United States
Environmental Protection
Agency

March 2014 I www.epa.gov/hfstudy

Summary of the Technical Roundtable on EPA's Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

December 9, 2013

Disclaimer

This report was prepared by EPA with assistance from Eastern Research Group, Inc., an EPA contractor, as a general record of discussions during the December 9, 2013, technical roundtable on EPA's study of the potential impacts of hydraulic fracturing on drinking water resources. The report summarizes the presentations and facilitated discussions and is not intended to reflect a complete record of all discussions. All statements and opinions expressed represent individual views of the invited participants; there was no attempt to reach consensus on any of the technical issues being discussed. Except as noted, none of the statements in the report represent analyses or positions of EPA.

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Table of Contents

Agenda

Technical Roundtable
EPA's Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources
December 9, 2013

US EPA Research Triangle Park Campus
"C" Building Auditorium
Research Triangle Park, NC

Final Agenda

8:00 am **Registration/Check-In**

8:30 am **Welcome**
Ramona Trovato, Acting Principal Deputy Assistant Administrator, EPA Office of Research and Development (ORD)

8:35 am **Introductions** (all participants, led by facilitator)
- Name and affiliation
- Ground rules

8:45 am **Opening Remarks**
Ramona Trovato, EPA-ORD

9:00 am **Study Update: Potential Impacts of Hydraulic Fracturing on Drinking Water Resources**
Jeanne Briskin, Coordinator of Hydraulic Fracturing Research, EPA-ORD

9:15 am **Panel Discussion - Technical Workshops**

Analytical Chemical Methods –
Jennifer Orme-Zavaleta, EPA-ORD

Well Construction/Operation and Subsurface Modeling –
Kris Nygaard, ExxonMobil Production Company

Wastewater Treatment and Related Modeling –
Tom Starosta, Pennsylvania Department of Environmental Protection

Water Acquisition Modeling –
Jennifer Orme-Zavaleta, EPA-ORD

Case Studies –
Cindy Sonich-Mullin, EPA-ORD

How technical workshops informed the EPA study –
Jeanne Briskin, EPA-ORD

10:15 am **Break**

10:30 am **Discussion on Technical Workshops** (all participants)

11:30 am **Lunch** (on your own)

1:00 pm **Plans for Federal Multiagency Collaboration on Unconventional Oil and Gas**
Kevin Teichman, EPA-ORD

1:15 pm **Overview of EPA's Hydraulic Fracturing Drinking Water Assessment Report**
Jeff Frithsen, EPA-ORD

1:45 pm **Question & Answer Period**

2:15 pm **Break**

2:30 pm **Stakeholder Engagement**
Ramona Trovato and Lisa Matthews, EPA-ORD

2:45 pm **Input on Stakeholder Engagement Process** (all participants)

3:45 pm **Wrap-Up and Closing Remarks**
Ramona Trovato, EPA-ORD

4:00 pm **Adjourn**

List of Attendees

Hydraulic Fracturing Technical Roundtable
December 9, 2013

PARTICIPANTS

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Chesapeake Energy

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American Water Works Association

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Introduction

At the request of Congress, the U.S. Environmental Protection Agency (EPA) is conducting a study to better understand the potential impacts of hydraulic fracturing on drinking water resources. The scope of the research includes the full cycle of water associated with hydraulic fracturing activities. In the study, each stage of the water cycle is associated with a primary research question:[1]

- **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 surface spills on or near well pads of flowback and produced water on drinking water resources?
- **Wastewater treatment and waste disposal:** What are the possible impacts of inadequate treatment of hydraulic fracturing wastewaters on drinking water resources?

On November 14–16, 2012, EPA conducted a series of five technical roundtables focused on each stage of the water cycle.[2] EPA's goals for these roundtables were to discuss key aspects of this complex study with stakeholders and develop a list of potential topics for future technical workshops. Based on feedback from the roundtables, EPA hosted a series of technical workshops in 2013 to address specific topics in greater detail. The workshops included Analytical Chemical Methods (February 25, 2013), Well Construction/Operation and Subsurface Modeling (April 16–17, 2013), Wastewater Treatment and Related Modeling (April 18, 2013), a follow-up technical discussion on subsurface modeling (June 2, 2013), Water Acquisition Modeling (June 4, 2013), and Case Studies (July 30, 2013).[3] The workshops were intended to inform EPA on subjects integral to enhancing the overall hydraulic fracturing study, increasing collaborative opportunities and identifying additional possible future research areas. Each workshop addressed subject matter directly related to the primary research questions.

For each workshop, EPA invited experts with significant relevant and current technical experience. Each workshop consisted of invited presentations followed by facilitated discussion among all invited experts. Participants were chosen with the goal of maintaining balanced

[1] EPA's study plan (http://www2.epa.gov/hfstudy/plan-study-potential-impacts-hydraulic-fracturing-drinking-water-resources-epa600r-11122) and 2012 progress report (http://www2.epa.gov/hfstudy/study-potential-impacts-hydraulic-fracturing-drinking-water-resources-progress-report-0) provide a complete description of the water cycle associated with hydraulic fracturing activities.

[2] Technical roundtable summary reports available at http://www2.epa.gov/hfstudy/2012-technical-roundtables.

[3] Technical workshop summary reports available at http://www2.epa.gov/hfstudy/2013-technical-workshops.

viewpoints from a diverse set of stakeholder groups, including industry; nongovernmental organizations; other federal, state and local governments; tribes; and the academic community.

On December 9, 2013, EPA reconvened the roundtable to review the work addressed in the technical workshop series. EPA presented a study update, an overview of the technical workshops and how they informed the study, plans for multiagency collaboration on unconventional oil and gas, an overview of EPA's study report, and a review of stakeholder engagement. Individual roundtable participants provided comments and input on technical issues related to the study and on suggested next steps for stakeholder engagement.

Opening Remarks

Susan Hazen, Federal Consulting Group, opened the roundtable as the meeting facilitator. She noted that EPA was looking for individual participants' frank input and opinion; the roundtable was not being held under the rules of the Federal Advisory Committee Act (FACA), and therefore there would be no effort to reach consensus on the topics discussed.

Ramona Trovato, Acting Principal Deputy Assistant Administrator of EPA's Office of Research and Development (ORD), welcomed the participants and thanked them for contributing their knowledge and experience. She noted that this roundtable would recap the earlier technical roundtables and workshops and would be used as a forum to discuss next steps in stakeholder engagement.

Study Update: Potential Impacts of Hydraulic Fracturing on Drinking Water

Jeanne Briskin, Coordinator of Hydraulic Fracturing Research, EPA Office of Research and Development, presented an update on EPA's study of the potential impact of hydraulic fracturing on drinking water. She discussed the milestones reached in the study since the technical roundtables were held in November 2012:

- The December 2012 progress report (available at http://www.epa.gov/hfstudy) presented project-specific updates, including the research approach and status as of September 2012.
- The Science Advisory Board (SAB) Hydraulic Fracturing Research Advisory Panel met in May 2013. Panel members were impressed with the study accomplishments and acknowledged the challenges in presenting findings to a broad audience. They recommended that EPA:
  - Capture basin-specific trends and location-specific conditions (geology, hydrology).
  - Use professional judgment when making assumptions and interpreting results.
  - Write clearly and provide enough detail to inform the public and prevent misinterpretation of data and images, including assumptions and uncertainty.
  - Stay informed about new industry practices and technologies.
  - Manage expectations about what will and will not be included in the report of results.
- To date, five papers have been published in scientific journals. Overall, 17 research projects are expected to produce more than 30 peer-reviewed journal papers or EPA reports. These products will be considered along with the scientific literature in the draft assessment report to be released in late 2014.
- EPA conducted the 2013 technical workshop series as well as follow-up public webinars to provide updates.

Ms. Briskin then described the next steps in the study. EPA will continue to conduct research, analyze information and literature, and engage stakeholders. In addition:

- The completed research will undergo peer review.
- EPA will continue to exchange information with industry, academia, states, nongovernmental organizations, and the public.
- EPA will update the SAB panel on publications and research.
- In late 2014 EPA will release the draft assessment report, which will undergo peer review by the SAB panel as well as public comment.

Panel Discussion: Technical Workshops

Following the study update, co-chairs of the five 2013 technical workshops presented the questions addressed in each workshop and the observations and suggestions of individual workshop participants. EPA then provided an overview of how the technical workshops informed the study.

Summary of February 25, 2013, Technical Workshop on Analytical Chemical Methods

Dr. **Jennifer Orme-Zavaleta,** EPA Office of Research and Development, provided an overview of the discussions held at the Analytical Chemical Methods workshop. She opened her presentation by reviewing the specific questions that EPA asked the workshop participants to consider. As part of the discussion of analytical methods, EPA asked the workshop participants for input on:

- Other/different/new methods for the EPA list of analytes.
- Other analytes EPA should test for and the methods to be used.
- Special considerations relative to differences between matrices (injection fluids, ground water, surface water, produced and flowback water) considering high total dissolved solids (TDS), radionuclides and interferences.
- Levels of sensitivity needed for analytical methods to detect effects and serve as indicators associated with hydraulic fracturing.
- Advances in industry practices that change the chemical makeup of hydraulic fracturing injection fluids and implication for chemical selection or field sample analysis.
- Use of artificial tracers for tracking hydraulic fracturing fluids, and analytical methods used to measure those tracers.

Dr. Orme-Zavaleta then presented individual participant observations and suggestions made during the workshop. (She clarified that these observations were individual observations, not consensus opinions, and that not all observations could/would be addressed during the course of the larger study.)

Baseline Information

- It is important to understand the quality of formation water and produced water, including concentrations of organic matter and methane.
- Consider seasonal variations, natural variability and issues related to construction of private wells.
- Guidance is needed on baseline sampling (where, when; during what segment of well operations).

Sampling Procedures

- Focus on sample collection, timing of collection, preservation, holding times and storage. Refer to U.S. Geological Survey sampling protocols.
- Consider the impact of local geology on contaminants in flowback and produced waters.
- Collect field turbidity measurements before and after sampling.
- Consider monitoring at shale gas sites to evaluate water and gases in the subsurface.
- For field sampling for methane: look at grab sample vs. capturing methane in a submerged collection system.
- Need field protocols and quality assurance/quality control (QA/QC) procedures for methane.

Analytical Approaches

- Use a triage approach: first evaluate key indicators such as high TDS, chlorine or sodium. If first tier indicators are elevated, then perform second-level analyses associated with the well, local geology or company practices.
- Examine multiple lines of contamination evidence to determine if contamination is associated with an incident, natural variability of water or other factors.
- Consider lab capability, equipment and costs.
- Consider advantages and disadvantages of the use of isotopic signatures.

Analyte Selection and Methods Development

- Develop and test methods specific to matrix of concern—there is no "one size fits all."
- Develop analyses for disinfection byproduct precursors.
- Methods for radium 226 and 228 are useful; gross alpha methods are not useful.
- Isotopic and radioisotopic determinations are important. Breakdown or daughter products should be determined if possible.
- Need to evaluate for dissolved gases.

Detection Limits

- How low is low enough?
- Method detection limit (MDL) vs. lower limit of quantitation.
- Consider different detection limits for ground water and surface water vs. flowback and produced water matrices

Advancements in Industry Practices

- There is a trend toward use of more environmentally friendly chemicals.

- Increased use of recycled or reused water has decreased the use of fresh water.
- The additives list continually changes.
- With reused water, the need for additives decreases.

Tracers

- Tracers vs. indicators: tracers are specifically added to monitor movement of fluids. Indicators are chemicals already used in hydraulic fracturing fluids.
- Indicators can help in evaluations of well integrity.
- Conduct a specific assessment before use to determine the impacts of high pressure and temperature on stability.

QA/QC

- Appropriate QA/QC controls are important.
- Collect both preserved and unpreserved field samples.
- Use of field blanks and replicate analytes is a must.
- The issue of instrument sensitivity is tied to the matrix being tested.
- Revisit sample holding times from a regulatory perspective.
- There is a need for certified or standard reference materials.

Summary of April 16–17, 2013, Technical Workshop on Well Construction/Operation and Subsurface Modeling

Dr. **Kris Nygaard,** ExxonMobil Production Company, presented an overview of the Well Construction/Operation and Subsurface Modeling workshop. EPA asked workshop participants for input on a series of questions.

Well Construction

- What are the current design techniques that prevent leaks through production well casing and fluid movement along the wellbore?
- What factors are typically used to ensure adequate confinement of fluids that can move?
- How are ground water resources identified and documented (in terms of quality, quantity, etc.) prior to well installation and post-production? What is the breadth of approaches?

Well Operation

- What testing can be conducted to verify issues do not exist prior to, during and after hydraulic fracturing?

- What testing or monitoring techniques can ensure adequate confinement? What is the breadth of approaches?

Subsurface Modeling

- What additional potential failure scenarios not covered in the EPA study progress report could be investigated?
- What are the most important parameters and appropriate level of complexity for a model that studies the severity of the potential impact of hydraulic fracturing on drinking water resources?
- What are the advantages and disadvantages of different modeling approaches?
- What well performance data (e.g., micro seismic testing, pressure, tracer or other) are available to EPA that would be useful to build and evaluate the model?

Using these questions as broad headings, Dr. Nygaard presented individual participant observations and suggestions made during the workshop. (He clarified that these observations were individual observations, not consensus opinions, and that not all observations could/would be addressed during the course of the larger study.)

Individual participant observations and suggestions included the following:

Well Construction

What are the current design techniques that prevent leaks through production well casing and fluid movement along the wellbore?

- Engineered well designs considering the full operational life-cycle and local conditions:
  - Numerous layers of protection can be incorporated into the well's design, including natural barriers, engineered physical barriers, monitoring and response/remediation capabilities.
  - Type well designs can be used when there is not significant variation in local conditions.
  - Specific and customized engineering designs for casing, connections and cement.
  - Material selection specific to the conditions.

What factors are typically used to ensure adequate confinement of fluids that can move?

- Placement of multiple physical barriers (steel, cement, seals, etc.).
- Fresh water zones may be isolated with multiple barriers during initial drilling phase.
- Producing zones may be isolated with multiple barriers during the drilling phase.
- Barrier verification testing.
- Well assurance via monitoring, testing and logging.
- Annular pressure monitoring.

How are ground water resources identified and documented (in terms of quality, quantity, etc.) prior to well installation and post-production? What is the breadth of approaches?

- Use of geophysical logging tools:
  - Examination of existing geologic records, reports and regulations.
  - The local geologic situation and location of water sources may be determined by working with local regulators and performing review of historical well data and performing additional data collection such as wireline logging.
  - Ongoing annular pressure monitoring is performed to assess long-term barrier performance.

Well Operation

What testing can be conducted to verify issues do not exist prior to, during and after hydraulic fracturing?

- Baseline water sampling.
- Barrier verification testing.
- Real-time monitoring during hydraulic fracturing.
- Life-cycle well assurance via monitoring, testing and logging.

What testing or monitoring techniques can ensure adequate confinement? What is the breadth of approaches?

Examples include:

- Real-time monitoring during hydraulic fracturing.
- Barrier verification testing before hydraulic fracturing.

Subsurface Modeling

During the April session, there was extensive discussion on this topic. A follow-up session was held in June so that the Lawrence Berkeley National Laboratory (LBNL) and EPA researchers could discuss in more detail the model formulation and scenarios being considered. The input from individual workshop participants is summarized below.

What additional potential failure scenarios not covered in the EPA study progress report could be investigated?

- Risk-based evaluation based on probabilistic models.
- Broader range of bounding conditions on input data.
- Appropriate hydrodynamic characterization of fracturing and multi-phase flow conditions.

- No-failure scenarios and "baseline" scenarios.

What are the most important parameters and appropriate level of complexity for a model that studies the severity of the potential impact of hydraulic fracturing on drinking water resources?

- Recognize the broad audience and the goal of providing information to inform the public and policy makers.
- The model must faithfully represent the three-dimensional, transient solution to the coupled geomechanical, hydrodynamic and species/chemical transport physics.
- Broad input parameterization: formation stress, permeability, fracture/fault conductivity; associated heterogeneity and three-dimensionality were considered critical properties and flow/transport parameters must be adequately represented.

What are the advantages and disadvantages of different modeling approaches?

- Analytic models vs. computational models: Simple analytic models compared to "state-of the-art" high-complexity computational models were discussed. Some noted that simple analytic models will not faithfully reflect important physics, and complex models are computationally intensive.
- Significant effort would be required to evaluate the full range of probable outcomes when considering a risk-based approach.
- Model calibration, validation, and benchmarking: models should be calibrated and tested against a range of data sets.

What well performance data (e.g., micro seismic testing, pressure, tracer or other) are available to EPA that would be useful to build and evaluate the model?

- Existing government datasets.
- Published industry datasets.
- Formal EPA data request.

Summary of major suggestions and recommendations made by individual participants:

- Use of diagnostics is important to assess well integrity.
- Pressure monitoring is necessary.
- Cementing is a critical confinement technique.
- A number of practices are used to identify ground water resources.
- There is a need for better data.
- Collaboration between industry and regulators would be useful.

- Accurate diagrams of the scenarios should be developed and presented, and should reflect the presence of surface casing and cement to fully reflect the presence of multiple barriers which are often used to construct wells.
- Avoid physically impossible or implausible scenarios.
- Implement probabilistic and risk-based modeling.
- Use of "oilfield units" should be used when reporting results to help industry understand the results.

Summary of April 18, 2013, Technical Workshop on Wastewater Treatment and Related Modeling

Mr. **Tom Starosta,** Pennsylvania Department of Environmental Protection, provided an overview of the discussions held at the Wastewater Treatment and Related Modeling workshop. EPA asked the workshop participants to consider the following questions:

- What are some modern and potential future trends in reuse, recycling, zero-liquid discharge and commercial transport?
- How can the residuals of hydraulic fracturing be managed, disposed of and characterized?
- What are the consequences of disposal via landfills or beneficial reuse?
- What are the contributions of selected contaminants from hydraulic fracturing relative to other potential sources of contamination?
- What are some applications of surface and subsurface modeling?
- How much flowback or produced water is created, and what happens to it?
- How do we currently monitor wastewater disposition?
- How do the projected volumes of wastewater compare to wastewater management capacity, including underground injection wells and treatment systems?
- What are the regional differences in wastewater quantity and quality and potential impacts on drinking water sources?

Mr. Starosta presented individual participant observations and suggestions made during the workshop. (He clarified that these observations were individual observations, not consensus opinions, and that not all observations could/would be addressed during the course of the larger study.)

Individual participant observations and suggestions included the following:

- There have been rapid advances in wastewater reuse and recycling practices, both in the frequency and volume of wastewater reused and in the methods employed to support those practices.

- Flowback from one hydraulically fractured well may be immediately filtered at the well site and mixed with fresh makeup water to provide the hydraulic fracturing water for the next. If no new wells are scheduled to be hydraulically fractured, the flowback may be trucked to a storage facility to await disposition. Depending on its composition and quality, it may require more treatment at a centralized treatment facility before reuse in further fracturing operations.
- Chemical precipitation of the multivalent ions that constitute the scaling materials is still the most prevalent form of treatment to support reuse of the wastewater, but advanced treatment including evaporative methods are becoming increasingly common, at least in the Marcellus Shale region.
- For the concentrated brine waste, deep well injection is believed by some to remain the primary pathway for ultimate disposal in the Marcellus region.
- Despite the relatively high cost of advanced treatment methods, they are often cost-effective when avoided transportation costs are considered. Transportation costs seem to be the single largest cost element in the process.
- At the beginning of this effort, it seemed reasonable to consider the threat that point source discharges of treated shale gas wastewater would pose to community water system intakes on rivers and streams. Even if treated using common physical and chemical methods, such wastewater would still be high in dissolved solids, and the large mass of waste material involved is daunting. This is still a concern, but it is increasingly evident that this practice will be limited in some areas because of the harm that would be caused if wastewaters with high total dissolved solids are discharged into rivers or streams.
- Reliable and responsible pathways for wastewater reuse and disposal have been the priority. Anything less would impede development of the resource. Consequently, zero liquid discharge (ZLD) treatment facilities have become more the rule in the Marcellus region rather than the exception, and some believe that NPDES-related concerns have largely been obviated.
- Currently, some feel that the primary concern related to drinking water resources from shale gas development appears to be the aggregate impact on affected watersheds, including land use and storm water management.
    - Wastewater treatment is only one component of this aggregate impact, but it is a significant one.
    - Centralized storage and treatment facilities have to be established at locations convenient to well pads. A storage and treatment network may evolve as an affected watershed develops from supporting well drilling to supporting natural gas production.
    - Production wastewaters and indirect impacts from pipelines and compressor stations will fundamentally alter the nature of the wastewaters produced and the methods used to handle and treat those wastewaters, as well as the nature of the aggregate impact on the watershed.

Summary of June 4, 2013, Technical Workshop on Water Acquisition Modeling

Dr. **Jennifer Orme-Zavaleta,** EPA Office of Research and Development, provided an overview of the discussions held at the Water Acquisition Modeling workshop. She opened her presentation by reviewing the specific questions that EPA asked the workshop participants to consider:

- Existing sources of data that could be used to better understand the effects of hydraulic fracturing water acquisition on water system availability.
- The key attributes of a scientifically robust approach to measuring and monitoring hydraulic fracturing water use and disposition.
- The current state of industry practices with respect to recycling/reusing water in hydraulic fracturing operations.
- The long-term life cycle implications and regional trends of recycling/reusing water in hydraulic fracturing operations.
- What a more generalized, conceptual model for assessing hydraulic fracturing impacts in different areas of the U.S. and at different scales would look like and what factors should be included in such a model.

Dr. Orme-Zavaleta presented individual participant observations and suggestions made during the workshop. (She clarified that these observations were not consensus opinions but individual observations, and that not all observations could/would be addressed during the course of the larger study.)

- **Existing sources of data are limited.** Consider using projected drilling activity as an indicator of future water need and use; however, recognize that industry does not openly share future plans.
- **Key attributes of a scientifically robust approach:**
  - Analyses should function across geographies, understanding local community impact, and recognize other existing and future water uses.
  - The approach needs to account for different levels of industry activity in different geographic locations.
  - Focusing on water dynamics in heavily populated areas should be a priority.
  - Water impacts of hydraulic fracturing need to be assessed side by side relative to impacts from other energy alternatives.
- **Lifecycle implications:**
  - Water use efficiency is expected to increase as a play matures and usage projections are refined.
  - Future trends in water use may depend on many macroeconomic issues that drive water use, technology, innovation and adaptation.

- **Modeling approaches and considerations:**
  - Modeling should consider economic considerations, adaptive industry practices and relative efficiencies compared to other energy sources.
  - Modeling should consider the surface water–ground water nexus.
  - Models should account for regulatory programs, future energy scenarios and competition from other industries.
  - Modeling should consider water quality as well as water quantity (and the impact of quantity on quality).
  - Modeling should extend in time beyond cessation of operations to quantify cumulative effects.
  - Additional basins should be studied, including basins dominated by ground water.
  - Modeling should be commensurate with the precision of data available and should include uncertainty and sensitivity analysis.
  - Water availability and use at multiple spatial scales, ranging from small to large watersheds, should be explicitly addressed.
  - Temporal resolution should be increased to address seasonal and low-flow impacts.
  - Complex and dynamic aspects of "water management" should be represented, including regulatory constraints and hydraulic fracturing operator practices in scenario analysis.
  - EPA should meet with a variety of stakeholders in the study areas to ensure that water management practices are well understood at local level—there is considerable variability.

Summary of July 30, 2013, Technical Workshop on Case Studies

Ms. **Cindy Sonich-Mullin,** EPA Office of Research and Development, provided an overview of the discussions held at the Case Studies workshop. She opened her presentation by reviewing the specific questions that EPA asked the workshop participants to consider. She explained that the purpose of the workshop on the case studies portion of the Hydraulic Fracturing Drinking Water Study—consistent with all the workshops—was to provide an opportunity to inform EPA on subjects integral to enhancing the studies and identify additional possible future research areas. The workshop included two sessions: "Background Assessment" and "Characterization and Prospective Case Studies." EPA asked workshop participants for input on the following questions:

Background Assessment and Characterization

- What are the relative strengths of different approaches to assess background conditions?
- What are practical approaches to overcoming the challenges in developing a representative background assessment and characterization for a case study?

Prospective Case Studies

- What types of conditions, tests, monitoring, sampling and analysis are needed to assess impacts from hydraulic fracturing processes on drinking water in a prospective case study and why?

- What approaches can be used in situations where historical and/or ongoing industrial practices (e.g., mining, oil, gas, agriculture) may confound assessment of impacts of hydraulic fracturing processes on drinking water resources?

Ms. Sonich-Mullin presented individual participant observations and suggestions made during the workshop. (She clarified that these observations were individual observations, not consensus opinions, and that not all observations could/would be addressed during the course of the larger study.)

Background Assessment and Characterization

- **What data to collect or use in the assessment and characterization:**
  - It is important to use site-specific geochemistry in addition to gathering background data.
  - Participants noted issues that complicate retrospective case studies (e.g., past activity in the area), which is to be expected in any retrospective case study analysis.
  - It was suggested that it is important to develop a conceptual site model to help guide an initial causal analysis at a site.
  - The recommendation was made to work with industry to better understand the formations being studied, such as the origin of the brines or where injected water goes.
  - There was some discussion regarding the need to identify and evaluate the unique parameters that are potentially present at case study sites. These parameters may be present below quantitative levels but not present in background data from county and/or formation.
- **Statistical approaches:**
  - Participants discussed how the data will be analyzed; for example, when data are averaged or pooled, there is a risk of diluting the signal.
  - Another participant suggested that since we are looking at aquifer-based analyses, the focus should be on individual cases using a matched case-control design rather than comparing to background.
  - Additional specific suggestions were made regarding possible statistical analysis (e.g., principal component analysis, cluster analysis) as well as presentation of data (Stiff and Piper diagrams).
- **Ground water contamination occurrence and exposure:**
  - The importance of public health data was noted specifically, as public health impacts could be early indicators of water contamination. Following these impacts over time could provide additional helpful information on associations.
  - This point resulted in additional discussions on occurrence vs. exposure at sufficient quantities to elicit an effect.
  - It was suggested that exposure to mixtures of multiple contaminants as well as cumulative exposures should be considered.

  - It was suggested that EPA consider including a comparative risk analysis in the assessment (compare hydraulic fracturing to "familiar" risks) in order to provide context.

- **Practical approaches for overcoming challenges.** EPA received a wide range of suggestions to overcome the challenges of retrospective case studies with regard to background characterization. Examples included:
  - Increased collaboration with academia and industry to ensure that concurrent, relevant research is being considered.
  - To the extent possible, use data from universities and industry (e.g., pre-drill data; background data; analytical results for monitoring wells, ground water wells and production wells).

Prospective Case Studies

Workshop participants made some specific suggestions, including sampling for microbial indicators and stressed the importance of looking at hydrology data to determine, for example, how high pressure can cause high TDS in homeowner wells. They also suggested that the work of the Interagency Steering Committee on Multimedia Environmental Modeling to advance environmental modeling could be useful in the case study effort.

Participants also made more general suggestions regarding the planning of the prospective case studies, including:

- Select sites where the geology is well characterized (two sites in Marcellus were suggested).
- Refine objectives of the prospective case studies to better select and design a measurement system.
- Recognize that the most immediate impacts (within one year) are from stray gas migration. However, a longer-term study would add value.
  - The suggestion was made to study how hydraulic fracturing might affect the ability of production string cement to maintain zonal isolation; it was also suggested to monitor for more subtle changes in dissolved methane at water supplies over the longer term.)
- A participant suggested the need for onsite monitoring to ensure adequate data collection.
- It was suggested that the retrospective case studies could inform the prospective case studies and vice versa.
- It was suggested that EPA build conceptual models for the prospective case studies using lessons from the retrospective case studies; this could make the prospective studies more likely to yield useful information.

How the Technical Workshops Informed the EPA Study

Ms. **Jeanne Briskin,** EPA Office of Research and Development, stated that the roundtables and technical workshops were held to ensure that EPA obtains timely and constructive feedback on

data and analysis developed in the study, and to ensure that EPA is aware of changes in industry practices and technologies. Examples of how these objectives have been met are listed below.

Analytical Chemical Methods

- Established collaborations with other laboratories to participate in analytical methods verification studies.

Well Construction and Operation

- In conducting the well file review and literature synthesis, EPA will consider the following things it heard at the workshop:
  - Possible self-healing of cement.
  - There may be a higher rate of development of sustained annulus pressure in deviated and horizontal wells than in vertical wells.
  - Full cementing of annular spaces can be a means to enhance barrier functioning, but cement displaced to the surface eliminates the potential to monitor annular pressure for insights into well condition during operations.
  - Some newer cements are resin-based and can get into small cracks and may not be affected by water, acid or base.
  - Cementing effectiveness can be compromised by wellbore holes having significant washout zones.
  - Subsurface drinking water supplies are often not fully identified or characterized.
  - The presence of cement and the quality of the cement bond are not direct measurements of a lack of fluid movement.
  - The use of foamed or lightweight cements may make a quantified interpretation of cement bond logs difficult.
  - It is important to understand and characterize the condition of older existing wells before hydraulically fracturing them or near them.

Subsurface Modeling

- Improved conceptual models of scenarios being modeled for subsurface modeling that give details of well construction and heterogeneous geology.
- Incorporated additional data on deep well injection identified in the subsurface modeling workshop concerning a joint Department of Energy (DOE) and industry study in Colorado.

Wastewater Treatment and Related Modeling

- Industry noted that wastewater treatment has evolved from treatment largely at publicly owned treatment works (POTWs) to treatment at commercial wastewater and package plants. EPA will focus on understanding wastewater treatment at commercial and package plants too.
- Attendees assisted EPA in obtaining state spill data from Texas and Wyoming.

Water Acquisition Modeling

- Incorporating the ground water models (GFLOW and MODFLOW) mentioned in the water acquisition workshop, to be used in conjunction with HSPF and SWAT models.
- Explicitly addressing water availability and its use at multiple spatial scales ranging from small to large watersheds.
- Increasing temporal resolution in water acquisition modeling to address seasonal and low-flow impacts.
- Representing different water management strategies, including regulatory constraints and hydraulic fracturing operator practices, in water acquisition scenario analyses.
- Meeting with a variety of stakeholders in the study areas to ensure that water management practices are understood at the local level.

Case Studies

- The importance of understanding site-specific geochemistry, including using statistical techniques and other appropriate techniques to analyze geochemistry, in order to understand the sources of ground water contamination was discussed.
- EPA received the underlying data for Appendix B, "Water Quality Data," of Battelle's *Characterization Reports for Retrospective Case Study Areas* in November 2013.

Summary of Discussion of the Technical Workshops

Background on Workshops and Roundtables

- The process leading up to this technical roundtable was summarized. The 2012 roundtables provided an opportunity for diverse stakeholders to identify topics for the technical workshops. EPA gleaned the topics of stakeholder interest from the roundtable members and held workshops with subject matter experts to obtain more detailed, granular perspectives on those topics. The current roundtable will look at the key takeaways from the technical workshops.
- EPA noted that the summaries of every workshop are available on the study website (http://www.epa.gov/hfstudy). EPA asked the roundtable participants whether there are additional issues or topics that EPA should pay attention to, or that didn't come up in workshops. It was emphasized that EPA is not seeking agreement on any issues—only individual input. Additional issues and topics raised by individual roundtable participants are summarized below.

Physically Implausible Scenarios

- A participant requested clarification about another participant's statement (at the subsurface modeling workshop) that physically impossible or implausible scenarios should not be considered or reported. She stated that if a scenario is determined to be implausible, it would still be valuable to report that it had been considered and determined not possible, especially if it is of concern to the public.
- Another participant stated that reporting these scenarios could cause confusion.
- An EPA participant noted that one topic of concern from stakeholders is that some people didn't know what is physically possible and what is not. LBNL obtained input from stakeholders about what might be possible, as the basis for the five scenarios. The researchers are running sensitivity analyses to explore the range of situations and better describe possible impacts under a variety of scenarios.

Underground Injection

- A participant asked whether enough capacity exists for underground injection of wastewater. Another participant stated that underground injection is a dominant disposal method for concentrated brine; he expressed concern about the possibility of capacity running out or if underground injection were no longer an option, because other final disposal options are less desirable. He stated that this is a concern from the water utility's perspective—where will the wastes go and how will they impact water systems?
- An EPA participant noted that evaluating underground injection of these wastes is beyond the scope of the study, and a regulatory program is already in place to oversee underground injection disposal wells.

- Another participant stated that recycling takes place not just because of water scarcity, but because of economics and a lack of disposal options (e.g., underground injection is not developed in Pennsylvania).
- A participant stated that the oil and gas industry is always creating additional capacity as it develops wells. (The participant added that most underground injection wells are former oil and gas wells).
- Several participants mentioned potential sources of information on capacity, including carbon capture and sequestration studies that have inventoried capacity in the states and Battelle studies on capacity in Ohio.

Integrated Ground Water/Surface Water Models

- A participant suggested that the study consider integrated ground water/surface water models such as MIKE SHE software.

Self-Healing of Cement

- A participant stated that self-healing of cement has been demonstrated in studies in Norway and at the University of Texas, and is seen in inspections of well bores. The participant stated that self-healing occurs with both polymer and non-polymer cements.

Sulfate-Reducing Activity in Ground Water

- A participant asked whether the issue of sulfate-reducing activity in aquifers had been addressed. The participant described wells in Dimock, Pennsylvania, showing sulfate-reducing activity. He stated that this fundamentally changes the geochemistry of the ground water system, though it does not violate a standard. He also stated that it is one reason why pre-hydraulic fracturing water quality data are so important.
- Another participant said that sulfate-reducing activity mainly occurs where there is natural seepage of methane that can contaminate aquifers.

Aggregate Impacts of Development and Other, Broader Ground Water Issues

- A participant asked how EPA is incorporating aggregate impacts of intense development into the study. Another participant noted that the challenges posed by aggregate impacts from intense development, like challenges regarding analytic methods and baseline characterization, are not unique to hydraulic fracturing; they are challenges with respect to ground water generally. Characterizing them as issues for hydraulic fracturing only limits the value of this work for other industries. He suggested that the final report look at these issues broadly. He also mentioned the importance of factoring in regulatory constraints, as EPA is doing with water acquisition.

Spill Analysis

- A participant asked whether there have been any detailed assessments of fluid migration downward into ground water in various climates.

- An EPA participant noted that the study is looking at the frequency and causes of spills related to hydraulic fracturing, not the migration of spilled materials; many studies in the last 20 years have addressed the environmental impacts of spills.

Additional Data for the Study

Participants suggested several other potential sources of data for the study:

- A Penn State database on ground water quality.
- Information showing that industry is using longer laterals to reduce environmental impacts; this information might be available directly from operators and state databases.
- A U.S. Geological Survey study on Fayetteville shale impacts from gas production activities.
- Data requested from operators following a blowout in New Mexico.
- A multi-year study in Garfield County, Colorado, by TetraTech.
- The National Science Foundation–funded Shale Network.
- A DOE study and baseline sampling by Richard Hammack.

Plans for Federal Multiagency Collaboration on Unconventional Oil and Gas

Dr. **Kevin Teichman,** EPA Office of Research and Development, provided an overview of the Federal Multiagency Collaboration on Unconventional Oil and Gas. This is a multi-year effort by DOE, EPA, and the U.S. Department of the Interior (DOI). Its primary goal is to ensure coordination and collaboration among the agencies and partners in developing timely, policy-relevant science and technology research that informs the design of policy options. The multi-year strategy responds to the following guidance:

- The White House Office of Science and Technology Policy Memo M-13-16 recommending that agencies "give priority to [research and development] that strengthens the scientific basis for decision-making…including but not limited to health, safety, and environmental impacts."
- Office of Management and Budget Circular 2012-12, which calls for coordination among federal agencies and a reduction in duplication of tasks.
- Executive Order 13605, "Supporting Safe and Responsible Development of Unconventional Domestic Natural Gas Resources," which charges federal agencies to pursue multidisciplinary, coordinated research.
- The DOE/DOI/EPA Memorandum of Agreement, which commits to developing a plan to address the highest-priority research questions associated with safely and prudently developing unconventional oil and gas resources.

The collaboration takes into account the core competencies of each of the three agencies, noting where these competencies overlap. For example, both EPA and DOI conduct studies in ecosystem and environmental health, water quality monitoring, and water availability; these are therefore areas of collaboration in the multiagency study.

A Steering Committee made up of both policy leads and technical leads meets approximately weekly. Strategy topics include unconventional oil and gas resources, water quality, water availability, air quality, human health and communities, ecological effects, and induced seismicity.

Overall, the multiagency effort is:

- Outlining an approach to identify and address the highest research needs associated with safely and prudently developing unconventional oil and gas resources.
- Providing the foundation for engaging stakeholders in identifying and prioritizing the challenges and benefits associated with unconventional oil and gas production activities.
- Guiding the agencies in designing and implementing future efforts, including the creation of more-detailed research plans to address priority topics.

Overview of EPA's Hydraulic Fracturing Drinking Water Assessment Report

Dr. **Jeffrey Frithsen,** EPA Office of Research and Development, presented an overview of EPA's upcoming assessment report. The objectives of the assessment are to:

- Identify and assess the potential for hydraulic fracturing activities to impact the quality or quantity of drinking water resources.
- Identify the factors that may affect the severity and frequency of potential impacts.

For the assessment, "drinking water" is defined as both surface water and subsurface supplies that are or may be used in the future as a drinking water resource.

Dr. Frithsen noted that the assessment report will be a science report; it will not be a policy document, nor will it be a risk assessment or exposure assessment.

Sources of information for the assessment include not only EPA's research, but also other peer-reviewed literature and reports, government reports and technical papers, and information submitted by stakeholders. One of the challenges, Dr. Frithsen stated, is capturing new developments in this rapidly changing field. For this reason, information sources include more than the peer-reviewed literature. The SAB panel advised EPA to use its best professional judgment regarding how to pull these different types of sources into the report.

The scope of the report, consistent with the 2011 study plan and the 2012 progress report, covers the five stages of the hydraulic fracturing water cycle. Conceptual models for each stage will address activities that may influence drinking water. The report will also include a review of hydraulic fracturing and a review of what is known about the toxicity and mobility of chemicals used in hydraulic fracturing.

Impacts evaluated will include impacts related to normal operations; potential and actual accidents and unintended events; and potential immediate, short-term, and long-term impacts. The spatial scope will include evaluation of information for multiple regions, and evaluation of potential impacts at multiple scales (a single well, cluster of wells, a watershed, and shale plays).

Dr. Frithsen described the intended uses of the assessment as the following: contribute to understanding of the potential impacts of hydraulic fracturing on drinking water resources, identify pathways of greatest concern, and inform and promote dialogue among stakeholders. The assessment report will also identify knowledge gaps and information needs.

Next steps for the assessment report include internal review, interagency review, and review by EPA's independent SAB. The peer review process will include opportunities for public review and comment. The final report will reflect agency consideration of both SAB and public comments.

Summary of Discussion of the Multiagency Collaboration and EPA's Hydraulic Fracturing Drinking Water Assessment Report

Individual roundtable participants raised the following questions and suggestions regarding the multiagency collaboration and EPA's assessment report.

Plans for Multiagency Collaboration on Unconventional Oil and Gas

- A participant asked how the multiagency collaboration identified its high-priority research questions. He mentioned a comprehensive paper by George King (Apache Corporation) on risks associated with shale gas development. An EPA participant stated that the research questions were identified through technical workshops and discussions with scientists across the agencies, who also are informed by discussions with industry.
- A participant recommended replacing the term "unconventional" with "shale plays."
- A participant asked whether the multiagency study would include a holistic risk assessment. EPA noted that such an assessment was not included in the President's budget request.

Scope and Uses of EPA's Drinking Water Assessment Report

- A participant asked whether the report would constitute the end of EPA's drinking water assessment study.
- An EPA participant stated that as a science document, the report could be used in a number of ways by EPA or others. The report may spark requests for additional research. The Multiagency Collaboration is outlining additional research expanding beyond drinking water resources. Additional research will also depend on what the Administration requests and Congress appropriates.
- A participant recommended that the report take into account the fact that hydraulic fracturing is an adaptive technology, applied and optimized depending on the needs of a site.
- A participant stated that it is important to place the report within a risk framework—that is, not just identify hazards, but also take into account barriers that are in place and the severity of potential consequences. He stated that the risk framework is where dialogue among stakeholders will occur, and EPA can draw on its risk characterization framework. An EPA participant noted that the report will not be a risk assessment or exposure assessment, but will provide context to help inform assessments of hazards and risks.
- A participant asked how EPA could identify pathways of greatest concern without conducting a risk assessment to prioritize the pathways. An EPA participant stated that, in considering impacts on water quality and quantity, pathways may fall into "likely" or "unlikely" categories, depending on the strength of connections leading from some source or activity to drinking water resources. Some pathways can be eliminated from consideration if they are both extremely unlikely *and* of low consequence. Existing practices that minimize a pathway can be identified as well.

- A participant asked whether the report will discuss concentration ranges of chemicals as well as their toxicity and mobility. An EPA participant stated that it is a challenge to pin down the changing landscape of chemicals being used, particularly given the data supplied by industry. EPA is looking at toxicity and mobility to understand which chemicals would be of greatest concern in the event of a spill or blowout.
- A participant noted that the public might be frustrated if the report does not indicate whether a practice is safe or not. An EPA participant stated that where possible, EPA will discuss probabilities for failures, but there is often no simple answer.
- A participant stated that to fully understand policy options, it was necessary to take into account all of the options, including coal, nuclear, solar, wind, and imported energy, in comparison to hydraulic fracturing. An EPA participant noted that this overarching topic of national energy policy, and associated issues of sustainability, human health and ecosystem health, are important but are not part of the drinking water assessment report.
- A participant stated that it is important for the report to provide the context that commercial demands—the economics of oil and gas production—drive the development of hydraulic fracturing technology. The participant stated that safety is part of the economic consideration; if a company does not operate safely it will not progress and may be denied the ability to operate. An EPA participant stated that the assessment report will not discuss best management practices, but will aim to represent modern, usual industry practices. They stated that, in addition to capturing what industry is doing now, the report should accurately portray how the industry is evolving (e.g., with respect to chemicals used, water usage) but needs information from industry to do so.
- A participant stated that it would be valuable to include validation of the newer models.
- A participant asked whether the report will discuss the issue of methane leaks and their ultimate effects on drinking water (e.g., sulfur odors). An EPA participant said that the issue of stray methane gas will be considered as it relates to hydraulic fracturing activities.
- Another participant recommended looking at the risks of stray gas seepage, spills and other issues occurring outside of hydraulic fracturing.
- A participant suggested that EPA should not look at the study areas in isolation. For example, the types of chemicals used influence how much water is needed. He stated that tradeoffs, benefits, and opportunities should all be considered; for example, produced water can be used for livestock and agriculture. An EPA participant said that the interdependencies are important to capture, but in-depth knowledge of these tradeoffs is hard to obtain and will require stakeholder input.
- An EPA participant asked the roundtable participants to provide input to EPA about what defines "success" for this report, from stakeholders' perspectives.

Stakeholder Engagement

Ms. Ramona Trovato and Ms. Lisa Matthews, EPA Office of Research and Development, described stakeholder engagement for EPA's hydraulic fracturing study. Ms. Matthews explained that the goals of the stakeholder engagement are twofold:

- Develop effective, meaningful two-way engagement with technical experts to inform and positively impact EPA's research study.
- Engage the broader stakeholder community to provide status updates on the study, report out on technical roundtables and workshops, and seek information and data to inform the 2014 draft report**.**

Objectives for stakeholder engagement include increasing technical engagement with stakeholders to ensure that EPA has the needed access to expertise and data from outside the Agency, obtaining feedback on data and analyses, ensuring that EPA is current on industry practices and technologies, improving public understanding of the study, and providing useful information to stakeholders to reduce potential health and environmental impacts of hydraulic fracturing.

Ms. Matthews described the stakeholder engagement activities between 2010 and 2013, including public meetings, webinar consultations with tribes and an in-person meeting with the Haudenosaunee Environmental Task Force, roundtables and workshops involving 213 individuals from 138 organizations in 14 states and follow-on public webinars, in-person and phone/email contacts to exchange information for research projects, and responses to information requests.

Moving forward, EPA will continue stakeholder outreach, including reconvening the roundtable in 2014. The engagement effort will include an increased focus on the states, with the goal of making EPA's work useful for state decision-making, and will also include additional outreach to tribes. EPA is interested in learning what topics or issues within the study's scope stakeholders would like to see addressed in the final report.

Input on the Stakeholder Engagement Process

Roundtable members commended EPA on the proactive engagement with all stakeholders on this important study. The technical roundtables and workshops have been instrumental and invaluable in building stakeholder relationships and effective communication. EPA places a high value on the open discussion of technical issues with experts.

Individual participants provided the following recommendations regarding continued stakeholder engagement:

- A participant stated that given that EPA wants to increase state involvement, it should focus on the four states in which 75 percent of hydraulic fracturing activity is occurring (Texas, Oklahoma, North Dakota, Louisiana).
- A participant said that he appreciated seeing the five peer-reviewed papers listed in EPA's study update presentation, and suggested that the study website have an easily accessible tab for such papers.
- A participant suggested that "expert review" is important as well as "peer review"—for example, industry has expertise in well construction and subsurface modeling, which may be less accessible to academia or contractors. He suggested that EPA convene these experts to review the study.
- Individual participants recommended engaging the Association of State Drinking Water Administrators, local public health officials (e.g., the Association of State and Territorial Health Officials), and the American Water Works Association.
- Another participant noted that states engage with EPA at the regional level. He suggested that information be distributed not only on EPA's study website but also through the Interstate Oil and Gas Compact Commission and the Ground Water Protection Council.
- A participant suggested that EPA talk with the Texas Water Supply Board on issues related to water sources and water supply projects. A participant also suggested contacting the Texas Railroad Commission staff regarding spills research.
- A participant recommended frequent stakeholder engagement, e.g., via phone calls and Web technology.
- A participant requested that stakeholders be involved in providing expert opinion on conceptual models and methodology before EPA publishes results.
- A participant suggested that industry review the introduction to the hydraulic fracturing section of EPA's report, and stated that industry could provide information for the report on the typical solutions used to address challenges.
- A participant recommended conference calls with stakeholders, targeted at specific topics.
- An EPA participant noted the need for the Agency to ensure balance in stakeholder engagement by including all stakeholder groups in discussions.

- A participant stated that greater efforts need be made to engage Native American tribes. He suggested that EPA contact a tribal association to reach the four or five tribes whose reservations are at the center of this oil production.
- A participant stated that EPA has gone above and beyond what was required for stakeholder engagement, and continued transparency is crucial. She also stated that it is important to set the context and manage expectations for the report, by clearly articulating what the report is, and is not, designed to do.
- A participant requested that EPA provide to stakeholders a list of all deliverables, their status (e.g., submission to journals) and the dates of internal and external reviews.

Ms. Trovato summarized suggestions from the roundtable that would be taken under advisement: continue stakeholder involvement, whether in person or via Web/audio conference; engage states (including their public health, environmental, and oil and gas departments); engage tribes; post publications prominently on the study website; provide clear context for the study; and reconvene the technical roundtable after a number of study publications are available (likely summer 2014).

Wrap-Up and Closing Remarks

Ramona Trovato closed the roundtable, stating that all the stakeholder engagement sessions had been highly productive. She stated that EPA will continue these engagements in some form. Ms. Trovato thanked the participants on behalf of EPA's Administrator and Deputy Administrator, and also thanked the technical workshop co-chairs and all others who had helped make the meetings a success.