others may wish to undertake in the future, such as comparison of hydraulic fracturing impacts with those of other gas or energy production processes.

In developing the LCA framework, it will be necessary to think about the desired functional unit (e.g., single well, a multi-well pad, geological unit, or a watershed), the desired time horizon, and the most appropriate metrics (e.g., water use per unit of gas produced, total volume of water use for a region or watershed, number of conventional wells avoided each meter of horizontal drilling, mass of additives per unit of gas produced, greenhouse gas emissions per unit of gas produced). When choosing boundaries, time horizons, functional units, and metrics, EPA should acknowledge and recognize the degree to which such choices would address certain positive and negative impacts of hydraulic fracturing technology in the study and the degree to which such choices may preclude addressing certain impacts.

While there are multiple environmental impacts that could be associated with hydraulic fracturing, water issues are central and are the focus of the Congressional request for the research study. Because drinking water may be connected to many other water sources, water resources should be the central theme for the lifecycle framework development. Evaluation of the lifecycle assessment should be aimed at identifying knowledge gaps relevant to managing impacts on current and potential future drinking water sources and systems, and prioritizing these knowledge gaps for research. Although current and potential drinking water sources are a recommended starting point/priority for ORD research, the impact on water resources more generally, and their aquatic ecosystems and ability to support fishing and recreation, should eventually be investigated.

<u>Potential Relationships to Drinking Water Sources</u>

As discussed under Charge Question 2B, the Committee believes ORD should carefully compile and review available data and knowledge on hydraulic fracturing and interaction with current and potential future drinking water sources at the beginning of the research study. When compiling information on current and potential future drinking water sources, the definition of drinking water source should be broad, because some surface waters and deep aquifers bodies not currently considered drinking water sources will likely be viewed as such in the future. Also, many of these water sources are now or may be hydrologically connected.

Considering the range of potential environmental impacts associated with hydraulic fracturing and the range of geographic/geologic regions and site-specific conditions in which hydraulic fracturing may be implemented, it will be difficult to study hydraulic fracturing with sufficient depth and breadth for the allotted time and budget of the research study. ORD should identify reasonable short term goals and accomplishments (e.g., within one to three years) and long term goals and accomplishments (e.g., within five to ten years or longer) for this research.

The research planning team should consider performance of in-depth case studies at five to ten different locations selected to represent the full range of regional variability across the

nation. ORD has used the in-depth case study approach successfully in other multi-objective research programs. The in-depth case study approach is an efficient way to conduct research on groups of systems that exhibit significant variability between systems. Through careful design, the case-study approach can yield in-depth process understanding with some degree of generalization. This approach can provide a valuable basis for exchange of information between resource development companies (e.g., oil and gas industries) and interested citizen groups. Case studies offer the potential to increase our understanding of human and ecological exposure in relation to hydraulic fracturing activities in a rapid manner. Case studies can reveal those life cycle assessment parameters of significance for hydraulic fracturing analysis. Case studies can also help identify existing best management practices (BMPs) that favorably affect quality and quantity of source fluids, flowback water and produced water that is co-mingled with the flowback water. Case studies may also provide information on the impact of the composition and variability of source fluids on flowback/produced water. For example, some operators may use different source fluid additives that have different implications for flowback/produced water contaminants and management. (e.g., acidic additives may enhance metal leaching from the formation into flowback/produced water.) Case studies should be carefully designed to assess the range and variability of environmental and exposure conditions of areas where hydraulic fracturing is and will be occurring and where hydraulic fracturing fluids may be released. Also, because of the high cost of installing and operating hydraulic fracturing systems, it is recommended that the EPA partner with industries who would develop and operate the wellsites while EPA conducts research at the sites (e.g., to install monitoring stations, monitoring, wells, etc).

In order to define relationships between hydraulic fracturing processes and water sources, the Committee believes that significantly improved data and information are needed on the occurrence, volume, composition, treatability and/or disposal of hydraulic fracturing source fluids, flowback water and produced water that is co-mingled with the flowback water and the sources of the constituents (i.e., additive, reaction product, or leaching product) throughout different phases of the hydraulic fracturing lifecycle. The composition of hydraulic fracturing source fluids, flowback water and produced water that is co-mingled with the flowback water, and the sources of the constituents need to be understood to provide knowledge about physical-chemical mechanisms governing flowback and produced water chemistry and insight into ways to control this chemistry. For improved detection, reliable surrogate constituents should be investigated. The potential and desirability of introducing tracer constituents in hydraulic fracturing fluids for studying fate and transport in these complex fractured systems should also be investigated.

To help assess impacts to water sources, ORD should consider doing mass balances on chemicals of concern and water quantity in areas where hydraulic fracturing is or will be occurring. Also, because impacts to water quantity affect water quality, ORD should assess hydraulic fracturing impacts to water quantity for both surface water and groundwater.

After compiling and reviewing available data and knowledge on hydraulic fracturing and interaction with current and potential future drinking water sources at the beginning of the

research study, ORD should identify how to best address any potential problems identified through this effort, such as water treatability issues and applicability of emerging treatment technologies. The research plan should include a focused effort on treatability of hydraulic fracturing flowback and produced water that is co-mingled with the flowback water in several contexts. Research should be conducted on the effectiveness of municipal wastewater treatment systems with respect to hydraulic fracturing flowback and produced water that is co-mingled with the flowback water, as these waters are often being directed to Publicly Owned Treatment Works (POTWs). There are new methods emerging for treatment of very high Total Dissolved Solids (TDS) waters, such as membrane distillation. The potential for these technologies to be effective in treating hydraulic fracturing process waters should be systematically investigated. Research should be also conducted to determine the effectiveness of existing drinking water treatment technology, including public water treatment and point of use technology, for removing hydraulic fracturing flowback and produced water constituents that become introduced to water supply sources. Such constituents might be introduced into drinking water sources through inadequate treatment in POTWs or through pathways such as stormwater runoff.

In developing the research study plan, specific potential uses of the results should be considered. If one potential outcome is to develop scientific information to facilitate assessment of risk at particular sites, development of site assessment methodologies and related data requirements and acquisition methodologies is needed.

Potential Health and Environmental Risks

Health and environmental risk associated with hydraulic fracturing can only be assessed after sources and pathways of possible exposure are much better understood. Several activities must occur before such potential risks are assessed, including: a) characterization of the composition and variability of the source fluids, flowback water and produced water that is co-mingled with the flowback water; b) assessment of possible synergistic effects of mixtures of chemicals in fracturing fluids as well as synergistic effects of chemical mixtures interacting with materials in the fractured injection zone; c) evaluation of potential pathways to human and ecosystem exposure under a range of hydraulic fracturing process conditions relative to different geological formations and conditions; d) analysis of the existence and formation of hydraulic fracturing injection and product fluid transport pathways as a result of hydraulic fracturing; and e) identification of the conditions most likely to lead to impacts on drinking water resources.

As discussed above under Potential Relationships to Drinking Water Sources, another important factor to assess is the effect of hydraulic fracturing processes on water quantity. Changes in water quantity in groundwater or surface water can have significant influences on human and ecosystem health. Also, potential secondary effects associated with hydraulic fracturing should be considered (e.g., arsenic mobilization in groundwater and aquifers due to enhanced methane transport and resulting changes in redox conditions). It would be helpful to evaluate the cumulative impacts that additional uses of water resources have on water quality and quantity in water resource systems where hydraulic fracturing activities are occurring or are being considered (e.g., pumping of water for agriculture and urban/industrial uses). After these

efforts have been conducted, an initial analysis should be conducted that identifies the exposure routes likely to pose the greatest human health risk.

Geographic Information System (GIS) mapping with overlays of hydraulic fracturing activities and locations of human populations and ecological receptors would provide useful initial insights into potentially exposed populations and ecosystems. GIS mapping would be helpful in intersecting aquifer and surface water conditions with potential receptor and exposed populations, could be used to map reported incidents of problems potentially caused by hydraulic fracturing activities, and would help with the design of future health and ecosystem studies. There are readily available databases, including those related to the U.S. Census, Medicaid, Medicare, and others, to which GIS mapping techniques could be applied to assess spatial associations between hydraulic fracturing activities and human disease. This mapping would provide preliminary insights into locations for targeted current and/or future research.

Occupational exposure information and data for hydraulic fracturing processes could be a potential source of information to guide initial evaluations. Such information could, for example, give some initial information on the potential health effects of mixtures of chemicals present in hydraulic fracturing fluids.

The EPA and U.S. Department of Energy are developing risk assessment approaches and data for geologic sequestration of carbon dioxide. Knowledge, tools, and data are being developed through these efforts that are applicable to risk assessment for hydraulic fracturing. The Committee encourages ORD to make use of the ongoing research and expertise pertaining to geologic sequestration of carbon dioxide.

Regardless of which topics are ultimately selected for investigation, ORD should invest in and develop effective strategies for communicating and defending the chosen research topics of focus.

Charge Question 2B: What process does the SAB EEC suggest for prioritizing research needs given the Congressional request and a desire by the Agency to complete initial research products by the end of calendar year 2012?

<u>Priorities</u>

ORD should carefully compile and review available data and knowledge on hydraulic fracturing and interaction with drinking water resources in the peer-reviewed literature, in industry, in professional and non-governmental organizations, and in government agencies at the beginning of the research study. These efforts would help ensure accurate identification of data and knowledge gaps, maximize use of existing information, and optimize use of limited research funds.

This compilation and review of existing data and knowledge will need to be conducted with critical evaluation of the quality and relevance of the information. For example, some previous studies on hydraulic fracturing were conducted for different purposes such as on optimizing gas extraction efficiency, and the data collected and presented in this context are not likely to be sufficient for understanding solute generation or migration. It is important to engage the current state of oil and gas engineering and science to identify and evaluate existing knowledge and pertinent data. It is also important to realize that the open peer-reviewed literature in this field is limited and other literature must be carefully critiqued regarding its limitations and appropriateness for addressing ORD's specific research needs.

Knowledge of the characteristics of the injected fluids, the reactions that occur in the injection zone, the characteristics of the fluids leaving the injected zone, and the pathways for the fluids leaving the injection zone will be needed for assessing impacts on water resources, exposure of humans and ecosystems to hydraulic fracturing fluids and products, and the associated uncertainties involved in the assessment. As a priority, ORD should develop a risk-based research prioritization approach that would provide the scientific knowledge necessary for characterizing the risk of conditions that can lead to human and ecological exposure to hydraulic fracturing fluids and products at levels that impart health risks. ORD should also prioritize research towards the reactions and transport of hydraulic fracturing fluids in the complex subsurface environment, because experience with reservoir engineering and subsurface remediation makes clear that there is much to learn on developing basic scientific understanding of these processes.

The ORD research plan provides several lists of possible specific research questions. To help identify priority topics for research, ORD should develop several overarching, fundamental questions, perhaps through grouping the many questions suggested by ORD. These overarching questions can then be placed in order of priority. The Committee recommends that ORD conduct such an exercise before revising the research plan. The Committee discussed some fundamental questions, but did not undertake to prioritize them.

<u>Fundamental Questions</u>

- What are the fundamental physical and chemical water-related processes for each phase of the hydraulic fracturing lifecycle (below ground and above ground in treatment processes and surface water)?
- What is the quality and quantity of injected fluids, flowback water and produced water that is co-mingled with the flowback water?
- How does the specific composition of TDS vary among flowback and produced waters?
- What do field case studies tell us about the effects of hydraulic fracturing on the reactions, fate, and transport of injected constituents, and the fate and transport of potential contaminants in particular regions and geologic regimes?
- What do field data convey about region-specific issues related to hydraulic fracturing and its environmental impacts?

- In what way does hydraulic fracturing, at one or multiple sites, alter existing surface and subsurface flow paths?
- What are existing best management practices (BMPs) that affect quality and quantity of flowback and produced water?
- What are opportunities to develop technologies that could lead to green additives or improved approaches to managing process waters or waters impacted by hydraulic fracturing?
- What are the mass balances for water and constituents of concern at a hydraulic fracturing site?

Charge Question 3: What advice does the SAB EEC offer for designing a stakeholder process that provides for balanced input in developing a sound scientific approach for the overall research strategy?

The Committee recommends development of a balanced, collaborative advisory group of stakeholders representing a broad range of perspectives. Hydraulic fracturing for oil and gas development affects ecosystems and communities directly and is a topic of significant public interest. The technology also has the potential to vastly increase US gas production and is of great interest for energy security and economic development. Formation of an advisory group of stakeholders for the research effort will help inform the research, including helping the research teams to become aware of data and expertise that can benefit the research. To ensure that the stakeholder process is inclusive, collaborative, transparent, and legitimate, ORD should strive for broad representation on the advisory group.

The group could be comprised of representatives of industry, environmental groups, affected residents, state regulators, and other individuals. This group could assist ORD in accessing data held by the various groups and in establishing stakeholder-based evaluation criteria. At the conclusion of the research period, this group could assist other units of EPA in the transition from research results to policy recommendations. The group could also be used to help develop a community-based participatory research component that would develop technical capacity in affected communities. One approach would be to establish community-based sampling and testing centers in partnership with pro bono scientists and engineers, environmental groups, universities, and residents. Household water, private well water, and stream samples could be tested to provide screening level information. Hot spots could be identified for further, more comprehensive testing.

EPA needs to first set clear, realistic goals, expectations and objectives for hydraulic fracturing stakeholder engagement. EPA should then develop and undertake various approaches for stakeholder engagement with regard to the hydraulic fracturing issue. The stakeholder group should be engaged throughout the research process. With respect to stakeholder engagement for informing hydraulic fracturing research, the needs and responsibilities of ORD vs. other offices within EPA need to be considered. The Committee recommends that ORD's objectives and process for stakeholder engagement with the research should be carefully designed based on best

available social science. This will help determine the appropriate composition and charge for the advisory group of stakeholders that will provide advice and information on hydraulic fracturing research activities.

Based on submitted written and oral public comments to the draft ORD hydraulic fracturing research plan, it is clear that there is a wealth of data and experience in industry, in professional and non-governmental organizations, in state agencies, and in other groups for ORD to draw upon in the research effort. One important objective for engagement with stakeholders should be to gain access to and leverage the existing knowledge base on hydraulic fracturing and its environmental impacts.

There are many technological development activities and development and study of best management practices with respect to hydraulic fracturing that are ongoing in the states. It would be helpful if EPA engaged with relevant states to inventory and conduct performance evaluations of the effectiveness of state hydraulic fracturing regulatory, technological development and BMP activities. Among other benefits of such an endeavor, the Committee expects that opportunities for collaborative EPA and state research efforts will be identified through serious engagement with the states.

Through the discussions with stakeholder groups and the engagement with states, opportunities to leverage ongoing or planned community-based sampling and testing should be explored, with appropriate consideration of quality assurance/quality control requirements and utilizing community resources for meaningful contributions to meeting research objectives. There may be particular opportunities to engage community resources at case-study sites, if ORD decides to pursue case studies as a component of the research effort.

It will also be important for ORD to engage with other federal agencies to share data, collaborate, leverage expertise, and align research priorities for optimal use of limited resources.