

**Summary Minutes of the
U.S. Environmental Protection Agency
Science Advisory Board Hydraulic Fracturing Research Advisory Panel
Public Meeting, October 28-30, 2015**

Date and Time: Wednesday October 28, 2015 from 9:00 a.m. to 5:30 p.m., Thursday October 29, 2015 from 8:30 a.m. to 5:30 p.m., and Friday October 30, 2015 from 8:30 a.m. to 2:20 p.m. (Eastern Time)

Location: Washington Plaza Hotel, 10 Thomas Circle, NW, Washington, DC 20005

Purpose: The purpose of the October 28-30, 2015 public meeting was for the Environmental Protection Agency's (EPA) Science Advisory Board (SAB) Hydraulic Fracturing Research Advisory Panel to conduct a peer review of the EPA draft report, *Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources (External Review Draft, the EPA/600/R-15/047, June 2015)*.

Participants:

SAB Hydraulic Fracturing Research Advisory Panel (See Roster, Attachment A):

Dr. David A. Dzombak, Chair	Dr. Bruce D. Honeyman
Dr. Stephen W. Almond	Mr. Walter R. Hufford
Dr. E. Scott Bair	Dr. Richard F. Jack
Dr. Peter Bloomfield	Dr. Dawn S. Kaback
Dr. Steven R. Bohlen	Dr. Abby A. Li
Dr. Elizabeth W. Boyer	Mr. Dean Malouta
Dr. Susan L. Brantley	Dr. Cass T. Miller
Dr. James V. Bruckner	Dr. Laura J. Pyrak-Nolte
Dr. Thomas L. Davis	Dr. Stephen J. Randtke
Dr. Joseph J. DeGeorge	Dr. Joseph N. Ryan
Dr. Joel Ducoste	Dr. James E. Saiers
Dr. Shari Dunn-Norman	Dr. Eric P. Smith
Dr. Katherine Bennett Ensor	Dr. Azra N. Tutuncu
Dr. Elaine M. Faustman	Dr. Paul K. Westerhoff
Mr. John V. Fontana	Dr. Thomas M. Young
Dr. Daniel J. Goode	

Dr. Steven R. Bohlen participated via teleconference on October 29, 2015. Drs. Elaine Faustman and Dawn Kaback could not participate during the October 28-30, 2015 public meeting.

EPA SAB Staff:

Mr. Edward Hanlon, Designated Federal Officer, SAB Staff Office
Mr. Thomas Brennan, Deputy Director, SAB Staff Office

EPA Staff:

Dr. Thomas Burke, EPA Science Advisor and Deputy Assistant Administrator, the EPA Office of Research and Development
Dr. Jeffrey Frithsen, the EPA Office of Research and Development

Other Attendees: A list of persons present at the meeting, who requested information on accessing the teleconference line or live webcast, or who noted via email that they participated on the teleconference or live webcast, is provided in Attachment B.

Materials Available: The agenda and other meeting materials are available on the SAB website (www.epa.gov/sab) at the following SAB Hydraulic Fracturing Research Advisory Panel October 28-30, 2015 public meeting webpage:
<http://yosemite.epa.gov/sab/sabproduct.nsf/a84bf16cc358ad85256ccd006b0b4b/26216d9fbb8784385257e4a00499ea0!OpenDocument&Date=2015-10-28>

Meeting Summary

The public meeting was announced in the Federal Register¹ and was conducted according to the meeting agenda.² A summary of matters discussed and conclusions reached at the meeting is presented below.

October 28, 2015

Opening Statements

Mr. Edward Hanlon, the Designated Federal Officer (DFO), opened the public meeting, and made a brief opening statement noting that the SAB Hydraulic Fracturing Research Advisory Panel (hereafter “The Panel”) operates in accordance with the Federal Advisory Committee Act (FACA). He noted the meeting was open to the public and that Agency-provided briefing materials were posted on the SAB website. He noted the Panel would be conducting a peer review of the EPA’s draft report, *Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources* (External Review Draft, the EPA/600/R-15/047, June 2015) (hereafter “draft Assessment Report”). He noted the Panel would be seeking to identify points of agreement and consensus advice at this meeting. He noted the Panel previously met on May 7-8, 2013, where individual members of the Panel provided expert science and engineering comments on charge questions associated with the research described in the EPA’s December 2012 Progress Report on its hydraulic fracturing (HF) research. He also noted that the Panel held a teleconference on November 20, 2013, where the public provided new and emerging information related to HF for consideration by the Panel, and held a public teleconference on September 30, 2015, where the Panel received a briefing on the EPA’s draft Assessment Report and discussed the EPA’s charge questions. Mr. Hanlon noted that most Panel members were appointed as Special Government Employees, with one Panel member already being a regular government employee employed at the U.S. Geological Survey. He noted that all Panel members were appointed to provide individual expertise and advice, not to represent any organization. He stated that 260 sets of unique written public comments had been received as of October 28, 2015, for the Panel’s consideration and that 23 members of the public had requested to present oral comments during the meeting. He stated that the SAB Staff Office had identified no financial conflicts of interest or appearance of a loss of impartiality for any Panel member for this review. He also noted that minutes of the meeting were being taken to summarize discussions and action items in accordance with the requirements of FACA.

Mr. Thomas Brennan, Deputy Director of the SAB Staff Office, welcomed everyone. He noted that in October 2014, Chris Zarba, SAB Staff Office Director, recused himself from involvement on SAB’s advice to the EPA on the EPA’s Hydraulic Fracturing Assessment, and that Mr. Brennan took on the supervisory role for SAB’s advice to the Agency on this topic from

that point forward. He noted that members of this panel would be seeking to develop consensus expert advice at this advisory meeting and will deliberate after this meeting to develop SAB's advisory report in response to the Agency's charge questions. He stated that after the meeting, there would be additional opportunities for the public to provide comments and information for consideration by the Panel and the SAB as the SAB develops its peer review advisory report on the EPA's June 2015 draft Hydraulic Fracturing Assessment Report. He noted that the SAB would provide notice in the Federal Register and on the SAB website on the logistics for each of these various opportunities. He noted that members of the public could contact the Designated Federal Officer for more information on the advisory process and how they can best provide oral and written input for Panel members' consideration, and that information about the SAB advisory process and opportunities for public input is presented on SAB's website.

Dr. David Dzombak, Chair of the Panel, welcomed everyone. He noted the goal for the October 28-30, 2015, meeting was to conduct a consensus peer review of the EPA's draft Assessment Report, focusing on scientific, technical and engineering issues as the Panel identified points of agreement and consensus advice in responses to the charge questions. He stated that eight specific charge questions were developed by the EPA's Office of Research and Development (ORD) with review by the SAB, and that since ORD requested a "peer review advisory" effort, the Panel would seek to respond to and identify points of agreement and consensus advice on those charge questions during the meeting. He noted that preliminary individual written comments from Panel members were posted on the meeting website. Dr. Dzombak described the meeting process, noting that the Panel's Lead Discussants would take between three to five minutes each to provide their opening comments associated with the charge question. He noted that after Lead Discussants presented their views, other Panel members would then have opportunity to provide additional comments. Dr. Dzombak also noted that he and the Designated Federal Officer would be taking notes to keep track of the discussions which would be used to help prepare the minutes of the meeting that would be posted on the SAB meeting website after the meeting. He noted there were two separate sessions for oral public comments in the agenda, and that 23 members of the public had registered to present oral public comments during the public comment time on October 28. He asked members of the public who sought to provide short clarifying comments on October 29 to contact the Designated Federal Officer regarding that request. He noted that at the end of this meeting on the afternoon of October 30, he would summarize next steps and follow-up Panel and SAB activities associated with this review.

Dr. Dzombak then introduced Dr. Thomas Burke, the EPA Science Advisor and Deputy Assistant Administrator for the EPA Office of Research and Development, and Dr. Jeffrey Frithsen of the EPA ORD, and noted that Dr. Frithsen's slides were posted on the meeting website.

Remarks from the EPA's Office of Research and Development

Dr. Thomas Burke, the EPA Science Advisor and Deputy Assistant Administrator for the EPA ORD, thanked the SAB for conducting a peer review of ORD's draft Assessment Report. He stated that scientific credibility was extremely important for the EPA's goal to protect drinking water resources in the United States. He noted that the draft Assessment Report was the EPA's capstone effort in its study of potential impacts of HF on drinking water resources in the United States, and that the EPA's efforts in this study had been ongoing since 2010. He noted that the EPA's Science Advisory Board played an important role in the evolution of the draft Assessment Report, and that the SAB had provided advice on the EPA's Scoping Document and Study Plan for its research and had consulted with the EPA on its progress report on this topic. He stated that

in addition to the draft Assessment Report, the EPA produced 12 technical reports and 14 peer-reviewed journal articles on this topic. He noted that the EPA integrated available science, conducted an enormous outreach effort to stakeholders, industry, states and the public, and gathered information from over 950 publications in developing the draft Assessment Report. He noted there were gaps, uncertainties, and limitations associated with the draft Assessment Report, as in most scientific studies. He stated that the draft Assessment Report was a resource that the public could use to find better ways to protect drinking water resources, and that it has already had an impact at the state level and in the scientific community.

Dr. Jeffrey Frithsen of the EPA ORD thanked the SAB for conducting a peer review of ORD's draft Assessment Report, then presented his slides entitled "Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources."³

On slide 2, Dr. Frithsen noted that drinking water was broadly defined in the draft Assessment Report. On slide 3, Dr. Frithsen noted that over 950 references/sources of information were cited in the draft Assessment Report, and that ORD gathered information from industry, states, non-governmental organizations and the public in drafting the Assessment Report. He stated that the EPA's Docket for public comment remained open for use by the EPA as it goes forward in considering changes to be made to the draft Assessment Report. He also noted that the draft Assessment Report focused on potential impacts to drinking water, and did not look at all aspects of HF. Dr. Frithsen noted that, for example, potential HF impacts to land and socioeconomic impacts were not assessed in the draft Assessment Report. He stated that the draft Assessment Report was not a risk or exposure assessment.

On slide 5, Dr. Frithsen stated that the HF process was simplified as depicted in the slide in order to bring information to a wide audience. He noted that while underground resources were portrayed in solid blue in the figure, this was not actually what occurred in nature, where water flowed throughout strata. On slide 7, Dr. Frithsen noted that because HF used large volumes of water, 2% of a well volume can be tens of thousands of gallons used per well. He also noted that 1000 chemicals were never used at any one time during HF, and that Frac-Focus 1.0 was used to provide information on HF chemicals. On slide 9, Dr. Frithsen noted that multiple barriers did not always exist during HF operations, and that these absences of redundancies can create pathways for releases to groundwater. He noted there were data limitations on HF well integrity and how well integrity changes over time.

On slide 10, Dr. Frithsen noted that the separation between the HF production zone and drinking water resources is often thousands of feet, and sometimes less than a thousand feet. He stated that HF fractures may interact with natural fractures. On slide 12, Dr. Frithsen noted that hundreds of HF spills have been documented. On slide 13, Dr. Frithsen stated that 95% of HF wastewaters in part of the Barnett formation were disposed of through underground injection control, while HF wastewaters in Marcellus Shale were disposed of as follows: 10% through underground injection, 20% to centralized wastewater treatment facilities, and 70% through reuse. He also noted that inadequately treated HF wastewaters increased downstream constituent concentrations, particularly halides and disinfectant byproducts.

On slide 14, Dr. Frithsen noted that the list of chemicals used in HF is incomplete, partly due to disclosure issues, and that this was an area of uncertainty. He also stated that oral reference toxicity values were available for approximately 12% of HF chemicals.

On slide 16, Dr. Frithsen noted there were various sources of uncertainty associated with the

draft Assessment Report. He stated that groundwater may move very slowly or relatively quickly, taking perhaps 10 years or a few days to move 100 feet. He noted that since there are limited data from before and after HF operations at HF sites, it was difficult to assess causal relationships in situations where impacts to drinking water wells have been indicated. He noted it was a challenge to gather proprietary or unpublished industrial HF data or information on HF practices. He also stated that sometimes there was a 2-4 year lag in literature on current industrial HF practices. He noted that data on the amount of water used in HF was changing rapidly and that reuse of HF fluids was occurring more frequently.

Dr. Dzombak thanked Dr. Frithsen, and asked if Panel members had any clarifying questions for Drs. Burke or Frithsen, or comments related to Dr. Frithsen's presentation. Hearing none, Dr. Dzombak then provided a review of the charge questions.

Review of Charge Questions

Dr. Dzombak noted there were eight charge questions that the Panel would respond to during the meeting. He noted that the charge questions were those that the EPA requested SAB to respond to in its advice on the Agency's draft Assessment Report, and that the charge questions were posted on SAB's website. He noted that near the end of the initial discussion on each charge question during October 28 and 29, the Panel's lead writer for the charge question would summarize preliminary draft consensus key points responding to the charge question, and then a Panel discussion would occur on those preliminary draft areas of consensus and key points before moving on to the next charge question.

Public Comments

Dr. Dzombak noted that it was important for the Panel to consider public comments, and that Panel members had an opportunity to request clarifying questions to the public commenters. He noted that 260 sets of unique written public comments were received for the Panel's consideration and were posted in the EPA's Docket. He stated that instructions on how to see these comments were provided on the Panel's meeting website. Dr. Dzombak also noted that 23 members of the public requested to present oral comments during the meeting. He stated that while the SAB was not obligated to respond to public comments received in its deliberations for the review, Panel members should keep these comments in mind and consider points made in public comments as they developed their own comments and advice. He also noted that each member of the public who was presenting slides or a video should be aware that the SAB Staff Office was webcasting the meeting live on the SAB's website, and that whatever was shown on the presentation screen would be presented on the webcast.

Ms. Elizabeth Tatham presented her oral remarks, reading from a statement⁴ that was posted on the SAB website. Ms. Tatham expressed disappointment in the EPA's draft Assessment Report, noting that the draft Assessment was limited by lack of water data and physical testing data, lack of investigation into water contamination, lack of data on the number and severity of earthquakes related to hydraulic fracturing, dependency on FracFocus as the main data source, and lack of data on health impacts related to hydraulic fracturing. Ms. Tatham noted that EPA had planned to test 62 wells in Pennsylvania, which did not occur. Ms. Tatham asked that the EPA re-open and complete investigations of impacts related to hydraulic fracturing in Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas.

Ms. Tracy Carluccio, representing the Delaware Riverkeeper Network, presented her oral comments, reading from a statement⁵ that was posted on the SAB website. Ms. Carluccio requested that the EPA not issue a final Assessment Report based on its draft Assessment Report, withdraw the conclusion that hydraulic fracturing causes no widespread, systemic impacts on drinking water resources in the United States, and start over with a more inclusive scope, all necessary data, and on-the-ground studies that would provide the information needed for an accurate and reliable assessment. Ms. Carluccio stated there are two key areas of failure in the draft Assessment Report: (a) the EPA ignored the environmental impacts of hydraulic fracturing and failed to meet the charge given by Congress by narrowing the scope of its study and failing to recognize the connection between drinking water and the contributing environment; and (b) the EPA relied on poorly documented information or industry-supplied information and used built-in assumptions that were not justified to support its conclusions. Ms. Carluccio stated that in several key areas of examination, the EPA accepted industry statistics without critique. She also noted the EPA made several false assumptions in assessing the potential effects of hydraulic fracturing to groundwater, well injection and the potential for contamination, and problems related to wastewater treatment and disposal. She expressed her view that potential pathways to groundwater from fugitive or spilled HF fluids have not been adequately considered. Ms. Carluccio stated that the EPA sidestepped issues that were emerging as top water quality issues, and did not examine or acknowledge the dangers of not knowing the ultimate disposition of hazardous radioactive materials associated with hydraulic fracturing.

Ms. Susan Carty, representing the League of Women Voters of the United States, presented her oral comments, reading from a statement⁶ that was posted on the SAB website. Ms. Carty noted that the EPA's draft Assessment Report was not the comprehensive and definitive study that Congress funded in 2010, and urged SAB to conduct various actions to restore integrity to the final report, including: broaden the scope of the EPA's draft Assessment Report to include impacts to surface and ground water; make information available to health professionals and the public about chemicals associated with hydraulic fracturing; conduct the prospective studies as originally planned for at least two years; reopen the study sites in Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas; do not limit scope of the research to voluntary disclosures compiled from the industry-supported FracFocus database; lift exemptions from the Safe Drinking Water Act and other federal laws to inform the public on what is being injected into the ground; make federal record keeping systems related to hydraulic fracturing available to the public; utilize studies and reports done by the U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), and other federal agencies; assess the impact of directional hydraulic fracturing drilling on groundwater contamination; directly measure levels of toxic hydraulic fracturing chemicals in drinking water intakes in watersheds where there have been high concentrations of hydraulic fracturing operations; make regular measurements of bromide concentrations in treated water for all watersheds that have seen moderate to high levels of hydraulic fracturing; and record and track all hydraulic fracturing wellheads.

Mr. John Noel, representing Clean Water Action, presented his oral comments, reading from a statement⁷ that was posted on the SAB website. Mr. Noel commended the EPA on its hard work in developing an extensive review of the current science that will remain a useful resource for many years. He urged the SAB Panel to recommend that the EPA include updated research and explain the missing prospective case studies in the draft Assessment Report. He noted that the prospective case studies were highly anticipated. He also stated that the Executive Summary of the draft Assessment Report should be revised to accurately convey the findings of the assessment. He recommended that the EPA should revise statements in the draft Assessment Report that there was no evidence of widespread, systemic impacts on drinking water resources in the United States. He

also noted that statements that data limitations preclude a determination of the frequency of impacts with any certainty, and that there was a high degree of uncertainty about whether the relatively few instances of impacts noted in the draft Assessment report were the result of rarity of effects or a lack of data, should be brought forth as a major finding in the Executive Summary. He noted that the general public and journalists reporting on the draft Assessment Report interpreted the draft Assessment Report to be a positive assessment of hydraulic fracturing, and noted that to avoid having the draft Assessment Report's findings misunderstood or intentionally misconstrued, the draft Assessment Report's high level conclusions must be supported by the underlying data. He recommended that the Executive Summary be revised to clarify that the EPA cannot say with any certainty how widespread or systemic the impacts of hydraulic fracturing were, due to the lack of available data and because the EPA did not perform a statistical analysis of the number of cases of drinking water impacted by fracturing activities versus the number of fracturing activities.

Ms. Nichole Saunders, representing Environmental Defense Fund, presented her oral statement, reading from a statement⁸ that was posted onto the SAB meeting website. Ms. Saunders noted the EPA's draft Assessment Report was a good step towards filling a number of significant gaps in understanding regarding hydraulic fracturing's potential impacts on drinking water resources. She noted that the EPA failed to appropriately recognize and address how the large number of unknowns, uncertainties, and limitations in the draft Assessment Report qualify the EPA's widely-cited conclusion that the Agency did not find evidence that hydraulic fracturing activities have led to widespread, systemic impacts on drinking water resources. She asked SAB to urge the EPA to revise its main finding to more clearly and accurately represent the body of the draft Assessment Report, and noted that if the draft Assessment Report supported any broad conclusion, it was that the Agency does not at this time possess adequate information to make a definitive statement regarding widespread, systemic impacts of hydraulic fracturing. She expressed concern about the EPA's reasoning that "the number of identified cases . . . was small compared to the number of hydraulically fractured wells," noted there were acknowledged data gaps, limitations, and uncertainties associated with this conclusion, and asked whether there was adequate data to scientifically and accurately represent the stated numerator and denominator – identified cases versus fractured wells. She also expressed concern regarding limited data on the total number of hydraulic fracturing-related spills, release volumes, and associated concentrations, and physicochemical properties and key chronic toxicity information for the 1,076 chemicals listed as used in hydraulic fracturing. She noted that the EPA's finding that there was no evidence of widespread, systemic impacts could misdirect future scientific research and policy making both in the United States and internationally, negate the time and effort the EPA devoted to compiling this Highly Influential Scientific Assessment, and potentially impede forward progress in addressing the highlighted vulnerabilities and uncertainties of the draft Assessment Report. She recommended that the EPA should use the draft Assessment Report to more clearly highlight and define the scientific and technical data needed to support more definitive answers in the future. She stated that EDF believes that every impact matters, even if not widespread. EPA needs to advance science to understand and address all impacts.

Mr. Trevor Penning, representing the University of Pennsylvania Center of Excellence in Environmental Toxicology, presented his oral statement, reading from a statement⁹ that was posted onto the SAB meeting website. Mr. Penning noted he submitted comments to the EPA's Docket that addressed concerns relating to each chapter of the EPA's draft Assessment Report. He commented that the EPA acknowledged that significant data gaps exist, including a lack of pre- and post-fracturing water quality data and knowledge of the composition of the hydraulic fracturing fluid itself due to Confidential Business Information (CBI). He stated that based on this significant data gap, the EPA does not have sufficient analytical data to claim that water

contamination from hydraulic fracturing was neither widespread nor systemic. He noted that the EPA should state that the potential for contamination of drinking water resources exists from wastewater management in the absence of stricter regulations. He also stated that centralized water treatment facilities (CWTs) are not effective in removing all contaminants, and that some constituents in HF wastewaters are toxic, with potential impacts on CWTs. He recommended that because of the large volumes of wastewater processed, the EPA should require there to be full disclosure of the composition of the hydraulic fracturing fluids to either the EPA or a designated state authority.

Mr. Adam Carpenter, representing American Water Works Association, presented his oral statement, reading from a statement¹⁰ that was posted onto the SAB meeting website. Mr. Carpenter noted that regarding the EPA's assertion that the evidence of impacts of hydraulic fracturing on drinking water resources is not widespread or systemic, even rare impacts are significant when and where they occur, and technical and policy discussions to further reduce both the incidence and consequence of rare impacts is still extremely important to drinking water resources. He recommended that the EPA provide more analysis of the consequence of rare events, and include analyses of impacts of wastewater injection through the underground injection control program and of potential induced seismicity, from fracturing itself or from wastewater disposal through injection. He also recommended that the EPA assess the feasibility and potential usefulness of unique "tracer" or "fingerprint" substances that could be easily distinguished from naturally occurring substances as an "early warning" for potential contamination events. In view of the numerous research gaps that exist, Mr. Carpenter stated that EPA needs to prioritize the research needs and continue to pursue them.

Mr. Jeff Zimmerman, representing Damascus Citizens for Sustainability, NYH2O, and Citizens for Water, presented his oral statement, reading from a statement¹¹ that was posted onto the SAB meeting website. Mr. Zimmerman noted that he took issue with the EPA's conclusion expressed in the Executive Summary that the study team did not find widespread systemic impacts of hydraulic fracturing mechanisms on drinking water resources. He stated that the EPA's draft Assessment Report did find instances of drinking water resource contamination from hydraulic fracturing, and that there were numerous references throughout the body of the EPA's draft Assessment Report that were directly contrary to the Executive Summary conclusive statement about no widespread systemic impacts. He also pointed out that the EPA's draft Assessment Report repeatedly noted that there is a lack of data to support conclusions such as the Executive Summary statement. He stated that the failure rate of 10% identified in the report is unacceptable and wouldn't be accepted in other contexts. He noted that on October 14, 2015, Concerned Health Professionals of New York and Physicians for Social Responsibility released the *Third Edition of its Compendium of Scientific, Medical and Media Findings Demonstrating Risks and Harms of Fracking (Unconventional Gas and Oil Extraction)*, and noted that the documents referenced in the Compendium demonstrate that the impacts of hydraulic fracturing were widespread and systemic across the entire nation. He stated that the EPA should include in its investigation and report information from three well known and extensively documented hydraulic fracturing impact cases: Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas.

Mr. Dusty Horwitt, representing Partnership for Policy Integrity, presented his oral statement, reading from a statement¹² that was posted onto the SAB meeting website. Mr. Horwitt noted that the EPA's widely quoted conclusion in the Executive Summary of the EPA's draft Assessment Report about how the Agency did not find evidence of "widespread, systemic impacts on drinking water resources" was highly misleading and implied that while evidence

might come to light pointing to a different conclusion, the available data allowed the EPA to make this judgment. He noted that the Agency's news release omitted the word "evidence" and stated that "hydraulic fracturing activities have not led to widespread, systemic impacts to drinking water resources." He noted that the body of the EPA's draft Assessment Report highlighted so many data gaps that a reasonable scientist could not make a conclusion about how widespread or systemic the impacts were. He commented that the EPA's draft Assessment Report should state that there is not enough evidence to evaluate how widespread or systemic impacts to drinking water are, if the data continue to support that conclusion. He also stated that the EPA's draft Assessment Report notes that underground injection of often toxic hydraulic fracturing wastewater "predominates in most regions" as a disposal method and that such injections likely comprise billions of gallons per year. He noted that government agencies and news outlets have found serious contamination from such injections, and expressed concern that the EPA omitted study of the risks to drinking water from underground injection of hydraulic fracturing wastewater from its assessment while analyzing risks from other waste disposal practices. He commented that risks to drinking water from underground injections should be included in the EPA's final Assessment Report. He noted that risks associated with spills that occur during the transport of chemicals or wastewater to and from well sites, spills of fluids required to drill a well prior to fracking, spills on or off the well pad of diesel fuel that is required to operate HF machinery and risks of underground migration of drilling fluids, should be addressed in the EPA's final Assessment Report.

Mr. Aaron Mintzes, representing Earthworks, presented his oral statement, reading from a statement¹³ that was posted onto the SAB meeting website. Mr. Mintzes stated that hydraulic fracturing contaminates drinking water resources in a widespread and systemic manner. He noted that the EPA identified 225 spills from flowback and produced water in its draft Assessment Report, and that 146 of these spills reached environmental receptors (soil, surface water, or groundwater). He noted that in 1988s Congress exempted oil and gas drilling muds, oil production brines, and drilling fluids, produced waters, and other wastes associated with the exploration, development, and production of crude oil and natural gas from regulation under Subtitle C of the Resource Conservation and Recovery Act (RCRA), and stated that if these exemptions were lifted, that some portions of both the large-volume and associated waste generated in hydraulic fracturing activities would be considered hazardous under RCRA. He commented that the EPA Assessment Report should conclude that hydraulic fracturing operations pollute drinking water resources and sometimes do so with hazardous contaminants. He stated that the groundwater contamination cases in Dimock, Pennsylvania and Pavillion, Wyoming provide evidence; these sites were investigated by EPA and impacts were found.

Mr. Ray Kemble presented his oral statement, reading from a statement¹⁴ that was posted onto the SAB meeting website. Mr. Kemble, a resident of Dimock, Pennsylvania, noted that a moratorium on hydraulic fracturing drilling was put in place in his neighborhood by the Pennsylvania Department of Environmental (PADEP) Protection after Cabot Gas and Oil contaminated the local aquifer. At least 20 families lost the use of their water wells. He also noted that PADEP confirmed 243 cases of water contamination related to hydraulic fracturing, and that other states have also identified many cases of similar contamination. He invited anyone to contact him for a tour of his neighborhood to see how he lives, and encouraged the EPA to include all known cases of water contamination due to hydraulic fracturing processes into its draft Assessment Report. He stated that the EPA should include in its investigation information on groundwater contaminations from hydraulic fracturing operations at Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas.

Mr. Bryce Payne presented his oral statement, reading from a statement¹⁵ that was posted onto the SAB meeting website. Mr. Payne, a resident of Parker County, Texas, described problems with subsurface methane migration in his neighborhood, and difficulties with monitoring the methane migration. He noted that the EPA should include Henry's Law (the scientific principle describing the solubility of gases in water) in its assessment concerning the potential impacts of hydraulic fracturing on drinking water resources in the United States in order to better characterize any potential impacts to drinking water resources from hydraulic fracturing. He stated that Henry's Law described how dissolved hydrocarbon gases, especially methane, would move into the gas phase rather than being dissolved in water, and that this was ignored in data synthesis and interpretation by numerous parties in the Southern Parker County hydraulic fracturing case. He stated that collecting a representative sample of water that contains any appreciable amount of methane presents a serious challenge, and that sampling for methane should not be conducted using open sampling vials. He noted that water samples using open sampling vials in the Southern Parker County hydraulic fracturing case indicated methane at levels no higher than 3 ppm, and that samples using methods that did not expose the water sample to open air indicated methane in the 40-70 ppm range. He stated that analysis of sampling data should also include knowledge of the methods used to acquire that data. He also stated that there is much useful scientific information to be gained from study of the situation in Parker County, Texas.

Mr. Zac Hildenbrand presented a set of slides¹⁶ that were posted onto the SAB meeting website. Mr. Hildenbrand noted that his research indicated that a number of contaminants were present in groundwater sampled from approximately 500 water wells in west Texas near hydraulic fracturing operations. He stated that a large amount of volatile organic contaminants were present in these groundwaters, and that heavy metals were detected also. He noted that a compositional and isotopic match occurred between dissolved gas in groundwater collected near hydraulic fracturing wells and dissolved gas in groundwater collected from nearby hydraulic fracturing wells, indicating a link between these water samples.

Ms. Hope Forpeace presented her oral statement, reading from a statement¹⁷ that was posted onto the SAB meeting website. Ms. Forpeace stated that she has visited and filmed¹⁷ at many locations where hydraulic fracturing has been conducted. She noted that many cases of hydraulic fracturing contamination have not been reported to authorities because many contamination victims were afraid to go public. She noted that victims often work for industry and fear losing their jobs, or they were afraid to be labeled anti-hydraulic fracturing activists for reporting water contamination. She noted a situation of a water well that produced good water for years before hydraulic fracturing occurred nearby, after which the well water turned fizzy and smelled like gasoline. She noted that the EPA's draft Assessment Report stated that water contamination from hydraulic fracturing was not widespread or systemic, and commented that the draft Assessment Report did not mention virtually all of the known contamination cases resulting from the recent hydraulic fracturing boom. Ms. Forpeace noted that there were hundreds of cases of water contamination resulting from hydraulic fracturing, including 243 cases reported by Pennsylvania's Department of Environmental Protection, and that all of these cases were omitted from the EPA's study. Ms. Forpeace noted that she was informed by the EPA that the EPA's draft Assessment Report was not meant to cover actual cases, but was intended to determine the potential for water contamination, and commented that she was mystified by the idea that a study on the potential for hydraulic fracturing to contaminate drinking water would leave out all the actual cases of fracking contaminating drinking water. She noted that, based on a Freedom of Information Act request of the EPA's communication with the gas oil industry completed by Greenpeace, the EPA found no widespread or systemic water contamination associated with

hydraulic fracturing because the gas and oil industry inhibited the EPA's ability to do baseline testing and compare such testing with tests conducted after drilling occurred. She commented that at the Lipsky property in Texas, the EPA used isotopic testing to match gas in the Lipsky water well to nearby production gas from Range Resources gas wells in December 2010.

Mr. Steve Lipsky presented a set of slides¹⁸ and pictures that were posted onto the SAB meeting website. Mr. Lipsky's pictures indicated depictions of water on fire, and stated how the Henry's Law chemistry principle affected what the concentration of methane would be in his water well. He said he was informed that his water was safe, but that he would be soon connecting his house to public water supplies. He stated that well water must have at least 28 mg/l methane to light on fire, and that Duke University testing indicated that the methane concentrations in his well water were between 50-70 mg/l. He included slides of maps where contamination occurred on or near his property, and slides indicating 2015 testing results for his well. He stated that EPA has abandoned him and his family, and that the problems with his well water and his efforts to address the problems with companies and the government have ruined his life for the past five years. He stated that the EPA should apologize to him.

Mr. John Fenton stated that within four hundred feet of his home in Pavillion, Wyoming there are about 200 hydraulic fracturing wells. He noted he tried for years to get the State of Wyoming to do a groundwater study near his home to assess potential contamination from nearby hydraulic fracturing activities. He stated that the EPA finally agreed to do a groundwater study, collected data, and developed conclusions that were controversial to some. He noted that the EPA data showed reasons to be concerned with water, and that these concerns could be potentially be from hydraulic fracturing activities. He stated that a separate study funded by oil and gas companies showed opposite results than the EPA's data. Further, he stated that in response to the controversy "EPA folded", and that he and his family are back to having to look out for themselves. He asked why the government is not doing its job and being influenced so much by industry. He noted that the State of Wyoming recently passed a law that made it illegal to collect data on public property, and expressed concern that companies that made a profit from hydraulic fracturing operations were left to assess these types of issues. He stated that the FracFocus database noted that a large number of chemicals were exempt from rules and reporting. He encouraged the EPA to do more than review industry data in developing its draft Assessment Report, and to conduct an on the ground study of hydraulic fracturing activities.

Mr. Shane Davis had registered to speak during the public meeting, but was not able to attend nor was able to present his oral statement on the public meeting line. Dr. Dzombak then recognized the next public speaker.

Mr. Craig Stevens stated that in drafting its Assessment Report, the EPA failed in its mission to protect human health and the environment, and in conducting a national study that was based on best available information. Mr. Stevens noted that he lives in Silver Lake Pennsylvania, and that he was very disappointed to read the EPA's press release that noted there were no widespread impacts from hydraulic fracturing activities. He stated that in Dimock Pennsylvania, 33 wells were contaminated in one day from hydraulic fracturing activities. He stated that a January-June 2012 investigation by the EPA indicated that groundwater was poisonous in the area, and that the Agency for Toxic Substances and Disease Registry (ATSDR) found alarming results in the groundwater. He stated that in 2013, his well water tasted like metal and that he had nosebleeds. He requested the EPA to please use science to share truth on what was occurring across the country from hydraulic fracturing activities. He stated that the State of Pennsylvania has not

responded to his requests for help and that action by the EPA is needed. He urged the Panel members to come and tour Dimock, Pennsylvania.

Mr. Ron Gulla stated that he worked in the oil and gas industry for seven years, and noted that the stories that the Panel was hearing were not anecdotal. He invited Panel members to visit areas where hydraulic fracturing was occurring, and that he would introduce Panel members to people who were sick. He noted ponds and drinking water have been contaminated with metals and benzene, toluene, ethylene and xylene (BTEX), well water has been drying up, and cows and cattle have died due to hydraulic fracturing activities. He noted Dr. Robert Puls visited Washington County, Pennsylvania, who reviewed water results that local citizens brought in, and stated that Dr. Puls noted that he heard folks who noted they were sick, lost livestock, and had contaminated wells in every state he visited on this topic, including Colorado, Texas and Arkansas. Mr. Gulla stated that gas migration to wells is occurring and that the industry response is to deny responsibility and to pay some of the people affected with a requirement to not go public with information.

Mr. Hugh MacMillan, representing Food and Water Watch, presented his oral statement, reading from a statement¹⁹ that was posted onto the SAB meeting website. Mr. MacMillan noted that he was a computational scientist and well versed in the methods employed to model the simplistic contamination scenarios considered in the EPA's draft Assessment Report. He stated that the interests of both the oil and gas industry and investment banks that finance the hydraulic fracturing industry have shaped the EPA's draft Assessment Report. He expressed concern that the EPA aborted its investigations in Dimock, Pavillion and Parker County and excluded these cases of contamination from its assessment. He also expressed concern that the assessment referred to impacts people have suffered as "vulnerabilities," that the EPA relied on voluntary cooperation of industry for access to data and wells sites, and that an untold number of hydraulic fracturing cases were hidden in sealed court settlements. He further expressed concern that the draft assessment does the public a disservice and was not candid when it used the phrase "widespread, systemic impacts," and noted there were many gaps left by the scientific uncertainties that were spelled out clearly in the body of the assessment. He noted that more problems and more leaks would occur in the future due to hydraulic fracturing activities, and that the EPA's draft assessment paves the way for this to occur.

Mr. Ken Dufalla, representing Izaak Walton League, had registered to speak during the public meeting, but was not able to attend nor was able to present his oral statement on the public meeting line. Dr. Dzombak then recognized the next public speaker.

Mr. Randy Moyer had registered to speak during the public meeting. A video of Mr. Moyer was presented on the presentation screen in the meeting room and on the live audio/visual webstream. The video noted that Mr. Moyer drove trucks for the oil and gas industry, working on well pads. He noted he has lost memory, has red marks on his body, has an enlarged tongue, lost his sense of smell and taste, gets a spinning feeling, and cannot put his children on his shoulders due to his work on the oil industry's well pads. He noted that mats were placed around wellheads, and that his job was to use a squeegee to suck up spilled material and mud near the wellhead. He noted he had waterproof boots that melted, and that he worked two to three years without ever having a safety meeting.

Mr. Lance Larson, representing Natural Resources Defense Council (NRDC), presented his oral statement, reading from a statement²⁰ that was posted onto the SAB meeting website. Mr. Larson stated his concerns regarding the conclusions drawn from the EPA's draft Assessment Report.

He noted that the assessment's statement that "We did not find evidence that these mechanisms have led to widespread, systemic impacts on water resources in the United States" did not clearly define or quantify what would constitute a 'widespread' or 'systemic' impact, and that the EPA did not attempt to justify how the underlying data and analysis would or could support such a conclusion. He recommended that the SAB ask the EPA to clarify, modify, or remove these conclusory statements based on the available data. He also noted that there was a sizable data gap regarding spatial and temporal impacts to water quantity and quality, and that the EPA's draft Assessment Report inadequately accounted for long-term impacts to groundwater supplies. He also noted that groundwater transport of contaminants is extremely complex and could take decades to impact a potential drinking water source, and that potential future impacts to water supplies from failed well casings were highly uncertain. He encouraged SAB to recommend to the EPA to invest significant resources into future research, monitoring, data collection, and modeling to address these knowledge gaps. He also noted that a yearly update or amended assessment could help improve the knowledge gaps. He stated that NRDC interpreted the findings in the EPA's draft Assessment Report to confirm that hydraulic fracturing activities pose a range of risks to human health and to an unknown quantity of surface and groundwater supplies, and encouraged the EPA to continue to fill the gaps in data to quantify and adequately assess these risks, both now and in the future.

Dr. Dzombak thanked all public commenters, and asked if Panel members had any clarifying questions for the public oral commenters. Hearing none, Dr. Dzombak then moved on to the next agenda item.

Discussion of Panel's Responses to the EPA Charge Questions

Dr. Dzombak noted that the EPA's research Study Plan discussed the EPA's plans to conduct prospective case studies that would involve conducting hydraulic fracturing characterization and monitoring efforts before and during hydraulic fracturing activity, and study the hydraulic fracturing water cycle in its entirety from a research standpoint. Dr. Dzombak and several other Panel members commented that members of the public pointed out that prospective studies were not in the EPA's draft Assessment Report, and asked Dr. Frithsen why prospective case studies were not in the EPA's draft Assessment Report. Several Panel members asked whether the EPA's budget for prospective studies was used for the rest of the assessment, or whether the EPA's research funds were still allocated for this work. Another Panel member noted that the draft Assessment Report did not include recommendations for future research, and asked whether the EPA would consider including such recommendations in the final Assessment report.

Dr. Frithsen responded that the EPA's original Study Plan did include prospective case studies to inform the EPA's draft Assessment Report. Dr. Frithsen stated that the EPA engaged with industry to identify study sites with an appropriate combination of land ownership and hydraulic fracturing activities that could be used for the EPA's purposes in prospective studies, and was close to some agreements but for a number of reasons could not get the agreements finalized. Dr. Frithsen noted that an important issue was schedule. If one or more prospective case studies could have been launched in 2011, it would have been possible to obtain several years of data. However, as discussions with industry became extended, it became clear that there would not be time to collect sufficient data even if a prospective study could be initiated. He noted that the EPA currently does not have a relationship with industry partners or sufficient resources to conduct hydraulic fracturing prospective studies. Dr. Frithsen also noted that prospective studies were not absolutely essential in moving forward with the EPA's draft Assessment Report,

although including such studies in the draft Assessment Report would have helped lower the draft Assessment's uncertainties. Dr. Frithsen stated that the draft Assessment tried to identify sources of uncertainties but did not identify research needs, and that he welcomed the Panel's input on how to best move forward. He also noted that the EPA would appreciate receiving SAB's suggestions on which uncertainties were larger or more important than others. He noted he was uncertain on the limitations on the EPA's research budget for 2016.

A Panel member asked why the EPA did not use retrospective studies in the draft Assessment Report, and why the EPA did not investigate potential impacts related to hydraulic fracturing in wells or well casings in the case studies at Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas that were described in the oral public comments. Dr. Frithsen noted that site investigations in Dimock, Pavillion, and Parker County were being conducted by the states, and that the data that the EPA had access to from these site investigations was not finalized yet. He noted that the EPA may further assess these data when they are considered final. Dr. Frithsen also noted that the scope of the EPA's draft Assessment Report was not site-specific. He noted that if there is information from those case studies that informs, for example, on a specific type of well integrity problem or other problem, that the EPA would find that information helpful to know.

Another Panel member stated that information on potential human exposure related to hydraulic fracturing is important to be able to assess potential human health impacts. He noted that while the EPA stated there was no human exposure problem related to hydraulic fracturing on a national scale, he was unsure whether there was a potential human exposure problem related to hydraulic fracturing on a worst case basis. He expressed concern that this problem should not be left to the states, and recommended that the EPA assess a worst case scenario to determine whether there was a potential human exposure problem related to hydraulic fracturing. Dr. Frithsen responded that if the EPA did conduct an exposure assessment, the EPA would likely have to do such an assessment on a site-specific basis and gather site-specific information on where members of the public were getting exposed. He commented that such a site-specific assessment was not part of the EPA's national assessment of the potential impacts of hydraulic fracturing for oil and gas on drinking water resources.

Dr. Dzombak then noted that the Panel would begin discussing each charge question, and described the process the Panel would follow during those discussions. He stated that after Lead Discussants provided their opening comments associated with the charge question, other Panel members would then have opportunity to provide additional comments. Dr. Dzombak stated that the Panel members assigned to each charge question in a writing role should keep track of all preliminary draft areas of consensus and key points made by the Panel during the discussion of that charge question. Dr. Dzombak noted that approximately ten minutes before the scheduled end of the Panel's initial discussions/deliberations on each charge question during October 28 and 29, he would ask the Panel's Lead Writer assigned to that charge question to summarize the preliminary draft areas of consensus and key points that were reached by the Panel during the meeting discussion. Dr. Dzombak then noted he would ask the other writers assigned to that charge question for any comments they may have on the Lead Writer's draft summary, and then ask the entire Panel for its thoughts, before the Panel moved on to discuss the next charge question.

Charge Question 1, regarding the background, scope, approach and intended use of the assessment, and the context and background of hydraulic fracturing and drinking water resources

Dr. Dzombak read the entire charge question, and noted the charge question related to Chapters 1, 2 and 3 of the EPA's draft Assessment Report.

Goals, background, scope, approach, and intended use of EPA's draft Assessment Report

Regarding the goals, scope, approach and intended use of the EPA's draft Assessment Report, a Panel member noted that the EPA's draft Assessment Report was structured around five stages of the HF water cycle, which was a good structure for the EPA's draft Assessment Report. Several Panel members noted that Chapter 1 of the EPA's draft Assessment Report did not explicitly state the goals of the assessment, and that while the goals could be inferred they should be explicitly stated in the EPA's draft Assessment Report. A Panel member noted that while the draft Assessment Report stated that one goal was to synthesize literature, the EPA also conducted research, performed case study reviews, gathered stakeholder input, and conducted other efforts. A Panel member suggested that the EPA acknowledge the need for additional assessment in the EPA's draft Assessment Report, and note limitations regarding potential impacts to human health and ecosystems. A Panel member stated that the presentation by Dr. Frithsen during the earlier part of the meeting more clearly presented the goals and objectives of the EPA's draft Assessment Report than Chapter 1, and that that presentation overview could assist the EPA as it revises the assessment.

Several Panel members suggested that the EPA discuss why certain water resources were and were not included in the scope of the EPA's draft Assessment Report. A few Panel members noted they thought the EPA should better explain how drinking water resources was defined, and one Panel member stated that the expanded definition of drinking water resources in the draft Assessment Report was commendable.

Descriptions of hydraulic fracturing and drinking water resources in Chapters 2 and 3

Several Panel members commented that Chapters 2 and 3 of the EPA's draft Assessment Report presented basic HF background information in a clear and useful manner. A Panel member recommended that Chapters 2 and 3 include information on the distances/spaces between HF wells, distances to water supplies from these wells, human population near HF wells, and the frequency of impacts. Another Panel member suggested that either Chapters 1, 2 and 3 of the EPA's draft Assessment Report should include discussion on depth of HF wells. Another Panel member stated that these Chapters should clarify the length of time that HF actually occurs, noting that in reality HF occurs during a limited time.

A Panel member recommended that the EPA describe more broadly in the EPA's draft Assessment Report what the various terms/acronyms mean. Another Panel member noted that the EPA's draft Assessment Report's footnotes were generally well done, but that footnotes in the EPA's draft Assessment Report's toxicity discussions should include details associated with those footnotes to improve clarity for the reader. Dr. Frithsen stated that the EPA struggled with defining terms in the document, since there were multiple audiences with multiple backgrounds for the EPA's draft Assessment Report. Dr. Frithsen asked the Panel to identify what worked and did not work in its review of the EPA's draft Assessment Report, and whether the footnotes leading the reader to journals assisted the reader. Dr. Dzombak asked the Panel to include in the

SAB's written response to charge questions any specific terms that need to be defined better.

Topics that should be added to Chapters 2 and 3

Several Panel members stated that the EPA did not but should consider and discuss various HF-related activities or scenarios in these chapters of the draft Report, or that the EPA should better describe various analyses that it did conduct, regarding:

- Fluid transport.
- Site selection.
- Other infrastructure development.
- Well installation, closure and abandonment.
- Reclamation of HF wells and water.
- Situations when problems occur during HF activities/operations, and outliers to systemic problems.
- Chemical transport and spills of such transport to a HF well.
- Social science aspects of HF activities/operations including information on social acceptance of HF activities/operations by communities.
- The linkage between HF and seismic events.
- Releases of radioactivity and radioactive elements from HF operations and drilling activities into ground and surface water, and into landfills.
- Regulations and guidelines at the state and federal level associated with HF activities/operations.
- HF well drilling and cementing.
- Limitations associated with projecting potential impacts with regard to population growth.

A Panel member recommended that the EPA quantify the frequency and severity of potential impacts associated with HF, and identify the limitations associated with identifying the factors that affect the frequency and severity of potential impacts associated with HF. A Panel member noted the EPA should clarify the timing and water volumes associated with different stages of HF. The Panel member noted that the draft Assessment Report inconsistently described the timing associated with HF, noting that a typical HF operation occurred between two-ten days or for 60 days, that HF operations were short but repetitive, and that HF has between ten-twenty or fifty-nine stages. The Panel member noted one could infer that there may be a higher probability of acute exposure to HF workers exposed to higher volumes of HF fluids. The Panel member stated it was unclear what were the most significant exposure concerns regarding HF, and what HF toxicity data was needed. The Panel member also noted that the EPA should define terms used in the draft Assessment Report such as short, intense HF process activity, and repetitive HF activities.

One Panel member noted that HF well closure should particularly be covered within the EPA's draft Assessment Report's scope, since well closure may result in potential impacts to drinking water resources over a long time. The Panel member noted that in Pennsylvania there were about 180,000 abandoned wells and the State of Pennsylvania did not know the location of most of these wells. Another Panel member noted that there was nothing unique about abandoning a HF well vs. abandonment of another type of well. A Panel member noted that it was important to provide information on what is happening outside of well casing, and that the draft Assessment should consider well closure and abandonment to provide simulations on what would occur after a hundred or a thousand years in terms of long-term potential risk.

A Panel member suggested that it may be appropriate to consider worker health and safety on HF well pads out of scope since that is an Occupational Safety and Health Administration (OSHA) concern. One Panel member noted that wellpad exposure information would potentially provide information on the degree of acute, sub-chronic or chronic risks associated with such exposures. Another Panel member commented that it would also be helpful to assess the degree of acute, sub-chronic or chronic risks associated with pulsed releases of HF-related wastewaters and chemicals into groundwater and surface waters, and into HF wastewater treatment facilities. A Panel member noted that while the EPA considered these various activities outside of the HF water cycle, this was a mismatch with the Congress's original request to broadly assess the potential impacts of HF to drinking water resources. Several Panel members stated that the EPA's draft Assessment Report should provide rationale why the activities described above, and other activities related to HF that the EPA decided not to address in its draft Assessment Report, were not within scope, and discuss why the five HF water cycle stages captured the bulk of the potential risks associated with HF.

Draft summary of preliminary draft key points

Dr. Dzombak provided a draft summary of preliminary draft key points that he heard during the Panel's discussion in response to charge question 1. He noted the following with regard to the draft Assessment Report's Chapters 1, 2, and 3:

- Chapter 1 of the draft Assessment Report should better explain the goals and scope of the research and the frequency and severity of impacts, and provide more rationale for what is and is not included in the draft Assessment.
- The goals for the assessment were more than conducting a literature review, and that the other HF research activities that the EPA conducted as part of the assessment should be described in the EPA's draft Assessment Report (as outlined in the presentation made by Dr. Frithsen).
- The EPA should better explain and acknowledge the challenges of assessing quantitative uncertainties associated with the frequency and severity of impacts.
- The draft Assessment Report should be presented in a manner that is understandable for a general audience.
- Terminology should be better explained, and the Panel should consider whether the EPA's draft Assessment Report's glossary or footnotes could be improved.
- The EPA should discuss the timescale for HF activities, noting that timescales should be provided for the full lifecycle of HF activities from both before and after HF production occurs.
- The EPA should discuss how the various HF processes affected exposure and risk assessment associated with HF activities.
- While the EPA's draft Assessment Report notes that an exposure and risk assessment were not conducted as part of the assessment, it would help inform future work if the draft Assessment Report identified exposure and risk issues that would be relevant to future exposure and risk assessment.

Several Panel members suggested additional preliminary draft key points in response to Charge Question 1. These members noted that the draft Assessment Report should also:

- Provide information on best practices utilized by the HF industry.
- Discuss and/or reference regulatory guidelines and responsibilities applicable to HF activity (including how the Clean Water Act and Safe Drinking Water Act requirements

- apply).
- Discuss how radioactive materials were generated and/or managed resulting from HF activity.
 - Acknowledge failures associated with HF activities.
 - Include a better understanding of temporal issues associated with all HF activities, including short and long term impacts of HF on small and large scales, on confined and unconfined aquifers, and on watersheds. A Panel member noted that there were many available references that the EPA could cite that discuss this temporal issue, particularly from the USGS.

Dr. Dzombak asked if Panel members had any additional comments on Charge Question 1. Hearing none, Dr. Dzombak began discussion on Charge Question 2.

Charge Question 2, regarding water acquisition - the use of ground or surface water for hydraulic fracturing

Dr. Dzombak read the entire charge question, and noted the charge question related to Chapter 4 of the EPA's draft Assessment Report.

Comments on available information concerning the sources and quantities of water used in hydraulic fracturing

The Panel had various comments on the draft Assessment Report's summary of available information concerning the sources and quantities of water used in hydraulic fracturing. A Panel member noted while the goals of this chapter of the draft Assessment Report focused on drinking water resources and were clearly stated, the EPA should also consider potential impacts of HF water acquisition on wildlife and streams. A few Panel members noted that the executive summary and Chapter 4 discussion on water acquisition and use should be geared toward the general public and not be too technical. The Panel member commented that both Chapter 3 and Chapter 4 discussed water acquisition. The Panel member stated that the draft Assessment Report should more clearly describe total water budget. A few Panel members noted that a number of statements in the Chapter 4 did not make sense and should be reviewed for comprehension.

A Panel member noted that while the draft Assessment Report was geographically comprehensive, only three states were assessed in detail with twelve other states being assessed superficially. The Panel member commented that since the draft Assessment Report relied on published reports, it was a confirmatory report that did not illuminate the reader.

A Panel member commented that the EPA should describe why it solely relied on FracFocus for data, and why the EPA did not also use local USGS and other data (e.g., the EPA WaterSense data) in addition to FracFocus data in the draft Assessment Report. The Panel member noted that it would be useful if the EPA identified what data (at what time and space scale, in broad water use categories) should be collected by states, locals, the USGS, and from FracFocus, to assist in assessing potential impacts of HF on drinking water resources.

A Panel member noted that the EPA should have used its well file review to assess information from industry.

Comments regarding whether quantities of water used and consumed in hydraulic fracturing were accurately characterized with respect to total water use and consumption at appropriate temporal and spatial scales

The Panel had various comments on the draft Assessment Report's characterization of quantities of water used and consumed in hydraulic fracturing with respect to total water use and consumption at appropriate temporal and spatial scales. A Panel member commented that the EPA should improve the assessment of hydrologic units and timeframes within the case studies that were assessed, further describe how small streams and other surface waters may be affected, and note that potential impacts to drinking water supplies were expected to be transient and at local scale.

A Panel member commented that the EPA did a good job in classifying different types of water use. Several Panel members noted that while there is an adequate supply of water nationally for hydraulic fracturing activity, the EPA should have assessed potential impacts at a local or small scale using information from states and industry, since local scale was where there was potential for impacts to drinking water supplies from multiple uses of water. A Panel member noted that the footnotes provided in this chapter were helpful in providing water availability information, and noted that it was difficult to distinguish water quantity data at a county scale.

A Panel member noted that the description of produced water reuse should be improved, including the description on water reuse technologies and the description of areas that use less vs. more reused water. Several Panel members noted that the draft Assessment Report stated that HF was less than 1/10 of 1 percent of water use, and commented that the EPA's draft Assessment Report should expand upon the other uses for water and the discussion of combined uses under drought conditions. The Panel member noted that a major issue within the EPA's draft Assessment Report was the lack of available water use and availability data on local scales, and commented that it would have been useful if two datasets on cumulative water use were assessed to compare percentages on water use vs. amount of water available (e.g., compare 2009 to 2012 FracFocus data). The Panel member further stated that it would be helpful if the EPA used acre feet of water to identify how much water was impacted. One Panel member noted that stable HF operations rely on stable HF water supply, that the HF industry has no desire to transport HF waters long distances, and if HF water can be reused, then that was a preferred option. He stated that there were technologies available to provide reused HF waters.

A Panel member recommended that the EPA consider the lack of uniformity in the state-by-state reporting that it relied upon, and consider the regulatory landscape and how that landscape affected the availability of data when considering effects at local scales.

Comments on major findings

The Panel had a few comments on the draft Assessment Report's major findings for this part of the HF water cycle. A Panel member noted that major findings should address how scale of hydraulic fracturing affects water acquisition and use. A Panel member noted that the lack of prospective case studies was a major deficiency. A Panel member commented that some major findings on water use were not brought forward from the main body of the EPA's draft Assessment Report.

Comments on the frequency or severity of impacts

The Panel had various comments on the draft Assessment Report's description of the frequency or severity of impacts associated with this part of the HF water cycle. A Panel member commented that there were some concerns with the agency's use of the term cumulative in the discussion on assessed impacts in Section 4.3 of the draft Assessment Report, and stated that total use rather than cumulative use should be assessed. The Panel member noted that while it was helpful that the EPA tried to consider potential impacts on a state by state basis, considered modeling studies that have been conducted, and gathered data on a state and county-wide basis, the EPA should have assessed effects on water quantity and quality in more than fifteen states with HF activity. One Panel member noted that it was helpful that the EPA added qualifiers to descriptions of impacts (e.g., whether lower or higher impacts were seen).

A Panel member noted that the draft Assessment Report should describe cases where water availability would have an impact on drinking water resources. The Panel member commented that States such as Pennsylvania were considering requirements for when water could be taken from streams, and that information on water availability and low flow statistics from sources such as cooperative extension offices could be used to help assess this topic. Several Panel members noted that some databases that were not peer reviewed (e.g., data in state regulatory offices in paper form, and industrial data) may still be useful to identify the potential for local impacts.

A Panel member noted that public comments provided by Bridget Scanlon in the EPA's Docket as comment #EPA-HQ-OA-2015-0245-0094 were particularly useful to consider regarding whether factors affecting the frequency or severity of any impacts were described to the extent possible and fully supported.

Comments on uncertainties, assumptions, and limitations

The Panel had a few comments on the draft Assessment Report's description of uncertainties, assumptions, and limitations associated with this part of the HF water cycle. A Panel member noted that there were many key data limitations that affected the proper understanding of HF impacts on water acquisition, such as the draft Assessment Report's heavy reliance on industry-provided data. A Panel member commented that the EPA did a good job describing uncertainties and additional information that was available, and that it would be helpful if the EPA added some information at the local scale.

Comments on additional information, background, or context that should be added, research gaps, or relevant literature or data sources

The Panel had various comments on additional information, background, or context that should be added, and on research gaps or relevant literature or data sources that should be considered, within the draft Assessment Report's description of this part of the HF water cycle. A Panel member noted that the draft Assessment Report should better describe how pulling water out of a watershed affects water quality, and gave as an example that total dissolved solids (TDS) might double if streamflow is reduced by half. The Panel member commented that the draft Assessment Report should note rules of thumb for how water quality is affected due to reduction in stream flow (e.g., how increases in chloride concentration resulting from water removal for HF operations would increase water supply and treatment costs due to pipe and equipment corrosion). The Panel member noted that the draft Assessment Report should consider

desalination technologies for removing TDS from water. The Panel member noted that the draft Assessment Report should discuss the linkage between HF and seismic events, particularly regarding whether disposal of HF fluids affects seismic events and results in increased disposal costs of HF fluids.

A Panel member stated that recent literature discusses the effects of HF on stream drawdown, extreme habitat changes, and other local effects. The Panel member recommended that the draft Assessment Report assess projected effects in the future, and temper projections by accounting for uncertainties in assumptions on HF activities.

A Panel member recommended that the EPA consider doing state or local hydrogeological modeling to assess impacts. Another Panel member commented that USGS national water census data could be used to help identify consumptive use, and that USGS and other future water availability models could help identify projected uses on a watershed or basin-wide basis. The Panel member noted that uncertainty and variability increases in upper reaches of a basin.

A Panel member stated that the draft Assessment Report should examine how HF affects costs for water on a county or local level, and noted that Colorado had some site-specific information on this. Another Panel member noted that the costs associated with lower groundwater depths caused by HF operations should also be assessed, noting that the electric power, grain and livestock industries in Kansas have been affected by these costs. One Panel member suggested that the draft Assessment Report should assess water use during drilling of HF wells, noting that some drillers case HF wells to protect from such water losses.

Draft summary of preliminary draft key points

A Panel member and Dr. Dzombak provided a draft summary of preliminary draft key points that they heard during the Panel's discussion in response to charge question 2. They noted the following with regard to the draft Assessment Report's Chapter 4:

- The draft Assessment Report's national and regional assessment of water use and availability may not be meaningful due to the large space and time scale of such an assessment, and county-wide and local assessments would be helpful and reasonable to focus on and include.
- There were a large amount of additional sources of information and references that the EPA should consider on this topic.
- The EPA should provide information and tables on the water quantities involved in terms of acre feet.
- It was helpful when the EPA discussed case studies in this chapter, and the boxes that the EPA included for case studies could be expanded upon (e.g., to discuss modeling and hydrogeology associated with these case studies).
- The EPA should better explain why some data sources were used and not others, and should consider using other data sources in addition to FracFocus.
- The EPA should improve the discussion on and assess the scale of water used for HF as compared with other water uses.
- The EPA should more clearly and prominently discuss how well file data were used and why such data were not more heavily relied upon.
- Chapter 4 describes potential impacts more comprehensively than other chapters.
- The EPA should assess the role of water economics related to HF activities, including how water acquisition affects water costs and the water costs for other uses.

Several Panel members commented that there is some value in a national assessment as well as an assessment that considers local and seasonal effects.

Dr. Dzombak asked if Panel members had any additional comments on Charge Question 2. Hearing none, Dr. Dzombak began discussion on Charge Question 3.

Charge Question 3, regarding chemical mixing - the mixing of water, chemicals, and proppants at the well pad

Dr. Dzombak read the entire charge question, and noted the charge question related to Chapter 5 of the EPA's draft Assessment Report.

Comments on the composition, volume, and management of the chemicals used to create hydraulic fracturing fluids

The Panel had various comments on the draft Assessment Report's description of the composition, volume, and management of the chemicals used to create hydraulic fracturing fluids. Several Panel members stated that this chapter of the draft Assessment Report was well organized and broke down complex HF operations and overarching factors into a logical progression (e.g., the chapter provided a clear breakdown of the HF pumping process). A Panel member stated that the chapter accurately described treatment volumes on unconventional wells, which is a key aspect of HF operations.

A Panel member stated that a large number of chemicals were being used during HF, and many of these chemicals do not have analytical methods and therefore are not being detected. Another Panel member noted that many HF chemicals are polymers, and that the higher molecular weight polymers are difficult to analyze in a water setting. A Panel member noted that a current trend was the use of synthetic polymers in light gel systems for HF slick water. Another Panel member noted that spills at different stages of HF operations would not include all HF chemicals used in that operation (e.g., some stabilizers such as sodium thiosulfate).

A Panel member noted that while Table 5-3 provided a good summary of HF fluids used in particular states, information on HF fluids used at a local level, perhaps organized by shale play using a time-series approach over 5-10 years, would be more helpful.

A Panel member stated that the EPA's draft Assessment Report broke down 457 spills that were reported into two parts of the HF water cycle, and that this subdivision was not helpful. The Panel member commented that the EPA should include figures that the EPA developed on the 457 spills into the draft Assessment Report.

A Panel member stated that the EPA should expand the title of this chapter of the draft Assessment Report, to note the chapter covered chemical spills, spill prevention and fate/transport issues. Another Panel member stated that Section 5.2 should discuss actual HF mixing processes, and noted that mixing additives were typically included days or weeks in advance before the mixes were used at HF sites. The Panel member noted that the EPA's analysis of sources for leaks was not thorough, and that the EPA should further assess leaks from hoses. The Panel member stated that the discussion on pumping from tanks was somewhat confusing, and that spills could involve low concentrations of HF chemicals.

The Panel member stated that three million gallons of HF fluids were typically produced during a well's HF activities, and that while this volume would fill 150 tanks, this number of tanks is not needed at a HF site since HF occurs in stages. The Panel member noted that certain additives should be further discussed, including hydroxy methyl cellulose additives. The Panel member noted that proppants were stored in vessels near the mix and then pumped into the mix at the site, and that it would be helpful to show pictures of such unit processes within the draft Assessment Report.

A Panel member noted that while Figure 5-14 in the chapter noted total releases by HF activity and that data were provided on spill volumes for 151 HF-related spills, the previous page noted that 125 of 155 HF spills did not report spill volumes. The Panel member noted this chart should be presented as a histogram. The Panel member observed that some chemicals noted in Table 5-2 were used in food, and suggested that it would be helpful if the chapter described which chemicals in the table were also in food. The Panel member noted that the draft Assessment Report should not speculate on which media are contaminated from a HF operation chemical release (e.g., the text describing Figure 5-19). Another Panel member noted that many food additive chemicals listed in Table 5-2 had no available safety data. Also, a Panel member noted that the chapter's summary section should discuss toxicity information in addition to information on chemical composition and physical/chemical properties.

A Panel member noted that the EPA calculated volume for only a handful of chemicals where density data were available, and noted that it was not clear why the EPA did not use mass information regarding chemicals in assessing potential impacts. The Panel member expressed concern about the broad national generalizations that this chapter made regarding frequency and severity of impact, and suggested that it would be helpful if the EPA developed separate spreadsheets that provided more localized information on chemicals used and geologies and formations in which wells were located to assess severity.

Comments on the frequency or severity of impacts

The Panel had various comments on the draft Assessment Report's description of the frequency or severity of impacts associated with this part of the HF water cycle. While one Panel member noted that the chapter adequately described HF fluids and impacts and that factors affecting frequency and severity of impacts were identified to extent possible, several Panel members stated that since the EPA's draft Assessment Report stated that there was a lack of data on spills and that the severity of spills is largely unknown, the EPA's draft Assessment Report could not conduct quantitative analyses nor make a finding on the frequency, severity, and potential impacts associated with spills. In addition, while one Panel member noted that the composition and management of HF fluids was well reported, another Panel member noted that only a small fraction of chemicals used in HF wells are known and the chemicals and volumes used vary depending on the time of use within the HF operation. The Panel member further noted that chemicals may have different effects as they are mixed, such as when acids are mixed with HF constituents. Another Panel member stated that while the chapter's synthesis section (page 5-71) noted there were no documented impacts to groundwater, other sections of the chapter cited situations where spills occurred and affected groundwater (e.g., one section discussed 77 spills in Colorado that affected groundwater).

While one Panel member noted that the chapter's presentation on fate/transport discussion was well presented, several Panel members noted it was difficult to understand which chemical fate/transport information was speculative, and noted that the chapter's fate/transport discussion

read like a book chapter without stating any conclusions. Another Panel member noted that the EPA's EPI-Suite database could potentially be used to assess mobility of chemicals, but noted that while that while EPI-Suite worked well in assessing hydrophobic chemicals, it did not work as well for polar chemicals. A Panel member noted that within the chapter, the EPA presented histograms of physical/chemical properties for HF chemicals, but noted that these data were limited (e.g., octanol/water partition coefficient information was provided for only 42% of chemicals, and that the other 58% of chemicals may be the more mobile chemicals).

Comments on uncertainties, assumptions, and limitations

The Panel had a few comments on the draft Assessment Report's description of uncertainties, assumptions, and limitations associated with this part of the HF water cycle. A few Panel members noted that uncertainties and the concentrations of chemicals used during HF were well described in the chapter. A Panel member noted that while the chapter's descriptions of case studies were helpful, the third case study presented in the chapter noted that conclusions could not be drawn from that case study.

Regarding the limitations associated with sole reliance on FracFocus data, a Panel member expressed concern that the chapter's discussion on severity did not appear to link to volume or frequency of chemicals detected within FracFocus. The Panel member also expressed concern regarding how CBI prevented the EPA from assessing a significant portion of HF chemicals, and noted it would be helpful if the EPA better described what percentage and volumes of HF chemicals were subject to CBI. Another Panel member noted that the EPA should better describe whether CBI chemicals listed in Table 5-8 are unique, and whether safety and physical/chemical information for these chemicals are available.

Comments on additional information, background, or context that should be added, research gaps, or relevant literature or data sources

The Panel had various comments on additional information, background, or context that should be added, and on research gaps or relevant literature or data sources that should be considered, within the draft Assessment Report's description of this part of the HF water cycle. Several Panel members stated that the EPA did not but should consider and discuss various HF-related activities or scenarios in this chapter of the draft Report, or that the EPA should better describe various analyses that it did conduct, regarding:

- Results of any testing that the EPA conducted on chemicals used during HF.
- Descriptions of which type of HF wells used certain chemicals.
- Descriptions of chemicals in HF fluids before and after these fluids were sent down and retrieved from HF wells.
- Information on toxicities (using material safety data sheet, MSDS, data) and molecular weights of chemicals presented in Tables 5.7 and 5.8.
- Information on scenarios of how HF chemicals would mobilize in different geological/rheological properties in varying settings (e.g., temperatures).
- Descriptions of which geologies were most at risk from HF spills.
- Information on BTEX chemicals used in HF fluids.
- Quantification of the temporal differences in the volumes and types of chemicals used during HF.
- Limitations associated with sole reliance on FracFocus data, including limited testing for many HF compounds, the voluntary nature of how data is provided to FracFocus, and

how CBI data is not included within FracFocus.

- Analyses that involve randomly sampling data from FracFocus and assessing that data.
- Analyses that used a later version of FracFocus data, since the FracFocus 1.0 data that the EPA assessed was very limited and was taken from only a few states.
- Gather and report data taken from states who require that HF operators provide data on composition of chemicals used during HF (e.g., Colorado and Texas).
- Gather and report data on the efficiency of industrial processes for containing spills.
- Reduce the uncertainties associated with spills by better describing the volumes, chemistry, severity and frequency of spills (noting that the spills database that the EPA used provided spill data from only nine states).
- Describe how agencies respond to spills and who conducts spill cleanup.
- Present and discuss industry best practices.
- State what is known about fate/transport in complex media over large distances.
- Analyze the mass of constituents injected into HF wells to help assess releases of HF constituents.
- Synthesize new information on chemical fate/transport issues associated with HF spills.
- Gather data to support statements on uses of new materials being used during HF and how the trend in the HF industry was moving towards use of environmentally friendly and less materials (e.g., changing from use of solvents to use of biodegradable chemicals such as biodiesels).
- Risks associated with spills before HF chemicals reached wellpads.

Regarding research gaps, several Panel members noted that the EPA should conduct more studies on HF chemicals used during pre- and post-injection activities, gather in situ data, and gather long term data taking into account seasonal variation.

Draft summary of preliminary draft key points

A Panel member and Dr. Dzombak provided a draft summary of preliminary draft key points that they heard during the Panel's discussion in response to charge question 3. They noted the following with regard to the draft Assessment Report's Chapter 5:

- The draft Assessment Report should better assess and describe frequency and volume of spills, and should separately discuss spills from chemical mixing vs. flowback activities.
- The EPA's draft Assessment Report should describe the lack of analytical capability on a number of chemicals, and the need for safety data on many HF chemicals including those chemicals that are also used in food.
- The EPA's draft Assessment Report generally did a good job describing the industrial processes of mixing, but noted that information on new chemicals being used in HF and trend information should be better described.
- There was insufficient information and data presented to support a conclusion that there were no major spills, and the EPA should provide information on the frequency, concentration and temporal nature of chemical spills.
- The chapter title should include fate and transport.
- The chapter's fate/transport discussion is generic and does not specifically address the potential effects of HF on drinking water resources.
- Rather than noting there were no observations of spills, the EPA's draft Assessment Report could note that it was unlikely that there should not be spills.
- The EPA's draft Assessment Report should better describe the likelihood of spills, and

consider using updated FracFocus data and other databases to gather information on spill severity and frequency.

- Geological information should be included in the Chapter's fate/transport analyses, and some of the separate published HF reports prepared by the EPA's contractors on high end modeling were not adequately described in the EPA's draft Assessment Report.
- The EPA's draft Assessment Report should also better describe the frequency, severity, density and toxicity of HF polymers and CBI chemicals.
- The chapter should include discussion on how frequency and severity of impacts related to toxicity.
- It was difficult to make conclusions in the EPA's draft Assessment Report on the absence of chemicals if the EPA did not monitor for presence or absence of such chemicals, and the EPA's draft Assessment Report should provide additional information and figures on the known 450 spills.

Several Panel members also noted that additional preliminary draft key points included that the chapter could include a discussion on how best practices in the HF industry could affect outcomes, and noted that for example, such best practices are established and available in Alaska and Pittsburgh to prevent spills. A Panel member recommended that the EPA include more case histories of HF in environmentally sensitive areas. Another Panel member suggested that the EPA describe roles and responsibilities of the federal, state and local authorities associated with managing spills once they occurred.

Dr. Dzombak asked if Panel members had any additional comments on Charge Question 3. Hearing none, Dr. Dzombak began discussion on Charge Question 4.

Charge Question 4, regarding well injection - the injection of hydraulic fracturing fluids into the well to fracture the geologic formation containing oil or gas

Dr. Dzombak read the entire charge question, and noted the charge question related to Chapter 6 of the EPA's draft Assessment Report. Since the Panel's discussion on this charge question began late in the day, the Panel completed its discussion during the Panel's October 29, 2015 meeting. The following describes the discussion that occurred on October 28 and October 29 related to this charge question.

Comments on the available information concerning well injection, including well construction and well integrity issues and the movement of hydraulic fracturing fluids, and other materials in the subsurface

The Panel had various comments on the draft Assessment Report's summary of available information concerning well injection, including well construction and well integrity issues and the movement of hydraulic fracturing fluids, and other materials in the subsurface.

Regarding overall clarity of the draft Assessment Report, several Panel members stated that this chapter of the draft Assessment Report was a herculean task and noted that the EPA should be commended for its efforts in developing this chapter and for providing an excellent overview of factors affecting the relationship of HF and drinking water during the HF production phase. They noted that this Chapter was particularly dense and geared toward the professional audience and not the average reader. They suggested that the EPA should include some of the graphs provided in publications developed or supported by the EPA for this assessment to improve the clarity of

the text. A Panel member suggested that the EPA simplify the chapter's discussion on the modeling work conducted by Dr. Moridis that showed through back of the envelope calculations that long-distance movement of HF fluids will not happen in the subsurface. Another Panel member suggested that the EPA provide more clear discussion on technical terms such as well communication. Several Panel members suggested that the EPA include simple graphs that depicted HF events, and add more 'boxes' in the draft Assessment Report to help the general public better understand HF well construction and how potential releases from HF wells may differ from other types of wells. A Panel member also noted that Figure 7-1 was confusing as it implies that all chemicals going into a well are returned in recovered water, and noted that 100% recovery of injected HF fluids should not be expected. Another Panel member noted that while the charts and discussion on amounts of fluids per basin were useful, the EPA should also summarize and make conclusions about this information.

Several Panel members suggested that the EPA clarify that an integration of disciplines was required to develop the chapter, and noted that the draft Assessment Report's descriptions and definitions of HF vs. fracturing vs. well injection vs. other aspects of the HF water cycle were confusing and should be rewritten to clarify distinctions among these definitions. A Panel member suggested that it was important to define HF, whether produced water was part of HF, and what HF chemicals are of most concern. Another Panel member noted that injection of wastewater is not HF, and injection is usually conducted in a different geologic formation than the formation where HF is performed (i.e., injections occur in permeable formations that are at greater depth than zones where HF is performed to get petroleum hydrocarbons). The Panel member also noted that these wastewater injection wells are often hydraulically fractured in order to enhance the permeability of the zone to accept these wastewaters, and that such distinctions should be made in the text to more clearly describe the purposes and type of HF that are conducted. A Panel member clarified that HF does not increase permeability; rather, HF creates an inductive pathway that increases the injectivity of a production well. Another Panel member noted that while terminology was important, the primary concern is whether an impact is caused by HF, regardless of whether the problem is caused by HF drilling, HF injection, or other HF-related activity.

Several Panel members noted that cementing operations are critical for well integrity, particularly for gas operations, and that most issues that occur are related to well construction. While one Panel member noted that the EPA provided a generally good discussion within the draft Assessment Report on cementing techniques, cement integrity and failure points, several Panel members had suggestions to improve this discussion. A Panel member commented that there is limited information presented within the draft Assessment Report on the constructed integrity of these cementing systems in HF wells. One Panel member noted there was a disconnect between a failure to systematically look for problems and a failure to find problems, and that perhaps the EPA did not systematically look for cementing problems. Another Panel member noted that a new borehole will cause a leak unless cementing is conducted properly. The Panel member stated that understanding cementing techniques and integrity testing can be very confusing, noting that it is very difficult to identify where and how a well has been cemented. A Panel member noted that the pressure cycling information related to cementing techniques presented in the draft Assessment Report is a very important discussion. A Panel member noted that HF wells are often fractured several times, and that fluids entering HF wells after repeated fracturing are hotter than fluids entering wells that are only fractured once. The Panel member commented that there is limited information provided in the draft Assessment report on cementing, well construction, and aging HF wells. The Panel member noted that until cement sets in a HF well, it remains in a viscous, liquid form in the annulus between the outer well

casing and the wall of the formation. The Panel member noted that until the cement sets, any gas coming in can migrate into the cement, and that there is a large literature base on these effects. The Panel member noted that the manner in which cement sets is dependent on local geology. The Panel member also recommended that available data on well cementing should be carefully examined, since information may only be provided on where the top of cement is for the well, but may not provide information on how much cement surrounds the well as it goes down into the formation.

Several Panel members noted that many members of the public were concerned with stray gas entering their water supplies, and noted that conducting causal analysis to identify the source of stray gas is a very complex scientific undertaking and that many studies on this topic were sealed or held confidential and were not publicly available. These Panel members noted that there are abundant natural methane releases, and the draft Assessment Report should explain how difficult it is to identify the source of methane that enters a drinking water well. Gas releases could be due to either natural or anthropogenic activities. Several Panel members suggested that the EPA include a separate analysis on this topic in the draft Assessment Report, and noted that there are many sound publications on this topic. A Panel member noted that baseline testing is usually required to identify whether the cause for the gas releases to individual home drinking water supplies was natural or anthropogenic. The Panel member also stated that acoustic logging and ultrasonic testing techniques can help identify casing gas seeps and open cement gaps. A Panel member noted that drilling may be a reason for methane movement in the subsurface, and that new HF wells such as in Pennsylvania may be causing gas migration problems to occur in new drilling areas.

A Panel member suggested that the EPA should update its Report discussion regarding HF activities in Bainbridge, Ohio in consideration of public comment the EPA-HQ-OA-2015-0245-0136 that was submitted to the EPA's Docket. Another Panel member noted that several state reports were released on Bainbridge Ohio HF activities, with several lawsuits occurring as well. The Panel member noted that water wells in homes had methane releases, and investigations and published findings indicated there was a clear cementing problem that caused releases from wells in Bainbridge. The Panel member stated that industry conducts cement bond logging which can sense the radius between rock and cement of a well, and that this instrument can indicate whether a well's cement completely fills the annulus between well casing and rock. The Panel member stated that HF in Bainbridge occurred in karst limestone which made it difficult to cement the well from top to bottom. The Panel member also noted that permeable rocks such as sandstone near areas where methane is being released from a HF well would receive the methane gas as a leak-off zone, and thus lower pressure in the system.

A Panel member suggested that the EPA include additional case studies in this section of the draft Assessment Report since they are very important, and noted that it was not understandable that the EPA did not want the overall assessment to include any site specific assessments. The Panel member commented that the Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas case studies should be included in the draft Assessment in some way, and noted that not including these famous case studies will make the EPA's draft Assessment Report less defensible.

A Panel member stated that there is a significant amount of research on induced seismicity resulting from HF activities (particularly waste disposal), noting that since 2009 there has been a significant increase in induced earthquakes related to HF in certain areas of the U.S. The Panel member suggested that the EPA map locations of induced seismicity and earthquakes relative to

locations for high volume HF injections and waste fluid disposal, and noted that USGS was trying to do this for the eastern U.S. The Panel member noted that the Texas Railroad Commission and the oil and gas commissions in Pennsylvania, Ohio and Colorado were gathering monthly data on seismic activity related to HF.

A Panel member noted that HF design is critically based on natural fractures. A Panel member noted that in order to assess the level of induced fractures a detailed understanding of geologic features was required, including how many natural fractures were present in the formation. Another Panel member noted that rocks have fractures and joints in all different directions and locations. The Panel member also noted that a significant portion of HF occurs in shale which has unique properties, and stated HF occurs in a different manner in shale geology than in other geologies.

A Panel member noted that higher probability situations should be clearly listed, naturally occurring scenarios should be identified, and problems associated with older HF engineering systems should be described. Dr. Dzombak noted that the EPA narrowed the scope of this HF assessment in part due to the significant amount of public comment raised during the scoping discussions in 2010. Dr. Dzombak encouraged the Panel to think of the HF water cycle as a system with multiple potential points of failure - similar to how a chemical engineer would evaluate risk in a chemical production process, and note areas where efforts should be spent to mitigate risks.

Dr. Dzombak noted that in the SAB reviews of the EPA Scoping Document and final Study Plan associated with its hydraulic fracturing assessment, there were extensive discussions on scope for the research, and it was agreed that processes common to other activities in oil and gas development (e.g., transportation of chemicals to/from sites) would not be assessed as part of the HF assessment since those activities were not unique to HF. Dr. Dzombak also noted that the opening chapter of the draft Assessment Report provided a discussion on scope, and he encouraged the Panel to consider this as the Panel develops advice. Dr. Dzombak recognized that it was challenging to differentiate unique HF-related activities from other activities involved with HF for oil and gas development.

A Panel member noted that HF data should be more robust, transparent and available, noted that it takes a significant amount of time to produce data electronically and make it public, and stated that there are many reasons why data are not shared (e.g., desire to publish; confidential business information; privacy). Another Panel member noted that in 2013, the State of Colorado set requirements for groundwater monitoring of any drilling activities that require well pads, and thus any HF wells in Colorado after 2013 would have groundwater monitoring data for years after HF activities occurred. The Panel member noted that such data would help provide reference data that would indicate whether chemicals detected in the groundwater were present before HF activity occurred. The Panel member suggested that the EPA and the 38 states that were conducting hydraulic fracturing should establish a joint system to provide this type of information to the public. A Panel member commented that it would be helpful if the draft Assessment Report described the current federal and state regulatory requirements applicable to HF.

A Panel member noted that in Pennsylvania, a much larger number of HF-related violations was recorded in 2008 than in 2011, and suggested that it would be informative if the EPA assessed what best management practices (BMPs) occurred in Pennsylvania to cause such improvements in HF activity.

A Panel member recommended that the EPA conduct structural integrity testing on older HF wells to assess their potential to impact drinking water supplies, since these older HF wells and casings could potentially be pathways to drinking water reservoirs.

One Panel member suggested that the EPA incorporate Figure 3-20 on page 116 of the EPA's publication "An Introduction to the Technology of Subsurface Wastewater Injection (EPA 600/2-77-240, December 1977). Another Panel member suggested that instead of this figure, perhaps a pressure/time chart developed by industry might be better to incorporate and/or a current graph from industry that shows the moment a rock breaks at the time of HF. Another Panel member suggested that the EPA include pictures of rocks in the EPA's draft Assessment Report (e.g., a shale vs. sandstone). A Panel member suggested that the EPA include three dimensional figures in the chapter, and noted that the depth of wells should be depicted in these figures. A Panel member noted that the EPA's draft Assessment Report's extensive section on sustained casing pressure should be removed, since there was no evidence of sustained casing pressure from HF activity.

A Panel member suggested that the EPA retitle Section 6.2.2. and remove the word 'evidence,' since a model was a representation of reality but is not an observation of nature. The Panel member suggested that the EPA should rewrite several sentences in this section to qualify the discussion to a description of results of interpretive models and model simulations, and also clarifies when the description describes simulations or scenarios that used measured values.

A Panel member noted that Figure 6-4 was very helpful, but noted that the disc-shaped fractures depicted in this figure do not exist in nature. Several Panel members noted that Figure 6-5 does not realistically depict natural fractures, faults, and well construction, and that induced fractures should be discussed as they relate to this figure. A few Panel members stated that rocks do not allow appreciable flow unless the rocks are fractured, and commented that once fractured rocks did not allow flow to occur for a long distance (e.g., probably a maximum of a few hundred feet) since the flow would hit a boundary, fault or clay layer and stop at that location. The Panel members suggested that the modeling that the EPA conducted should support these basic premises, and it would help if the EPA brought some of the modeling discussions on this topic that were described in the EPA's draft Assessment Report's appendices into this chapter, and consider using the stim-plan fracture propagation model to show stress contrast. A Panel member stated that the EPA should discuss spatial boundaries and temporal aspects regarding the presentation on error bars associated with the cement logs.

A Panel member recommended that the EPA's draft Assessment Report should note that the permeability of the formation after HF operations have occurred has drastically increased.

Comments on major findings

The Panel had various comments on the draft Assessment Report's major findings for this part of the HF water cycle. A Panel member noted that the EPA should rewrite the findings and conclusions of this chapter, since the findings were not well organized and not bulleted, and were not comprehensive given the significant amount of detail provided on various injection and drilling issues. Another Panel member noted it was important that the draft Report accurately describe and summarize actual problems at wells due to HF. Several Panel members suggested that the EPA revise this chapter's summary discussion that stated there was increased opportunity for HF releases and that drinking water resources may have been affected, since this

summary was speculative and presented no statistical evidence and limited conclusive evidence to support this statement. In addition, these Panel members noted that the first sentence of the summary paragraph should be more carefully written to provide the basis for stating that fluids can migrate from the wellbore (e.g., state whether this conclusion was based on modeling or observations).

A Panel member noted that conclusory statements on impacts in this chapter did not recognize statements on page 6-54 of the draft Assessment Report regarding identified impacts in Ohio. Another Panel member noted that the EPA should clarify and differentiate which impacts were from conventional oil-based drilling and which impacts were from HF activities. The Panel member noted that the EPA should also state which impacts were the most frequent and severe and which were less frequent and severe, and also further describe how cementing causes certain impacts.

A Panel member noted that a key conclusion was stated on pages 6-56 and 6-57, which noted that "...evidence of any fracturing-related fluid migration affecting a drinking water resource (as well as the information necessary to connect specific well operation practices to a drinking water impact) could take years to discover." The Panel member suggested that this conclusion be included in the Executive Summary of the draft Assessment Report. Another Panel member recommended that the EPA provide focused conclusions on the frequency and severity of impacts and spatial and temporal variations in HF operations.

Several Panel members suggested that due in part to the complexity of issues described in the chapter, the chapter should present 'leading order effects' to help clarify the most important concerns regarding potential impacts to drinking water associated with these topics. For example, a Panel member noted that literature on carbon sequestration emphasizes that abandoned wells are leading order regarding potential for leakage of brines and gas from geologic storage reservoirs. This led another Panel member to suggest that for each chapter of the draft Assessment Report that dealt with a part of the HF water cycle, it was important to identify the most important concerns described in that chapter. The Panel member noted that that information would be folded into the Chapter 9 discussion on toxicity. The Panel member stated that Chapter 9 did not present a sense or perspective on which HF issues and uncertainties are the leading or most important issues and presented information in a manner that indicated that all issues were of equal importance. The Panel member recommended that earlier chapters of the draft Assessment Report identify a prioritized list of issues and uncertainties associated with each part of the HF water cycle.

Comments on the frequency or severity of impacts

The Panel had several comments on the draft Assessment Report's description of the frequency or severity of impacts associated with this part of the HF water cycle. Several Panel members suggested that the EPA clarify its discussion on frequency, severity and types of impacts (particularly in Section 6.4.4. of the draft Assessment Report). Several Panel members also recommended that the EPA provide more information on the frequency and likelihood of HF problems, discuss how the frequency of HF may lead to more impacts, and prioritize the most important issues associated with HF, taking a systems view of HF operations.

A Panel member noted there was a large amount of available information that the EPA did not tap into regarding this topic. The member stated that injection into Class 1 underground injection wells has been occurring since the mid-1960s (for example, Ohio used to have 11 Class 1 wells

and now has seven Class 1 wells, and Texas and Louisiana have more Class 1 wells than Ohio), and that such injection experience can provide information on the escape of fracture fluids to the ground surface. The Panel member noted that pressure measurements have been taken on the pressurized sleeves of these wells. The Panel member noted that study of this information has provided information on gas transport pathways and what mechanically was occurring in these wells. The Panel member stated that the EPA's Bruce Kobelski has information on these Class 1 wells. Another Panel member recommended that the EPA assess the frequency of small and large natural vs. induced fractures in rock, and how these fractures affected mobility of contaminants.

Comments on uncertainties, assumptions, and limitations

The Panel had a few comments on the draft Assessment Report's description of uncertainties, assumptions, and limitations associated with this part of the HF water cycle. A Panel member noted that the Chapter 6 uncertainty discussion provided a good summary of uncertainties associated with topics covered within this chapter of the draft Assessment Report. Several Panel members suggested that the EPA revise this chapter's summary discussion of increased opportunity for HF releases and impacts on drinking water resources, since this summary was speculative and presented no statistical evidence and limited conclusive evidence to support this statement. Another Panel member stated that Chapter 9 did not present a sense or perspective on which HF issues and uncertainties are the leading or most important issues and presented information in a manner that indicated that all issues were of equal importance. The Panel member recommended that earlier chapters of the draft Assessment Report also identify prioritized lists of issues and uncertainties associated with each part of the HF water cycle.

Comments on additional information, background, or context that should be added, research gaps, or relevant literature or data sources

The Panel had various comments on additional information, background, or context that should be added, and on research gaps or relevant literature or data sources that should be considered, within the draft Assessment Report's description of this part of the HF water cycle. Several Panel members stated that the EPA did not but should consider and discuss various HF-related activities or scenarios in this chapter of the draft Assessment Report, or better describe various analyses that it did conduct, including:

- Mobility of HF contaminants in rock, including the volumes of HF fluids going into the reservoir and returning to the well, and how HF fluids could move upwards thousands of feet from geologic formations thousands of feet deep where HF occurred.
- An assessment of time involved with injection and when rock fracturing occurs.
-
- Principles of well construction design; industry best practices on how to do HF safely and responsibly.
- State-by-state well construction requirements, with a state-by-state analysis of well files to assess HF wells that met or did not meet such requirements, and why.
- The use of flexible and self-healing cements, and insertion of plugs to mitigate impacts, during HF well construction.
- Operator practices in assessing nearby abandoned wells.
- Expansion of the EPA's well file review for well construction to help assess potential impacts to groundwater from HF activities (for example, expand the number of well files assessed to at least 10% of the available well files; and also consider the 20,000 well files

available for Erie, Pennsylvania).

- Use of acoustic technology in addition to cement bond logs in assessing how gas is moving along well bores;
- Situations and scenarios where HF or drilling would or has affected stray gas migration.
- How to improve HF data management and make HF data more robust, transparent and available.
- Updated, current cementation processes and well integrity requirements.
- New technologies that have developed.
- The hierarchy of the types of fractures that occur during HF, with discussion on what fractures commonly or rarely occur; compare modeling results to any data or failures that have occurred.
- Assess potential impacts during pressurized situations and not only during hydrostatic conditions.
- Assess potential impacts over terms longer than two years.
- Identify scenarios that the EPA planned to further assess.
- Assess how joints, faults, discontinuities, orientation of fractures, and preexisting fractures affected subsurface flow.
- Unrecovered HF water.
- Induced seismic activity such as earthquakes due to high volume HF fluid injections and waste disposal.
- Modeling scenarios that the EPA stated it would do as stated in the EPA's HF Research Study Plan.
- Potential for leaks from wells and casings that are more than 15 years old, using technologies such as pressure testing, X-ray systems, and others to assess structural integrity of these wells and casings.
- Best Management Practices (BMPs) for monitoring (including methane monitoring, and drilling and well construction/casing).
- Guidance to homeowners on recommended monitoring to conduct before HF drilling is begun (e.g., sampling frequency, duration, and other baseline information).

A Panel member commented that the EPA's prospective studies would have been very helpful to identify situations where impacts may occur due to HF, and suggested that the EPA continue to keep prospective studies as a goal for future research. A Panel member noted that until the cement sets, any gas coming in can migrate into the cement, and that there was a large literature base on these effects.

A Panel member noted that the EPA should include information on how likely it is for HF to communicate with existing well bores, and noted that a good article on this topic was by James A. Montague and George F. Pinder: *Potential of hydraulically induced fractures to communicate with existing wellbores*, Journal of Water Resources Research, Volume 51 (Issue 10), October 2015, Pages 8303–8315 DOI: 10.1002/2014WR016771.

Draft summary of preliminary draft key points

A Panel member provided a draft summary of preliminary draft key points that they heard during the Panel's discussion in response to Charge Question 4. The Panel member stated the following preliminary draft key points:

- The EPA should prioritize the most important issues so that the assessment does not overstate how significant a problem may be, note which problems could possibly happen

but were not first order problems, and distinguish what is likely to be a problem and what is not a problem.

- Improve the discussion on magnitude and severity to include site-specific statistical data.
- Describe temporal information and variation, and how HF technology has changed over time.
- Clarify the discussion and include more pictures and graphs to make the text more understandable to the public. Provide clear discussion and pictures on how HF wells really fail, revise the confusing terminology discussions, and correct acronyms. Distinguish between produced water, HF waters, and other waters.
- Improve discussion on HF flowpaths, flow and fluid properties, and distinguish natural fractures from induced fractures.
- Note that models were interpretive, and should be ground-truthed to help interpret the modeling descriptions.
- Update the draft assessment to acknowledge the significant changes that have happened in the HF industry since 2012.
- Improve the cementing discussion to: note how cement is set (including how casings were installed and how cements were placed around casing); further discuss how cement integrity is determined including how cement is pressure tested and bond logs were used and other logs used to assess cement; and discuss new cementing technology. Describe how the Bainbridge Ohio example had cementing problems.
- Revise Figure 6-1 since it shows an un-cemented zone that does not occur in industry. Change Figure 6-5 and other text descriptions to more accurately describe geology and fractures.
- Improve the discussion on HF pressure changes, and use the Stim-plan fracture propagation model to show stress contrast.
- Describe principles and note possible failure points for well construction and design.
- Elaborate on Bainbridge Ohio case study.
- Adjust the discussion on sustained casing pressure which does not occur during HF.
- Adjust case study discussions to provide relevant information on when, why, and how widespread issues occur and have been mitigated.
- Improve discussion on migration of fractures and the available data associated with such fractures.
- Discuss aging wells and what available literature exists on such wells. Note that casings may have a 25 year lifetime, and discuss whether there is data on this before/after drilling, whether such casings were a problem, and how to test these casings.
- Note that HF does not increase permeability.
- Discuss how stray gas migrates throughout the formation, clarify discussion on stray vs. induced gas migration, and discuss how gas can migrate up cement.
- Provide information on stress contrast.
- Discuss how well data was used to assess impacts or describe how wells were constructed.
- Note that the public should have improved access to databases.
- Clarify that the EPA did not consider overpressure of HF systems that occurred for more than 2 years, and the importance of including discontinuities in such assessment.
- Provide information on fracture zone dimensions.
- Discuss how unrecovered water is or is not reused.
- Improve the Summary and Conclusions section, e.g., the last concluding sentence is contradictory.

- Discuss the importance of HF-induced seismicity due to injection of fluids, and note the increased seismicity in Oklahoma, Texas and Ohio since 2009 which should be reevaluated by states.
- Note that some states like Colorado have instituted requirements for testing of water supplies before/after drilling on a monthly/yearly basis, and that the Colorado model may be useful to be applied elsewhere.
- Describe best management practices for a scenario where releases dropped from 52% reduced to 20% in Pennsylvania, and discuss what efforts were needed to reduce such releases to zero.
- Clarify where HF violations have occurred and the magnitude of these violations.
- Distinguish between natural gas leaks and induced gas leaks. Consider the Illinois case study on methane. Clarify how natural seeps are distinguished from gas mobilized in HF activities. Note that there are many new HF wells being drilled in northern Pennsylvania and that many methane gas problems have occurred in this area. Note that the data associated with methane in this area was difficult to gather, should not be private and should be more available to the public.
- Discuss how Class 1 hazardous waste injection wells may provide useful insight into how HF wells could potentially impact drinking water resources.
- Reconsider conclusions on page 6-56.

Dr. Dzombak noted that it would be challenging to distill these preliminary draft key points into the most important preliminary draft key points, and to arrange preliminary draft key points around key themes. He noted that there was an interest in making this chapter more accessible to the general public, and that the Panel should consider whether additional technical information recommended by the Panel should be included in an appendix to the EPA draft Assessment Report. He stated that there were a number of comments on case studies, noted that these studies were important, and stated that the Assessment should examine the strengths and weaknesses of case studies and note which studies did or did not run modeling scenarios. Regarding modeling, Dr. Dzombak noted that the Progress Report described modeling scenarios, noted that the modeling efforts could be extracted from EPA publications developed in relation to the Assessment and focused on more clearly in the Assessment Report. Further, he stated that the modeling discussions could be improved through consideration of additional EPA modeling work that is underway and would soon be completed.

Dr. Dzombak also suggested that the Panel be as specific and direct as possible on how conclusions are or are not well supported. He commented that the SAB previously, in reviews of the Scoping Document and Study Plan, strongly endorsed the HF water cycle framework that the EPA followed for the Assessment. He commented that the link between wastewater injection and induced seismicity was a significant issue to the public, and noted that while the EPA may not have resources to do another study, a large amount of work has been developed and published on this topic. Dr. Dzombak also noted that the chapter should strengthen the discussion on the role of geology in how potential impacts from HF occur, and noted that figures should be improved to show the complexity of geology. He noted that the public's interest in certain topics can help guide the Panel.

A Panel member also noted that the Panel should recommend that the EPA consider how proximity to HF wells may affect impacts to drinking water supplies (e.g., what would be likely to occur if a supply was a half mile vs. ten miles away from a HF well).

A Panel member noted that this chapter was very long, and perhaps the induced seismicity discussion could be moved to the discussion in Chapter 7 on flowback and produced water.

One Panel member noted that since induced seismicity may have potential impacts in groundwater, it may not be appropriate to include its discussion in Chapter 7. Another Panel member noted that since induced seismicity could potentially increase the number of faults in the geology, the discussion that would be added on this topic should describe how such faults may be caused by induced seismicity and whether reactivation of HF wells causes seismic events to happen.

A few Panel members suggested that the states of Pennsylvania, Ohio, Texas, North Dakota, California, and Wyoming would be good states to examine to assess changes in HF-related regulations over time. A Panel member noted that changes in regulations should be described as an evolution, since some states may have regressed in its requirements on HF activity. Another Panel member also recommended that the EPA include the three case studies in Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas.

A Panel member suggested that the EPA should discuss what the probability would be for gas migration to occur from a casing failure rather than from HF itself (e.g., high or low probability). The Panel member also stated that the EPA should conduct an industrial process failure analysis on full casing cementing. Dr. Dzombak and another Panel member noted that the Panel should consider which parts of the HF water cycle warranted an industrial process failure analysis. One Panel member noted that he would submit photographs as additional preliminary comments that the EPA could consider for the assessment.

Dr. Dzombak stated that any member of the public who would like to make clarifying comments near the end of the October 29, 2015 Panel meeting should let DFO Edward Hanlon know by noon on October 29. The Designated Federal Officer recessed the meeting at 5:45 pm ET.

October 29, 2015

At 8:30 a.m., Designated Federal Officer Ed Hanlon opened the meeting and turned the meeting over to Dr. Dzombak.

Dr. Dzombak welcomed everyone. He noted that in Dr. Frithsen's remarks on October 28, he stated that to conduct the assessment, the EPA necessarily had to take a snapshot of HF operations for a certain time period for which data were available. Dr. Dzombak noted that Dr. Frithsen recognized that this was a fundamental limitation of the process in generating such an assessment, and that the HF industry was continuously evolving. Dr. Dzombak noted that Panel members should be as specific as possible regarding any suggestions on new practices or new data, since a general reference to such information was not actionable by the EPA. For example, Dr. Dzombak noted that Panel members should specify which states may have useful regulations or data for the EPA to consider.

Dr. Dzombak continued discussion on Charge Question 4. After the remaining discussion on Charge Question 4 occurred, Dr. Dzombak asked if Panel members had any additional comments on Charge Question 4. Hearing none, Dr. Dzombak began discussion on Charge Question 5.

Charge Question 5, regarding flowback and produced water - the return of injected fluid and water produced from the formation to the surface and the subsequent transport for reuse, treatment, or disposal

Dr. Dzombak read the entire charge question, and noted the charge question related to Chapter 7 of the EPA's draft Assessment Report. Dr. Steve Bohlen joined this portion of the meeting via teleconference.

Comments on the composition, volume, and management of flowback and produced waters

The Panel had various comments on the draft Assessment Report's description of the composition, volume, and management of flowback and produced waters. Several Panel members noted that the chapter was well written, clear, and encyclopedic. A Panel member commented that while the chapter was well written in general, the chapter could add some focus on helping the general public understand water quality data collected from wells, what other pre-existing sources of contamination may be causing problems in homeowner water supplies, and regulations that apply to HF wells. A Panel member stated that the draft Assessment Report included one paragraph that compared conventional and unconventional drilling, and noted that the draft Assessment Report should include more information on the volumes of HF waters used under each type of drilling method, and for production wells. The Panel member noted that Natural Resources Defense Council reports includes findings in boxes, which is helpful in clearly identifying findings.

A Panel member noted that the chapter provided a good description of the challenge in identifying contaminants in water without knowing what contaminants to search for, and that in particular organics were difficult to identify in part due to the high salt background in HF waters. Another Panel member commented that this chapter covered complex topics that described how over 1000 chemicals are used in HF, some of which are naturally occurring, and how some of these chemicals find their way into the environment depending on hydrogeology. A Panel member also noted that the composition of fluid being injected into HF wells is generally similar, noting that 90-95% of HF mixtures by weight are water. The Panel member noted that different formations being hydraulically fractured have different chemistry to consider, and that during drilling each HF well is custom-fit to the formation for that particular HF drilling method. The Panel member noted that HF operators do not introduce fluids that react, pressure and temperature differences occur depending on the formations being fractured, and that stress changes occur during HF.

Several Panel members discussed the distinction between flowback and produced water, noted the draft Assessment Report distinguished these waters well, and noted that flowback water was injected and produced during a relatively short period of time. Other Panel members recommended that the EPA clarify the importance for distinguishing between flowback and produced water and the different chemistries of these waters, and note whether these waters are fundamentally different, have higher or lower salinity content, and/or are produced/used through different operations resulting in different leak rates. A Panel member noted that operators have rules of thumb on distinguishing between these two fluids. Several Panel members noted the chapter only briefly described and should better describe the context associated with whether certain contaminants in flowback water (such as benzene and hydrocarbons) were in the initial flowback water or whether these contaminants entered the flowback water from the formation into which the flowback water was injected. Another Panel member noted that changes of HF

fluid chemistry over time was important to differentiate HF fluids from oil and gas operations, and in assessing different exposures and risks associated with such fluids. Dr. Dzombak noted that earlier SAB Panels who reviewed the Scoping Document and Study Plan suggested that the EPA consider referring to these waters as post-fracturing waters and not try to differentiate them.

A Panel member commented that the EPA should add to the discussion on leaks from HF surface impoundments, and note the causes of such leaks. The Panel member commented that the draft Assessment Report noted that 94% of HF spills were caused by container integrity, but that the Report did not and should have described why containers failed. The Panel member noted that the EPA's analysis on how truck crashes caused spills had questionable results that downplayed effects from such spills, and should be revised. A Panel member noted that recent spills in WV from an industrial site and at the Animus River in Colorado from a mining site significantly affected river waters and downstream drinking water facilities.

A Panel member noted that a statement in Section 7.7.3.2 that attributed well flange damage to flowback should be strengthened or revised, since it was not clear this damage was due to flowback. The Panel member noted that the EPA should clarify the draft Report's description of leaks through surface pipes, and noted that such leaks were a common occurrence in oil fields, that it is expected that leaks in older facilities would be more prevalent than in newer facilities, and that the EPA should clarify whether it is differentiating leak rates between HF and conventional oil drilling.

Comments on major findings

The Panel had various comments on the draft Assessment Report's major findings for this part of the HF water cycle. A Panel member noted that the findings and conclusions of the issues described in the chapter should be strengthened, improved, clarified, and prioritized. The Panel member noted that the EPA's draft Assessment Report provided only one-half page of summary points and conclusions, and stated that an encyclopedic description of activities in this chapter did not identify the most important issues of concern. Several Panel members noted that more data were needed before any broad conclusions could be made on potential impacts due to spills, and noted that the EPA should temper its conclusions on the lack of impact because the EPA only searched for certain chemicals.

A Panel member noted that the chapter's conclusions should be revised and rewritten to include the important findings noted within the chapter (e.g., that spills regularly occurred, and potentially occur at most HF sites), and how to mitigate such spills (e.g., through use of BMPs). The Panel member noted that the EPA should not conclude that the same species at the same concentrations of produced water and flowback water are involved when both injecting fluids into HF wells and pulling water out of HF wells. Another Panel member commented that the draft Assessment Report should include additional discussion regarding the relative frequency of impacts within the summary of findings for this chapter of the draft Assessment Report. A Panel member also noted that while the draft Assessment Report concluded that spills were cleaned up quickly with no impact, the body of the chapter should provide more information and clarification to support this conclusion.

Comments on the frequency or severity of impacts

The Panel had various comments on the draft Assessment Report's description of the frequency or severity of impacts associated with this part of the HF water cycle. A Panel member noted that

the EPA should identify the most important issues regarding potential impacts of produced water and flowback water on drinking water resources. A Panel member suggested that the EPA conduct a statistical comparison on the volumes of flowback vs. produced water, and frequency and severity of releases and spills from flowback vs. produced water. Another Panel member noted the draft Assessment Report should provide more information on the severity, probability of occurrence, and degree of risk associated with the effects of produced water on drinking water resources. The Panel member also noted that treatment can change the severity of contaminants (e.g., treated reuse waters have higher TDS).

A Panel member noted that the chapter should better assess what are temporary vs. longer-term impacts from HF spills. Another Panel member also noted that while the draft Assessment Report stated that the likelihood of potential impacts from HF spills relates to the distance from the HF well to receptors, spills on ridges in Pennsylvania can move along a joint and can move quite a far distance from a HF well. The Panel member noted that the draft Assessment Report should describe and prioritize how potential impacts occur from sustained or large volume spills and spills of very toxic and persistent chemicals. A Panel member recommended that the EPA improve its discussion on potential impacts of HF spills on downstream drinking water supplies. The Panel member noted that the EPA should describe various social impacts associated with HF spills and releases of HF fluids, including how a community should respond once such spills occurred.

Comments on uncertainties, assumptions, and limitations

The Panel had a few comments on the draft Assessment Report's description of uncertainties, assumptions, and limitations associated with this part of the HF water cycle. The Panel member noted that Section 7.8.3 of the draft Assessment Report did not include all uncertainties that should be described. A Panel member also noted that the EPA could not estimate toxicities through EPI-Suite for many HF compounds, and that the estimates that were provided were mostly for chemicals that were not highly mobile.

Comments on additional information, background, or context that should be added, research gaps, or relevant literature or data sources

The Panel had various comments on additional information, background, or context that should be added, and on research gaps or relevant literature or data sources that should be considered, within the draft Assessment Report's description of this part of the HF water cycle. Several Panel members stated that the EPA did not but should consider and discuss various HF-related activities or scenarios in this chapter of the draft Report, or that the EPA should better describe various analyses that it did conduct, regarding:

- New information through a statistical analysis of data regarding HF-related spills and on produced and flowback water, since there is continuous improvement in HF-related data.
- Information on how industry and the regulators respond to spills and makes sure spills are temporary and limited in impact.
- Information on the volumes of HF waters used under each type of drilling method, and for production wells.
- Whether injected HF fluids could naturally come to the surface, since, for example, subsurface brine naturally comes to the surface in some places in Pennsylvania.
- Why or why not indicator organic compounds were considered, and how some publications described how to assess the presence of suites of compounds rather than

specific compounds. A Panel member noted that the State of Wyoming enacted guidelines on indicator HF parameters such as bromide, with action levels.

- How flowback or produced waters contain a large amount of salt that has a distinct signature that is easy to measure.
- Information on spills and leaks in a diagram.
- Radionuclides and polymers in HF waters, and include such information in Table 7-4.
- Radioactivity in brine solids associated with drilling and drill cuttings, since the Marcellus shale is radioactive and these cuttings/materials are often sent to landfills.
- BMPs associated with managing HF flowback and produced water and for installation and use of horizontal HF wells, including state by state uses of lined pits, elimination of pits, and use of catchment areas. A Panel member noted that it was unclear whether there was a BMP for the installation and use of horizontal HF wells. Another Panel member commented that the EPA's draft Assessment Report could present specific HF requirements or BMPs since most states did not have such requirements or BMPs.
- Rules of thumb on chemical mobility to help focus discussion on mobility of HF contaminants associated with HF flowback and produced water (e.g., mobility of chemicals decreases as solubility increases; mobility increases as temperature increases).
- Statistical difference between the number of fractures associated with fractured and unfractured wells, and releases associated with such wells.
- Information on how mobility changes due to subsurface reactions within the EPA's subsurface contaminant analysis on mobility and chemistry.
- How HF fluids would interact with surface waters.
- Modeling predictions for spills across the HF water cycle and assess impacts to drinking water sources in different rainfall areas. A Panel member noted that the EPA's HF Research Study Plan noted that the EPA would make such modeling predictions, and stated that the EPA did not conduct nor report on these analyses in the draft Assessment Report.
- Relate chemicals listed in Table 7-4 to regulatory levels such as Maximum Contaminant Levels (MCLs) or Maximum Contaminant Level Goals (MCLGs), and discuss whether the chemicals are on the EPA's Contaminant Candidate List (CCL) of drinking water contaminants that are known or anticipated to occur in public water systems and are not currently subject to the EPA drinking water regulations.
- Improve and add to the chloride, bromide and iodide data in Appendix E of the draft Assessment Report, because chloride, bromide and iodide can form disinfection byproducts and such data could also be used to fingerprint HF operations if there are potential impacts downstream.
- How chemical mass impacted drinking water resources (while recognizing that the draft Assessment Report presented volumes of HF chemicals).
- Dissolved organic carbon (DOC), since DOC was commonly used in drinking water plants.
- Measure color in HF waters, since color was a common issue in water treatment and involved inexpensive measurements (e.g., see the EPA's advanced coagulation regulation).
- The importance of baseline monitoring.

Draft summary of preliminary draft key points

A Panel member and Dr. Dzombak provided a draft summary of preliminary draft key points that they heard during the Panel's discussion in response to charge question 5. They noted the

following with regard to the draft Assessment Report's Chapter 7:

- The chapter was generally well done.
- The chapter should identify which types of spills are more important than others.
- The EPA should include more diagrams in the chapter.
- Various data needs were identified.
- Radionuclides were not adequately described in this chapter.
- The EPA should describe why it is important to distinguish between HF flowback and produced water and waters produced by conventional vs. unconventional wells.
- The EPA should clarify and provide more context regarding whether leaks caused impacts.
- The EPA should explain how information on pre-existing conditions affected conclusions on potential impacts of HF flowback and produced water.
- The EPA should include MCLs and other information in Table 7-4.
- The EPA should discuss what states, industry and others are doing to control spills, including a discussion on BMPs.
- The EPA should improve the discussion on how HF fluids have impacted surface water supplies and treatment plants, and formed disinfection byproducts.
- The EPA should discuss social impacts and how treatment facilities are managing releases from HF spills.
- The EPA presented concentration volumes and should provide information on mass of contamination.
- The EPA should describe how difficult it is to search for HF contaminants if the compounds to search for are not known.
- The EPA could present information on pollution prevention of HF spills rather than on controls for leaks.
- The EPA should consider describing how spills have been addressed and what entities could do to manage spills.

A Panel member noted that the chapter and SAB Panel members have described situations where HF-related spills regularly occurred, and stated that that discussion was counter to the EPA's statements that there was no evidence of systemic impacts. Dr. Dzombak noted that the EPA should describe additional ways to monitor produced waters. A Panel member asked whether there are reporting requirements for spills, and suggested that the EPA focus on developing a realistic worst case understanding of HF-related spills. The Panel member also noted that the appendices of the draft Assessment Report provide data from different states that described the magnitude and frequency of spills differently, and that such information was important to consider when assessing relative toxicities associated with such spills. Dr. Dzombak noted that a risk assessment would require site-specific information, and that it was a challenge to describe risks associated with HF fluids. He noted there are many examples of impacts that occur from small chemical leaks and releases that occur over long period of time (e.g., the WV leak that was previously mentioned). Dr. Dzombak noted that case studies are very important and it would be helpful if case study scenarios were developed to provide information for the toxicologists to consider regarding relative risks.

A Panel member suggested that the EPA describe how to properly conduct groundwater monitoring using wells, in consideration of deep vs. shallow wells, site-specific geological aspects, artesian aspects of wells, and other factors. Dr. Dzombak noted that there was a fair amount of research in the past decade on monitoring geologic storage of carbon, with consideration of monitoring pressures in overlying formations and geophysical approaches, and

that the EPA could learn from the research and development on geologic storage of carbon in developing approaches for HF monitoring.

Dr. Dzombak asked if Panel members had any additional comments on Charge Question 5. Hearing none, Dr. Dzombak began discussion on Charge Question 6.

Charge Question 6, regarding wastewater treatment and disposal - the reuse, treatment and release, or disposal of wastewater generated at the well pad

Dr. Dzombak summarized the charge question, and noted the charge question related to Chapter 8 of the EPA's draft Assessment Report.

Comments on summarized information regarding hydraulic fracturing wastewater management, treatment, and disposal

The Panel had various comments on the draft Assessment Report's summary of hydraulic fracturing wastewater management, treatment, and disposal. A Panel member stated that the EPA provided a good description and informative tables on unit processes involved for treatment and disposal of HF wastewater.

A Panel member also stated that the EPA should describe how seismic activity affected how HF wastewater disposal occurred. Dr. Dzombak noted that regarding induced seismicity, the Panel should consider how induced seismicity links to water quality. Another Panel member noted that reports have indicated that induced seismicity has caused injection and monitoring well damage which would affect water quality assessment. The Panel member noted that if HF wastewater was restricted from being injected in wells, it was unclear where the HF wastewater would be disposed, and the draft Assessment Report should consider this.

A Panel member noted that while the title of the chapter referred to HF wastewater treatment and waste disposal, the draft Assessment Report should clarify whether the waste disposal that was discussed was restricted to wastewater treatment solids or also included HF well drill cuttings.

A Panel member noted that the EPA should clarify the chapter's discussion on example unit treatment processes (e.g., the dialysis and reverse osmosis discussions). The Panel member suggested that the EPA clarify in the EPA's draft Assessment Report what volumes in terms of gallons/wastewater daily were generated from HF operations, and that any such estimates (e.g., Figure 8-2) should include a discussion on the accuracy range of these estimates. The Panel member also suggested that the EPA clarify the estimated concentrations/mass of chemicals in the HF wastewaters, including information on Trihalomethanes (THMs) and haloacetic acids (HAAs), and the treatment capabilities associated with the prevalent chemicals in HF wastewaters. The Panel member stated that the EPA should describe how HF wastewater treatment differed from normal wastewater treatment at POTWs, including whether there are any temporal differences in such treatment operations (e.g., whether HF treatment occurred in batches, for say a week, and then stopped).

A Panel member noted that approximately 50% of drinking water facilities that used surface waters for water supplies have at least one wastewater treatment facility upstream of the drinking water plant.

Comments on the frequency or severity of impacts

The Panel had a few comments on the draft Assessment Report's description of the frequency or severity of impacts associated with this part of the HF water cycle. A Panel member stated that the EPA should describe who regulates centralized waste water treatment facilities (CWTs) for HF wastewaters, and suggested that Publicly Owned Treatment Works (POTWs) should consider changing their requirements if they are experiencing impacts from discharges from HF CWTs. The Panel member noted there is high uncertainty associated with whether drinking water plants are impacted by HF CWTs, and recommended that to help assess such impacts, the EPA should include or considering developing county maps that note water intake locations and locations of domestic wells in the counties relative to HF locations. Dr. Dzombak noted that in Pennsylvania, most HF CWTs are in rural areas and did not discharge to POTWs, and thus the CWTs probably operated under individual discharge permits.

Comments on uncertainties, assumptions, and limitations

The Panel had a few comments on the draft Assessment Report's description of uncertainties, assumptions, and limitations associated with this part of the HF water cycle. A Panel member stated that while the EPA provided a good description and informative tables on unit processes involved for treatment and disposal of HF wastewater, more information could have been provided on limitations. A Panel member noted that the modeling results that were presented in the chapter should describe the assumptions, sensitivity and uncertainty associated with the model, and stated that a better description was needed on modeling the dilution of high concentration bromide and TDS waters to reduce concentrations to background.

Comments on additional information, background, or context that should be added, research gaps, or relevant literature or data sources

The Panel had various comments on additional information, background, or context that should be added, and on research gaps or relevant literature or data sources that should be considered, within the draft Assessment Report's description of this part of the HF water cycle. Several Panel members stated that the EPA did not but should consider and discuss various HF-related activities or scenarios in this chapter of the draft Report, or that the EPA should better describe various analyses that it did conduct, regarding:

- The varying amounts of HF wastewater generated state to state.
- Effectiveness of treatment of detected HF contamination entering wastewater treatment facilities.
- Organic characteristics of HF flowback water, since this information was still largely unknown and more information on these chemicals was needed to determine if the available treatment processes were removing these pollutants before reuse or discharge.
- Modeling the dilution of high concentration bromide and TDS waters to reduce concentrations to background.
- How seismic activity affects how HF wastewater disposal is conducted.
- How HF drill cuttings and mud are being disposed, and how much radiation is in this waste.
- Predictions and estimates on HF wastewater, and validations of those predictions.
- Costs and cost curves regarding the use of various technologies for treating HF wastewaters.

- How radionuclides in HF would be land applied and how such land disposal could result in radionuclides re-entering watersheds (since HF wastewater treatment may generate solid residuals).
- Risks associated with treating HF wastewaters and then using that treated water for drinking water. A Panel member noted that wastewater in Houston and Texas El-Paso is treated at a municipal wastewater plant and converted into drinking water.
- State requirements that prevent water softening, and how these requirements relate to HF wastewaters. A few Panel members noted that the State of California prevents water softening and that HF wastewaters have high TDS.
- Focus the chapter's disinfection by-products discussion on by-products from certain disinfectants (ozone and chlorine), since these are the prevalent disinfectants. A Panel member noted that for example, 40-50 % of U.S. drinking water treatment systems use chloramines, especially in Texas, and that amines can react with chloramines to form other chemicals.
- Identify which HF wastewaters are of highest risk, and which treatment operations of HF wastewaters pose the largest risk to water quality.
- Effects associated with stopping HF in certain locations or discontinuing deep well injection of HF wastewaters.

A Panel member noted that a number of journal articles were recently published on how injection water was being reused, and that new technologies could treat the higher TDS contamination coming from HF operations.

Draft summary of preliminary draft key points

A Panel member and Dr. Dzombak provided a draft summary of preliminary draft key points that they heard during the Panel's discussion in response to Charge Question 6. They noted the following with regard to the draft Assessment Report's Chapter 8:

- The chapter should describe uncertainties associated with treatment of HF wastewaters, and the chapter could address this deficiency through scenario analysis on how many POTWs could be impacted from HF wastewater releases.
- The chapter should describe how to address seismic effects directly, whether HF monitoring or injection wells were closed down due to seismic activities, and how HF wastewaters would be managed if disposal wells are closed down.
- The chapter should describe how drilling waste materials are disposed, and if such wastes are disposed in landfills, describe impacts associated with such disposal.
- The chapter generally discussed some technologies but did not discuss multiphase treatment.
- The chapter should provide estimates on the volume and composition of HF wastewaters, including a description of what data are available on metals and disinfection byproducts associated with HF wastewater.
- The chapter should describe how HF CWTs operate differently around the country, whether reused water is discharged to rivers or POTWs, whether CWTs use equalized or pulsed treatment operations, and which HF wastewater treatment options present the highest risk.
- The EPA should include a discussion on how different states manage and regulate HF wastewaters, and consider whether to conduct a national survey to gather this information.
- The chapter should discuss how CWTs for HF wastewaters are permitted and regulated in

different states, including pretreatment requirements for such wastewaters.

- The chapter should discuss whether the regulations provide descriptions of best available developed technologies for treating HF wastewaters.
- The chapter should discuss the presence and amount of radioactivity in HF wastewaters and in wastewater residuals.

A Panel member suggested it would be helpful to describe which wastewater treatment plants consider or tested for indicator compounds associated with HF operations, and noted that bromide may be good tracer/indicator chemical.

Dr. Dzombak asked if Panel members had any additional comments on Charge Question 6. Hearing none, Dr. Dzombak began discussion on Charge Question 7.

Charge Question 7, regarding chemicals used in hydraulic fracturing or present in flowback and produced waters known physicochemical and toxicological properties

Dr. Dzombak read the entire charge question, and noted the charge question related to Chapter 9 of the EPA's draft Assessment Report.

Comments on the characterization of available chemical and toxicological information concerning chemicals used in hydraulic fracturing

The Panel had various comments on the draft Assessment Report's characterization of the available chemical and toxicological information concerning chemicals used in hydraulic fracturing.

A Panel member stated it was difficult to understand which HF chemicals were of most concern, what types of exposures to HF chemicals existed, and whether there were chronic or acute toxicities associated with such exposures, in order to assess potential risks associated with the HF chemicals. The Panel member noted concerns that the EPA considered physical/chemical information on chemicals used during HF operations, and used narrow criteria for determining which HF chemicals could be assessed under formal risk assessment. The Panel member noted that formal risk assessment could occur if oral reference dose (RfD) information was available, but that EPA applied such narrow criteria that only 147 of 1200 chemicals used during HF operations survived the EPA's criteria analysis. Several Panel members noted that the EPA could consider whether a chemical had MCLs, ATSDR Minimal Risk Levels (MRLs), available information on the State of California's toxicity databases, RfD information from Toxicology Excellence for Risk Assessment (TERA), the REACH chemical database that has test data for a large spectrum of chemicals, or toxicity information available on other toxicity databases. The Panel member also noted that subchronic toxicity studies conducted according to guidelines could have been used to obtain RfDs, and that information may be available on short term or subchronic HF-related exposures. The Panel member stated that while a full risk assessment on these HF chemicals would be time consuming, there was a large amount of available information on these HF chemicals that could be accessed for such an assessment. The Panel member noted that due to proprietary information, there was limited information available on chemical exposure levels in produced flowback water. The Panel member stated that the EPA described what additional information was needed, and noted that the EPA could do a worst-case analysis to assess whether there would be adverse health effects. The Panel member recommended that the EPA conduct these analyses in the draft Assessment Report, identify short or long term exposure to these HF chemicals, and describe what levels of concern existed related to exposure

to HF chemicals. Another Panel member suggested that toxicity information on HF chemicals would be useful to municipalities and other members of the public, and that the EPA should provide guidance on how to acceptably assess toxicity of HF chemicals. A Panel member suggested that the EPA could conduct a tiered approach towards assessing toxicity of HF chemicals.

Several Panel members noted that while the EPA listed 1076 chemicals used during HF operations, the EPA stated it had data on only 10% of these chemicals, and the EPA only fully assessed 37 chemicals (i.e., 3.5 %). The Panel member recommended that the EPA should note threshold toxicity values for any detected HF chemicals. The Panel member commented that compounds with no toxicity data listed in the EPA's draft Assessment Report often have known information in the EPA's and other databases, including dated hazard databases and the Food and Drug Administration's (FDA) databases. The Panel member also noted that some companies drew graphs of physical properties of HF chemicals.

A few Panel members expressed concern that for HF chemicals with highly uncertain information the actual safe level may be lower than suggested by that uncertain information, and suggested that the EPA should use safety factors or a point of departure for these chemicals. A Panel member commented that before setting a point of departure it would be helpful to review the uncertainty data for those chemicals. The Panel member also noted that in a European HF database, data were provided on 87% of the HF chemicals listed, and stated it was unclear why the EPA's HF database was so different than this European HF database. A Panel member recommended that the EPA review uncertainty data before setting a point of departure for chemicals.

A Panel member commented that the EPA should consider and describe toxicities and health effects of radiological HF chemicals including Naturally Occurring Radioactive Materials (NORM) generated during HF operations. The Panel member also stated that the EPA should consider and describe toxicities and health effects of degradation products from HF chemicals, and noted that sometimes a compound breaks down and can be more toxic than the original compound. The Panel member also recommended that this chapter should discuss potential endocrine disruption associated with HF chemicals, and noted that a separate discussion should be added on the toxicity of phenol ethoxylate surfactants used in HF and how this class of chemicals affect hormone function.

A Panel member noted that the EPA correctly tried to consider more than toxicity of a chemical to assess potential risks associated with HF chemicals, and that it was helpful that the EPA tried to consider exposure to those chemicals.

Comments on the identification and description of constituents of concern that potentially impact drinking water resources

The Panel had various comments on the draft Assessment Report's identification and description of the constituents of concern that potentially impact drinking water resources. Several Panel members noted that the EPA relied on data from FracFocus 1.0, and a Panel member noted that the EPA did a good job in identifying HF chemicals. The Panel member noted that FracFocus data was a good source and provided the most useful chemical data available at present on HF operations. The Panel member recommended that the EPA should discuss whether less toxic chemicals are coming into use over time. Several Panel members expressed concerns regarding the EPA's use of FracFocus for identifying HF chemicals, and noted that FracFocus is a non-peer

reviewed database assembled by non-chemists and that reliance on data that was not peer reviewed was of concern and potentially unacceptable. A Panel member noted that, for example, FracFocus information on polyethylene glycol had 12 chemicals listed and some of these listings did not use the Chemical Abstracts Service (CAS) number associated with the chemical. A Panel member noted that FracFocus sometimes lists HF chemicals at very low concentrations. A Panel member suggested that the EPA describe the deficiencies of the use of FracFocus in describing and identifying HF chemicals. The Panel member also recommended that the EPA assess how HF compounds have changed and/or become more protective over time. A Panel member stated that while there were problems with FracFocus data, before 2011 such data were not available in a database.

Several Panel members also noted that it was difficult to form conclusions on a large number of HF chemicals since information on 25 to 30% of HF chemicals was not available. Many of these chemicals are protected from release as Confidential Business Information (CBI), and industries who used these HF chemicals did not want to disclose their trade secrets. The Panel members expressed concern regarding CBI HF data as to whether these chemicals are truly novel, and recommended that the EPA disclose information that is known about HF CBI chemicals in an aggregated manner. Several Panel members stated that the EPA should better characterize what information is known regarding CBI chemicals, and commented that FracFocus 3 may have information on general chemistry classes of CBI chemicals. A Panel member stated that the EPA should describe whether CBI HF chemicals are being injected into or released to the ground or are being spilled. A Panel member suggested that the EPA describe in the draft Assessment Report the current requirements for disclosure of CBI chemicals if there is a HF spill, since there may be requirements for disclosure of spilled chemicals. Another Panel member noted that the extent of completeness of the EPA's information on HF compounds was not known, and that there are too many gaps in this information at this point.

A Panel member observed that state-by-state regulations for disclosure of HF ingredients varied, and that while some states sought disclosure of such ingredients, other states criminalized disclosure of such ingredients. A few Panel members noted that the EPA could assess many of the 1076 chemicals used during HF operations via techniques such as Quantitative Structural Activity Relationships (QSARs). A Panel member commented that while Section 9.3.4.1 of the draft Assessment Report discussed QSARs, the EPA's draft Assessment Report did not discuss whether the EPA conducted QSAR analyses on a number of HF compounds. The Panel member recommended that the EPA consider conducting QSAR analyses on HF CBI compounds, and compare those analyses to QSAR analyses on HF non-CBI to help assess properties of HF CBI chemicals.

A Panel member stated it was unclear what the EPA planned to do with its list of HF chemicals, and noted that if the EPA planned to consider these 'chemicals of concern', then the EPA and others are not but should be commonly monitoring these chemicals in groundwater.

Comments on the frequency or severity of impacts

The Panel had various comments on the draft Assessment Report's description of the frequency or severity of impacts associated with Chapter 9. A Panel member noted that while it was helpful that the EPA conducted multiple-criteria decision analysis (MCDA) on several HF compounds, the EPA did not fully and completely characterize the available toxicity information on HF chemicals, and that information on frequency, duration, and exposure occurrences (including whether spikes in exposure occurs) to the HF chemicals should be provided. The Panel member

stated that various exposures to HF chemicals could potentially be occurring, including oral, inhalation (including inhalation of methane and propane), dermal, and ingestion. The Panel member noted that members of the public may be exposed to HF in their drinking water supply while taking shower or a bath and while using drinking water for other purposes. The Panel member noted there could be chronic exposures to HF chemicals at a term shorter than lifetime, and that available data on sub-chronic studies should be considered by the EPA.

A Panel member recommended that the EPA synthesize available chemical information from earlier chapters of the draft Assessment Report within this chapter to help the reader understand the various exposures or potential exposures that are occurring (e.g., include information on the range of volumes of HF chemicals that were spilled). A Panel member commented that it would be helpful if the EPA carried forth two scenarios from earlier chapters that the EPA noted in the 2012 Progress Report it would do: assess potential exposures to released HF chemicals at a private drinking water well, and at a publically owned drinking water plant. The Panel member suggested that if the EPA assessed such scenarios this effort might assist in identifying which HF chemicals had potentially more significant impacts to drinking water resources. Dr. Dzombak noted that while the EPA did not set out to conduct an exposure or risk assessment within its draft Assessment Report, it would be appropriate if the EPA synthesized information that could be gathered from earlier chapters that were pertinent to exposure and risk assessment without actually conducting an exposure assessment.

Comments on uncertainties, assumptions, and limitations

The Panel had a few comments on the draft Assessment Report's description of uncertainties, assumptions, and limitations associated with Chapter 9. A Panel member suggested that the EPA identify which chemicals have any data and the level of uncertainty associated with that data. A Panel member noted that due to proprietary information, there was limited information available on chemical exposure levels in flowback and produced water.

Draft summary of preliminary draft key points

A Panel member and Dr. Dzombak provided a draft summary of preliminary draft key points that they heard during the Panel's discussion in response to charge question 7. They noted the following with regard to the draft Assessment Report's Chapter 9:

- The EPA should take this opportunity to use FracFocus information to characterize CBI HF chemicals (which may be similar to analyses that Europeans have conducted).
- FracFocus provides information on general chemistry, and the EPA should consider using QSAR analyses on HF chemicals (which may be similar to analyses that Europeans have conducted).
- The EPA did not characterize available toxicity information on HF chemicals and the EPA could conduct a tiered approach towards assessing toxicity of such chemicals rather than just focusing on use of chronic RfD information.
- The EPA should use threshold levels of concern, databases at the EPA and FDA, the REACH chemical database, and other databases to provide information on HF chemicals.
- The EPA's MCDA approach is conceptually a good approach since it takes into account hazard and exposure associated with HF chemicals. In its MCDA approach, the EPA should better synthesize information from earlier chapters of the draft Assessment Report on the types of exposures to HF chemicals that are occurring.
- The EPA should consider conducting a careful exposure assessment modeling exercise

- using private well and public surface water drinking water supplies.
- The EPA should identify what additional chronic and acute toxicity information is needed on HF chemicals.
 - The EPA should assess and publish information on endocrine disrupting HF chemicals.
 - The EPA should consider and describe toxicities and health effects of radiological HF chemicals including Naturally Occurring Radioactive Materials (NORM) generated during HF operations.
 - The EPA should synthesize available chemical information from earlier chapters of the draft Assessment Report within this chapter to help the reader understand the various exposures to HF chemicals that are or could potentially be occurring.
 - The EPA should better describe exposures to HF chemicals including methane and propane.
 - The EPA should consider comparing FracFocus 1 to FracFocus 3 data to assess what changes have occurred and whether changes towards greener chemistry in HF chemicals are occurring.
 - The EPA should identify what HF chemicals could potentially be substituted with greener chemicals.
 - The EPA should clarify what it planned to do with its list of HF chemicals (e.g., whether the list would be used to help guide groundwater monitoring efforts).
 - The EPA should also consider whether its MCDA approach could be applied to the list of HF chemicals, as a guide to states or local communities to help provide information on HF chemicals on a site-specific basis (e.g., identify which chemicals were more mobile).

Dr. Dzombak asked if Panel members had any additional comments on Charge Question 7. Hearing none, Dr. Dzombak began discussion Charge Question 8.

Charge Question 8, regarding integration and summary of major findings

Dr. Dzombak read the entire charge question, and noted the charge question related to the Executive Summary and Chapter 10 of the EPA's draft Assessment Report. Dr. Dzombak noted that while Chapter 10 was almost identical to the Executive Summary, Chapter 10 includes a short section on intended uses of the assessment.

Comments on the clarity and organization of the Executive Summary and Chapter 10

The Panel had various comments on the clarity and organization of the Executive Summary and Chapter 10 of the draft Assessment Report. A Panel member commented that the draft Assessment Report's Executive Summary would be the most widely read chapter in the entire assessment. The Panel member noted that the Executive Summary's outline was sufficient, and recommended that the EPA include in it more diagrams and graphs that are didactic and taken from the earlier chapters of the draft Assessment Report.

Several Panel members commented that Chapter 10 reiterated the summary sections of each chapter of the draft Assessment Report which was not necessary, and that Chapter 10 did not but should connect the chapters and synthesize and prioritize the uncertainties and potential outcomes of the assessment. A Panel member stated that the purpose of a synthesis chapter is to draw conclusions, draw inferences closely linked to supporting observations, and present new ideas. The Panel member commented that Chapter 10 did not serve this purpose and only summarized statements from earlier chapters. A Panel member noted that the EPA's draft

Assessment Report was a great springboard, that the EPA conducted a large amount of work to bring together various data on HF activities into this Report, and that the EPA's draft Assessment Report would benefit from a synthesis of this work.

Several Panel members noted that while Chapter 10 was written at the same level as the Executive Summary, the Executive Summary should be written at a broader level for a broader audience. A Panel member suggested that the EPA rewrite the Executive Summary so that the general public could understand conclusions of the assessment in fewer pages than in Chapter 10. Several Panel members recommended that the Panel provide advice for how the EPA should include within Chapter 10 recommendations for next steps, prioritized research needs, additional data that should be collected, future monitoring that should be conducted, and prioritized activities or actions that the EPA should focus on from this point forward. Another Panel member suggested that the Executive Summary should include diagrams and figures to add perspective.

Several Panel members suggested that additional background on HF (e.g., how long HF has been occurring, how long HF may be occurring), the EPA's mission, how and why the EPA began work on this assessment (including discussion on how the EPA developed a Study Plan and earlier reports related to its draft Assessment Report), and the SAB's role should be included in the Executive Summary or in Chapter 10. The Panel member commented that Dr. Frithsen's presentation on 10/28/15 provided useful information about context and objectives that were not in the draft Assessment Report and that could be added to the Executive Summary. The Panel member also noted that the importance of the assessment in educating the public and providing a framework for transformation of the HF industry should be discussed in the Executive Summary. A Panel member also suggested that the EPA recognize in the Executive Summary that there are HF-specific vs. gas and oil-specific outcomes, and describe why the EPA did not include prospective case studies within the assessment. Further, the Panel member recommended that the Executive Summary include a description of the process the EPA used to report data on safety and toxicity of HF chemicals. A Panel member commented that the new developments in hydraulic fracturing technology and the development of new resources that this technology enables could be described.

A Panel member commented that Chapter 10 should describe the differences between produced water and injected water, and how these differences have affected the assessment results. The Panel member also noted that well integrity issues associated with HF and injection/disposal wells should be brought out in Chapter 10. A Panel member noted that the Executive Summary should describe what mitigation practices and requirements (e.g., secondary containment) would change outcomes. A Panel member commented that the Chapter 10 discussion on relative scale should be defined (e.g., provide more information and numbers to support the chapter's statements that the number of impacts, spills or releases from HF activities is small in comparison to the number of HF wells). The Panel member stated that more information is needed regarding how often chronic releases from produced water occurs, and whether the trend for such releases is increasing or decreasing over time. The Panel member also noted that Chapter 10 should discuss the effectiveness of well construction in preventing releases, and include information on cases where well construction may have failed (e.g., in Bainbridge Ohio), and other information from the most influential cases that the EPA assessed (e.g., the Susquehanna River basin and other case studies). Another Panel member suggested that the EPA include discussion in Chapter 10 on whether or not there were impacts associated with the case studies that the EPA conducted.

A few Panel members recommended that the EPA include potential regulatory requirements associated with HF in Chapter 10. Dr. Dzombak commented that the Panel must be cautious in providing advice on future regulations. A Panel member recommended that the EPA synthesize current regulations and requirements applicable to HF, and also present best management practices (BMPs) associated with HF activities, in Chapter 10. Regarding BMPs, a Panel member noted that BMPs may not yet have demonstrated a particular outcome, and that some BMPs are not very protective.

Comments on major findings

The Panel had various comments on the draft Assessment Report's major findings for this part of the HF water cycle. A Panel member commented that there were major conclusions made in Chapter 10 that were not based on statements or information within earlier chapters of the draft Assessment Report and therefore these conclusions are misleading. Several Panel members commented that the findings described within earlier chapters of the draft Assessment Report affects conclusions raised in the Executive Summary and Chapter 10, and that the EPA included many caveat terms such as 'may', 'might' and 'could' in the findings within these earlier chapters. The Panel member recommended that the EPA improve its description of severity within these earlier chapters to eliminate these caveats. A Panel member noted that the EPA should not conclude something in Chapter 10 that was not based on specific statements earlier in the draft Assessment Report. A Panel member also recommended that the EPA be more specific and precise in describing above- and below-ground mechanisms, and below-ground migration of liquids and gases associated with HF, in the Executive Summary and Chapter 10. Dr. Dzombak requested that the Panel develop advice that was as specific as possible. Several Panel members suggested that the Executive Summary should modify the phrasing of findings taken from each chapter to clarify what are the high and low risk conclusions associated with those findings, and state and prioritize which HF activities are causing and may cause the greatest impact. A Panel member recommended that the Executive Summary should refer the reader to particular chapters or sections of the EPA's draft Assessment Report by including citations or references to where data or greater discussion is located on a topic, and have its own list of acronyms. A Panel member also suggested that the EPA should use the terms compounds and chemicals consistently and appropriately throughout the Executive Summary and throughout the draft Report.

Comments on major finding regarding water use and consumption

A Panel member expressed concern regarding the following statement within the Major Findings discussion on water acquisition, on page ES-9 of the Executive Summary: "High fracturing water use or consumption alone does not necessarily result in impacts to drinking water resources." The Panel member noted that this statement implies that to have an impact, HF activity must be the sole water use or consumption, and stated that the EPA should revise statements like this in the Executive Summary to reflect situations where HF may have influenced impacts that have occurred. The Panel member stated that the EPA should revise this statement to indicate the relationship between HF and drinking water resources, and refer to cases described in Chapter 4 that describe situations where HF may have influenced streams that ran dry and drinking water wells that ran out of water. The Panel member also noted that while the Executive Summaries of the EPA case studies for the Susquehanna River basin and upper Colorado River basin do not note where streams or wells went dry, these summaries describe how and to what degree any use of water affects other systems and how there is a balance between uses in a drinking water system. The Panel member stated that these study results are not reflected in the draft Assessment Report's Executive Summary.

Comments on major finding regarding widespread, systemic impacts of HF on drinking water resources

Many Panel members had concerns regarding the following statement within the Major Findings section on page ES-6 of the Executive Summary: “We did not find evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources in the United States.” Dr. Dzombak asked whether any Panel members supported this statement, and whether the statement was not supported by the body of the draft Assessment Report.

Several Panel members noted that while the EPA did qualify this statement in the next paragraph, this statement was very preliminary and very surprising, since several chapters of the draft Assessment Report noted that there are significant uncertainties associated with each part of the HF water cycle, that there are a small number of HF wells compared to incidence of spills, and that there are many possible or probable ways that HF could result in accidents or health effects. A Panel member noted that the EPA should explain the meaning of the phrase “did not find evidence,” and discuss whether it had methods in place to find evidence. The Panel member noted that while it was not clear whether this conclusion was accurate, the EPA could not state that something did not happen, not explain what was meant by the phrase, and not look for whether it happened or not. Another Panel member commented that there is high uncertainty regarding what the terms ‘widespread’ and ‘systemic’ mean. The Panel member commented that the EPA needed to support such a statement by conducting hypothesis testing using an appropriate sample size, and expressed concern that there is potentially insufficient, improperly designed, or no data to conduct such an analysis. Regarding the term ‘widespread,’ a Panel member suggested that the EPA acknowledge and discuss the local, severe HF-related well-head release and spill events that have occurred in relation to this statement.

A few Panel members commented that the EPA should define the scope of the statement regarding “no evidence of widespread, systemic impacts” and the particular systems to which it applies, e.g., does the statement apply to all drinking water in the nation? some water resources but not all? site-specific or local only? A Panel member noted that what happens in Texas may not be what occurs in Pennsylvania, and the EPA did not discuss the differences in geologic settings or how HF-engineered systems put into natural systems differ depending on the geographic locations. Another Panel member noted that public comments described HF impacts to private wells, and suggested that the EPA survey drinking water companies/operators throughout the nation to assess impacts/trends that they were experiencing related to HF. Dr. Dzombak commented that there are publications on impacts to the water treatment industry, and another Panel member suggested that a survey, if conducted, should focus on operators where HF is occurring. A Panel member noted that the EPA’s press release did not include the term ‘evidence’ with regard to the EPA not finding widespread, systemic impacts, and expressed concern that this colored the statement from the Executive Summary. Another Panel member stated that HF has problems like any other industrial process, scientists and engineers need to identify what the problems are, and society needs to define what is or is not tolerable. The Panel member recommended that the EPA include a range of estimates on the chances for HF problems within the draft Assessment Report.

A Panel member asked whether the statement was too biased. Another Panel member was unsure whether the statement was or was not supported by the body of the draft Assessment Report. The Panel member noted that it was unclear what the EPA’s basis was for making this statement, and that it was unclear whether the EPA had or did not have information on what the EPA considers

‘widespread.’ Another Panel member stated that the EPA reiterated this statement on page ES-23 of the Executive Summary, noted that the rest of that paragraph on page ES-23 noted types of impacts but did not provide information on frequency or severity of impacts, and suggested that the additional details provided on page ES-23 related to this statement could be restated in the text on page ES-6.

A Panel member stated that while the statement probably was true, it was incomplete in the way it was stated. The Panel member suggested that the EPA could add qualifiers to the sentence to note that while the assessment was hampered by an extreme lack of data, the EPA did not find evidence of such impacts. The Panel member also noted that instead of that revision, or in addition to that revision, the EPA could add to the sentence or statement wherever it appears in the draft Assessment Report by noting that HF has led to specific impacts to local drinking water resources. Another Panel member commented that it was not appropriate to make this statement in the draft Assessment Report and at the same time state that there was insufficient data to make that conclusion. The Panel member noted that perhaps the EPA could make this statement at a later time, but at present the EPA should not make this statement with such limited data.

A Panel member supported the statement, and noted that the draft Assessment Report did not provide sufficient information on where there has been an incident related to HF to cause impacts. The Panel member noted that members of the public who presented information during the 10/28/15 meeting were impacted, but that there was no evidence of systemic impacts. The Panel member noted the draft Assessment Report could be improved, and include discussion on how regulators and industry work together to look at oil and gas regulations and improve the HF process and HF industry. The Panel member stated that there were incidents and that the draft Assessment Report did a very good job in trying to compile a significant amount of information on systemic HF activities that were occurring. The Panel member noted that an important nuance was that this was not to say the process has not contributed to impacts to drinking water, but not in a widespread or systemic manner. Another Panel member agreed that the draft Assessment Report should include more information on high severity, low frequency incidences related to HF that have occurred (e.g., at Bainbridge Ohio).

Several Panel members noted that the draft Assessment Report discusses incidences related to the HF water cycle, or related directly to HF, and recommended that the draft Assessment Report clarify which scenario was at issue when discussing such incidences. A Panel member also suggested that the EPA focus on potential impacts associated with the HF water cycle and not on the actual act of fracturing. Another Panel member recommended that the Executive Summary clarify that most of the discussion in the draft Assessment Report focused on the HF water cycle and not on the actual act of fracturing.

A Panel member stated that as it stands, the draft Assessment Report seems to be seeking to draw a global and permanent conclusion about the safety/impacts of HF at the national level. The Panel member noted that this appears to be the motivation for the statement about no “widespread and systemic” impacts. The Panel member suggested that the blanket overview statement be replaced by a series of statements such as:

- 1) Water quality impacts associated with hydraulic fracturing have occurred in a number of locations. Occasionally, these have been severe.
- 2) Many of the impacts have been associated with failures to follow industry best practices and might be preventable.
- 3) Quantifying the frequency and severity of water quality impacts is difficult to do accurately because of data limitations including: reporting of incidents is often voluntary;

and there is uneven follow-up regarding impacts, lack of systematic study of these impacts, sealed information in litigation, and lack of knowledge about or monitoring methods for compounds in hydraulic fracturing fluids.

- 4) With the available information, the number of documented cases of impacts is small relative to the number of wells developed using HF.

Many Panel members audibly provided their support after this Panel member provided the above suggestion.

One Panel member asked what evidence was available that the HF industry has failed to comply with best practices. The Panel member who made the above-noted four-point suggestion responded that there have been failures in HF well construction as noted in the Report, and that it was implied that the cases described in public comments and in the draft Assessment Report were the result of activities that the industry would do differently if the industry could do the work again.

A Panel member responded to the Panel member who made the above-noted four-point suggestion by noting that it is not known what the industry would or would not do differently. The Panel member stated that cement logs require interpretation, there is uncertainty with that interpretation, and for example, if a micro-channel appears in the cementing process, the HF well construction personnel would need to decide whether to leave the micro-channel or do something to the micro-channel. The Panel member expressed concern that a Panel member could make such a general statement without having HF operational experience. Another Panel member commented that the statement on best practices was quite broad, noted it was unclear whether this statement focused on cement casing, and commented that this statement recognizes that the practices that were followed could be improved. Dr. Dzombak stated that the draft Assessment Report recognized problems with HF practices in the HF water cycle, and that the EPA can decide what to emphasize on those problems.

The Panel member who made the above-noted four-point suggestion responded that there was unease with the EPA's statement that there is no widespread impact, since that statement does not convey what is known and what is not known about impacts. The Panel member suggested that in the draft Assessment Report, the EPA should distinguish that there were not many episodes of impacts that were directly linked to HF, and acknowledge the problems with a sweeping statement in the draft Assessment Report if such a statement is made in the EPA's draft Assessment Report.

A Panel member agreed that the draft Assessment Report should distinguish that there were not many episodes of impacts that were directly linked to HF. Another Panel member noted there may be best practices on cement casing and other parts of HF activities, and that it was helpful if the HF industry was following best practices. The Panel member who made the above-noted four-point suggestion responded that many HF-related impacts are preventable. A Panel member responded that best practices were missing from the draft Assessment Report, and recognized that there clearly was impact at Bainbridge Ohio. Another Panel member suggested that the draft Assessment Report could describe what mitigation practices (e.g., secondary containment, elimination of open pits) could help stop releases from HF operations that may be occurring.

A Panel member noted that the EPA, not the Panel, wrote the statement on widespread, systemic impact, and suggested that perhaps the statement could be reworded to remove value judgment from a statement that was not supported by experience.

Draft summary of preliminary draft key points

A Panel member and Dr. Dzombak provided a draft summary of preliminary draft key points that they heard during the Panel's discussion in response to charge question 8. They noted the following with regard to the draft Assessment Report's Chapter 10 and Executive Summary:

- The EPA should provide more diagrams and graphs in Chapter 10 and the Executive Summary.
- The EPA should prioritize findings based on severity or likelihood of occurrence if possible.
- The EPA should restrict the narrative in Chapter 10 to key findings to help improve and focus the discussion.
- The EPA should be more precise and specific in its discussions within Chapter 10 and the Executive Summary.
- The Executive Summary should refer the reader to pertinent sections of the draft Assessment Report.
- Major conclusions presented in Chapter 10 and the Executive Summary are not necessarily consistent with conclusions stated in the chapters and body of the draft Assessment Report.
- The EPA should add key research needs to Chapter 10.
- Within Chapter 10 or the Executive Summary, provide a background discussion that includes why the EPA conducted this assessment.
- The EPA should improve its synthesis of the assessment and possibly include slides used by Dr. Frithsen in redrafting this synthesis.
- The EPA should improve and clarify terminology used throughout the EPA's draft Assessment Report and in the Executive Summary and Chapter 10.
- The EPA should provide rationale for excluding prospective case studies within the synthesis discussion.
- Regarding conclusions, the EPA should note that potential impacts are site-specific and that generalizations are difficult.
- Regarding the Executive Summary's statement that "We did not find evidence that these mechanisms have led to widespread, systemic impacts on drinking water resources in the United States.": the EPA should define the terms evidence, widespread, systemic, and impact, or exclude the statement altogether.
- Regarding whether or not impacts can be detected, the absence of evidence is not actually evidence.
- Perhaps the EPA could add key points at end of each chapter of the draft Assessment Report, and eliminate the Chapter 10 synthesis chapter, unless the EPA includes novel or new recommendations in this synthesis section. If Chapter 10 is retained it should provide integrated conclusions and syntheses and not just replicate major findings from the individual chapters.
- The EPA should include discussion on the modeling scenarios that it conducted in the Executive Summary or Chapter 10.

Dr. Dzombak asked if Panel members had any additional comments on Charge Question 8. Hearing none, Dr. Dzombak then noted it was time for brief clarifying comments from the public.

Clarifying Comments from Members of the Public

Dr. Dzombak noted that it was important for the Panel to consider public comments, and that Panel Members had the opportunity to present clarifying questions to the public commenters. He stated that four members of the public had requested to present clarifying comments, and that while the SAB was not obligated to respond to public comments received in its deliberations, the Panel should keep the public comments in mind and consider raising points made in public comments as the Panel developed advice on this topic.

Ms. Elizabeth Tatham presented her clarifying comments, reading from a statement⁴ that was posted onto the SAB website. Ms. Tatham thanked the Panel, and stated that she learned how little the Panel members knew about individual states. She stated that HF-related violations dropped between 2009 and 2011 in Pennsylvania because of large budget cuts to the Pennsylvania Department of Environmental Protection and a great reduction in number of inspectors available to give citations for violations. She requested that the Panel recommend that the EPA reinstate the site studies in Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas. She stated that no oil or gas company wanted to contaminate water wells, no waste hauling company wanted to have a spill that contaminated a stream or river, and no one wanted a catastrophic blowout that risked lives, water and crops as occurred in Bradford County, Pennsylvania in 2011. She noted that these releases were accidents, and asked how many accidents and how many earthquakes can be tolerated. She asked the Panel members to listen to those who were harmed, stated that voluntary compliance does not work, noted that members of the public must have driver's licenses, and stated that the gas and oil drilling industry should be regulated as much as driving.

Mr. Jeff Zimmerman presented his clarifying comments, reading from a statement⁴ that was posted onto the SAB website. Mr. Zimmerman stated that it was clear that the Panel heard and was considering the stories of regular citizens from Pennsylvania, Texas and Wyoming who had their lives changed by contamination from gas wells that have been hydraulically fractured. Mr. Zimmerman urged the Panel to recommend that the EPA resume investigation of the sites in Dimock, Pennsylvania, Pavillion, Wyoming, and Parker County, Texas, and include updated information from these sites in the EPA's draft Assessment Report. Mr. Zimmerman noted that the evidence continued to mount that methane levels in drinking water resources at these locations are between 50 to 80 mg/L or more and that gas levels in the vent space of these water wells is in the range of 50% to 80% or more, and recommended that this information be considered and included in the EPA's draft Assessment Report.

Mr. John Noel presented his clarifying comments, reading from a statement⁴ that was posted onto the SAB website. Mr. Noel thanked the Panel and the EPA, and stated that an incredible amount of work went into development of the EPA's draft Assessment Report and that the EPA's draft Assessment Report will remain a useful resource for many years. Mr. Noel noted that the effectiveness of the Panel in improving the final Assessment Report would be overshadowed if the top line messages of the final Assessment Report mislead the public. Mr. Noel noted that these top line messages could be developed either by journalists working on a deadline or could be deliberately misconstrued by stakeholders who would attempt to obfuscate or downplay the vulnerabilities described in the body of the final Assessment Report. Mr. Noel noted that policymakers and politicians were currently taking one or two sentences from the Executive Summary or the EPA's press release and using those sentences to negate concerns about oil and gas development that were raised by the public and were described in chapters of the EPA's draft Assessment Report. He stated that the Panel noted concerns with the EPA's

conclusions on “widespread,” “systemic,” and that “the number of impacts were small relative to the amount of hydraulically fractured wells,” and expressed concern that the general public may have difficulty discerning the EPA’s statements and what the public should be concerned about. He noted that the EPA’s statement on “widespread, systemic impact” should not remain in the EPA’s draft Assessment Report because the statement reflected a more nuanced situation than allowed by the sentence. Mr. Noel noted that such a statement would lead to news headlines of concern. He stated that the final Executive Summary must be revised to reflect the inherent uncertainty in the EPA’s ability to present any firm conclusions on how “widespread or systemic” impacts on drinking water are, state that further analysis is needed, note that access to more data is needed, and define the meaning of widespread and systemic.

Mr. Hugh McMillon presented his clarifying comments, reading from a statement⁴ that was posted onto the SAB website. Mr. McMillon stated he was pleased that the EPA’s topline findings of the draft Assessment Report were identified as being inconsistent with the text within the body of the draft Assessment Report. He referred the Panel to his written comments submitted in August 2015, where he researched the EPA’s past use of the term “widespread”. He commented that the EPA’s statement evolved from ‘we did not find evidence of widespread, systemic impacts’ in the draft Assessment Report to the ‘assessment shows no widespread, systemic impacts’ in press releases. He stated that while the EPA may have an awkward rationale for including high profile case studies within the draft Assessment Report, the EPA should present its rationale. He noted that given the relatively low frequency of well integrity failures, a handful of prospective studies supervised by the EPA may not be representative. He referred to his August 2015 written comments on the computational complexity of modeling, noted that the EPA’s modeling scenario did not approximate the potential flows of contaminants over long periods of time on the spatial scale of widespread drilling and fracking in a region, and stated that it was questionable whether such simulations on a regional scale would be feasible even using the most advanced supercomputer.

Recap and Preparation for Writing Session

Dr. Dzombak provided the Panel’s writing teams with instructions for the Panel’s writing session. He noted that during the meeting, Panel members assigned to each charge question took notes and kept track of preliminary draft areas of consensus and key points made by the Panel during discussion of charge questions. Dr. Dzombak noted that during the writing session, the eight different writing teams of the Panel (one team per charge question) would meet to further develop the preliminary draft areas of consensus and key points made by the Panel during the discussion of that charge question. He noted that the Panel’s writing teams should identify approximately five to ten key bullets in sentence format to describe the prioritized preliminary draft areas of consensus and key points for that charge question, and that more than ten bullets was acceptable if needed. Dr. Dzombak noted that charge questions have sub-parts, and that the Panel’s writing teams should indicate which bullets referred to what sub-parts.

Dr. Dzombak noted that during the morning of October 30, 2015, the Panel’s eight Lead Writers would present the writing team’s preliminary draft list of areas of consensus and key points for that charge question. He stated that the Panel would discuss each of these preliminary draft lists of areas of consensus and key points for that charge question, and amend or adjust those preliminary draft lists as appropriate, trying to achieve consensus position on these preliminary draft key points. Dr. Dzombak stated that if a point was promoted by one or two Panel member, and the Panel could not come to full agreement on the point, then that point probably should be omitted from the list.

Dr. Dzombak noted that there would be no minutes taken during the writing session since the product of the writing session would be presented during the Panel's October 30, 2015 meeting. He also noted that since discussions of eight different writing teams would be occurring concurrently, the audio portion of the Panel's live audio/visual feed onto the SAB meeting website would be muted, and the teleconference lines would be discontinued for the day and would start up on October 30, 2015 when the Panel's meeting reconvened beginning at 8:30am.

Designated Federal Officer Ed Hanlon adjourned the public portion of the meeting at 4:00pm.

Writing Session by Panel Subgroups

The Panel's writing session commenced at approximately 4:00 p.m. and was completed in the meeting room at approximately 6:30 p.m.

October 30, 2015

At 8:30 a.m., Designated Federal Officer Ed Hanlon opened the meeting and turned the meeting over to Dr. Dzombak.

Dr. Dzombak welcomed everyone. He noted that the Panel would discuss preliminary draft key points on charge questions, and noted that a 28 page compilation of preliminary draft key points and consensus points was developed in the October 29 writing session for the eight charge questions, and the compilation was posted to the SAB Panel's meeting website.²¹ Dr. Dzombak noted that an 80 page version of this document was being projected onto the meeting projector screen. He stated that each of the eight lead writers would present preliminary draft key points and areas of consensus, and then the full Panel would discuss these points. Dr. Dzombak noted that the Designated Federal Officer would be editing the preliminary draft list of key points in real time.

Dr. Dzombak stated that the Panel would seek consensus on each point, and noted that if most but not all Panel members were supportive of a preliminary draft key point, rather than continuing to discuss a point the Panel would move forward with the point and note the presence of minority disagreement. He noted that that minority view would be reflected in the final SAB report. Dr. Dzombak stated that these preliminary draft key points were not the final statement of the SAB advice, and noted that the Panel would be developing a full report of advice. He stated that Panel members would receive and have opportunity to review the entire draft report, doing so as individual members of the Panel and then as a group during a public teleconference where discussion on the draft text would occur. Dr. Dzombak noted that there would be at least one and possibly two teleconferences of the Panel for this review, and noted that the discussion during October 30, 2015 would not be the last chance for Panel members to reflect on and provide input to the SAB's report. He noted that the October 30, 2015 Panel discussion was important since it would help identify the main themes of the Panel.

Discussion of Preliminary Draft Key Points in Responses to Charge Questions

Six of the eight Lead Writers (for charge questions 1, 3, 4, 6, 7, and 8) presented their writing team's preliminary draft lists of areas of consensus and key points for their charge questions.²¹ The preliminary draft lists of areas of consensus and key points were shown on the projection screen at the meeting. The Panel discussed each preliminary draft list of areas of consensus and

key points that were presented, verbally amended and adjusted those preliminary draft lists, and worked to achieve consensus position of the Panel on preliminary draft key points that were presented. The Designated Federal Officer edited the preliminary draft lists of areas of consensus and key points that were presented in the meeting in real time, with the text shown onto the meeting projection screen and viewed online via webcast.

Two Lead Writers of the Panel (Drs. Elizabeth Boyer and Susan Brantley) were not able to present the preliminary draft lists of areas of consensus and key points for Charge Questions 2 and 5, respectively, since the meeting adjourned when a quorum of the Panel was no longer going to be present at the meeting.

Summary and Next Steps

At approximately 2:15 p.m., when a quorum of the Panel was no longer going to be present at the meeting, Dr. Dzombak provided concluding remarks. He thanked the members of the public for participating, including both those present in the room and online via the webcast and teleconference. Dr. Dzombak thanked the contractors and audio/visual support crew. He thanked the EPA ORD Assessment Report authors and contributors present for the three days of deliberations. Dr. Dzombak thanked the Panel, and noted that their collaborative and constructive spirit is what enabled the progress and consensus achieved.

Dr. Dzombak stated that the draft Assessment Report and the SAB review of this report were important for the nation. He cited the remarks of a Panel member on Thursday, who noted that the new developments in hydraulic fracturing technology and the development of new resources that this technology enables would carry forward for a long time. Dr. Dzombak stated that the EPA's efforts in this assessment was an initial research and development effort that would be the first of many to be conducted by multiple organizations and agencies in the years ahead, as the technology and approaches to protecting the environment and human health in the course of its deployment are advanced. He noted that the work of the Panel was not done, but that the Panel was off to a great start toward development of the SAB's advisory review report.

The Designated Federal Officer stated that the edited version of the preliminary draft lists of areas of consensus and key points that were presented during the October 30, 2015 Panel meeting would be posted onto the Panel's meeting website within the next working day. He also stated that a Federal Register Notice would be published soon to announce when the Panel would conduct a follow-up teleconference to present and conduct a Panel discussion on the preliminary draft lists of areas of consensus and key points for Charge Questions 2 and 5. With the meeting business concluded, the Designated Federal Officer adjourned the meeting at 2:20 pm ET.

Respectfully Submitted:

/Signed/

Mr. Edward Hanlon
Designated Federal Officer

Certified as Accurate:

/Signed/

Dr. David A. Dzombak, Chair
SAB Hydraulic Fracturing Research
Advisory Panel

NOTE AND DISCLAIMER: The minutes of this public meeting reflect diverse ideas and suggestions offered by Panel members during the course of deliberations within the meeting. Such ideas, suggestions and deliberations do not necessarily reflect consensus advice from the Panel members. The reader is cautioned to not rely on the minutes to represent final, approved, consensus advice and recommendations offered to the Agency. Such advice and recommendations may be found in the final advisories, commentaries, letters or reports prepared and transmitted to the EPA Administrator following the public meetings or teleconferences.

Materials Cited

The following meeting materials are available on the SAB website (www.epa.gov/sab) or through the following SAB Hydraulic Fracturing Research Advisory Panel October 28-30, 2015 public meeting webpage:
<http://yosemite.epa.gov/sab/sabproduct.nsf/a84bfee16cc358ad85256ccd006b0b4b/26216d9fbb8784385257e4a00499ea0!OpenDocument&Date=2015-10-28>

¹ June 5, 2015 Federal Register Notice announcing the public meeting (80 FR 32111 – 32113)

² Agenda for October 28-30, 2015 public meeting

³ the EPA Presentation - Assessment of the Potential Impacts of HF for Oil and Gas on Drinking Water Resources

⁴ Oral Statement submitted by Elizabeth Tatham

⁵ Oral Statement submitted by Ms. Tracy Carluccio, representing the Delaware Riverkeeper Network

⁶ Oral Statement submitted by Ms. Susan Carty, representing the League of Women Voters of the United States

⁷ Oral Statement submitted by Mr. John Noel, representing Clean Water Action

⁸ Oral Statement submitted by Ms. Nichole Saunders, representing Environmental Defense Fund

⁹ Oral Statement submitted by Mr. Trevor Penning, representing the University of Pennsylvania Center of Excellence in Environmental Toxicology

¹⁰ Oral Statement submitted by Mr. Adam Carpenter, representing American Water Works Association

¹¹ Oral Statement submitted by Mr. Jeff Zimmerman, representing Damascus Citizens for Sustainability, NYH2O, and Citizens for Water

¹² Oral Statement submitted by Mr. Dusty Horwitt, representing Partnership for Policy Integrity

¹³ Oral Statement submitted by Mr. Aaron Mintzes, representing Earthworks

¹⁴ Oral Statement submitted by Mr. Ray Kemble

¹⁵ Oral Statement submitted by Mr. Bryce Payne

¹⁶ Presentation submitted by Mr. Zac Hildenbrand

¹⁷ Oral Statement submitted by Ms. Hope Forpeace

¹⁸ Presentation submitted by Mr. Steve Lipsky

¹⁹ Oral Statement submitted by Mr. Hugh MacMillan, representing Food and Water Watch

²⁰ Oral Statement submitted by Mr. Lance Larson, representing Natural Resources Defense Council

²¹ Preliminary Summary Responses to Charge Questions from Members of the SAB Hydraulic Fracturing Research Advisory Panel, as of Oct 29, 2015

ATTACHMENT A – ROSTER

U.S. Environmental Protection Agency Science Advisory Board Hydraulic Fracturing Research Advisory Panel

CHAIR

Dr. David A. Dzombak, Hamerschlag University Professor and Department Head, Civil and Environmental Engineering, Carnegie Mellon University, Pittsburgh, PA

MEMBERS

Dr. Stephen W. Almond, Director of Research & Development, Fritz Industries, Inc, Houston, TX

Dr. E. Scott Bair, Emeritus Professor, School of Earth Sciences, Ohio State University, Columbus, OH

Dr. Peter Bloomfield, Professor, Statistics Department, North Carolina State University, Raleigh, NC

Dr. Steven R. Bohlen, State Oil and Gas Supervisor, and Head of the Division of Oil, Gas and Geothermal Resources (DOGGR), State of California Department of Conservation, Sacramento, CA

Dr. Elizabeth W. Boyer, Associate Professor, Department of Ecosystem Science & Management, Pennsylvania State University, University Park, PA

Dr. Susan L. Brantley, Distinguished Professor of Geosciences and Director, Earth and Environmental Systems Institute, Pennsylvania State University, University Park, PA

Dr. James V. Bruckner, Professor of Pharmacology and Toxicology, Department of Pharmaceutical and Biomedical Sciences, College of Pharmacy, University of Georgia, Athens, GA

Dr. Thomas L. Davis, Professor, Department of Geophysics, Colorado School of Mines, Golden, CO

Dr. Joseph J. DeGeorge, Global Head of Safety Assessment and Laboratory Animal Resources, Merck Research Laboratories, Lansdale, PA

Dr. Joel Ducoste, Professor, Civil, Construction, and Environmental Engineering Department, North Carolina State University, Raleigh, NC

Dr. Shari Dunn-Norman, Professor, Geosciences and Geological and Petroleum Engineering Department, Missouri University of Science and Technology, Rolla, MO

Dr. Katherine Bennett Ensor, Professor and Chair, Department of Statistics, Rice University, Houston, TX

Dr. Elaine M. Faustman, Professor, Department of Environmental Health, and Director, Institute for Risk Analysis and Risk Communication, School of Public Health, University of Washington, Seattle, WA

Mr. John V. Fontana, Professional Geologist and President, Vista GeoScience LLC, Golden, CO

Dr. Daniel J. Goode, Research Hydrologist, U.S. Geological Survey, Pennsylvania Water Science Center, Exton, PA

Dr. Bruce D. Honeyman, Associate Vice President for Research and Emeritus Professor of Environmental Science and Engineering, Colorado School of Mines, Golden, CO

Mr. Walter R. Hufford, Director of Government and Regulatory Affairs, Talisman Energy USA Inc. - REPSOL, Warrendale, PA

Dr. Richard F. Jack, Director, Vertical Marketing for Environmental and Industrial Markets, Thermo Fisher Scientific Inc., San Jose, CA

Dr. Dawn S. Kaback, Principal Geochemist, Amec Foster Wheeler, Denver, CO

Dr. Abby A. Li, Senior Managing Scientist, Exponent Health Sciences, Exponent, Inc., San Francisco, CA

Mr. Dean N. Malouta, White Mountain Energy Consulting, LLC, Houston, TX

Dr. Cass T. Miller, Daniel A. Okun Distinguished Professor of Environmental Engineering, Department of Environmental Sciences and Engineering, University of North Carolina, Chapel Hill, NC

Dr. Laura J. Pyrak-Nolte, Professor, Department of Physics, College of Science, Purdue University, West Lafayette, IN

Dr. Stephen Randtke, Professor, Department of Civil, Environmental, and Architectural Engineering, University of Kansas, Lawrence, KS

Dr. Joseph N. Ryan, Professor of Environmental Engineering and Bennett-Lindstedt Faculty Fellow, Department of Civil, Environmental, and Architectural Engineering, University of Colorado-Boulder, Boulder CO

Dr. James E. Saiers, Clifton R. Musser Professor of Hydrology and Associate Dean of Academic Affairs, School of Forestry and Environmental Studies, Yale University, New Haven, CT

Dr. Azra N. Tutuncu, Professor and Harry D. Campbell Chair, Petroleum Engineering Department, and Director, Unconventional Natural Gas and Oil Institute, Colorado School of Mines, Golden, CO

Dr. Paul K. Westerhoff, Professor, School of Sustainable Engineering and The Built Environment, Ira A. Fulton Schools of Engineering, Arizona State University, Tempe, AZ

Dr. Thomas M. Young, Professor of Civil and Environmental Engineering, University of California – Davis, Davis, CA

SCIENCE ADVISORY BOARD STAFF

Mr. Edward Hanlon, Designated Federal Officer, U.S. Environmental Protection Agency, Science Advisory Board Staff, Washington, DC

ATTACHMENT B – Other Attendees

List of Members of the Public at the Meeting, Who Requested Information on Accessing the Teleconference Line or Live Webcast, or Who Participated On the Teleconference or Live Webcast: October 28-30, 2015

Name	Affiliation
Akhara, Maryan	The Cadmus Group, Inc.
Akharan, Morgan	The Cadmus Group, Inc.
Arnold, Elizabeth	EDGE
Barrings, Belen	Telesur
Bitkhalzeu, Jeus	LBNL
Bolakas, John	Woodward & Curran
Briskin, Jeanne	EPA
Burden, Susan	EPA
Burkhart, Kira	EIP
Carluccio, Tracy	Delaware River Keeper Network
Carpenter, Adam	American Water Works Association
Carty, Susan	League of Women Voters
Cluff, Maryam	EPA
Demirkan, Deniz Incini	The Cadmus Group, Inc.
DiCosmo, Bridget	EPA
Dunlap, David	KCPS
Fenton, John	Pavillion WY
Fleming, Megan	EPA
Forpeace, Hope	AK Productions
Gibbons, Dayna	EPA
Graff, Michelle	EPA
Gulla, Ronald	DCS
Harmon, Shari	Baker Botts LLP
Hildenbrand, Zac	Inform Environmental
Horwitt, Dusty	PFPI
Jackson, Tom	Baker Botts LLP

Name	Affiliation
Kemble, Ray	No Affiliation Given
Klewicki, Ken	The Cadmus Group, Inc.
Knights, Chris	EPA
Konski, Alan	Bloomberg BNA
Koplos, Jonathan	The Cadmus Group, Inc.
Larson, Lance	NRDC
LeDuc, Stephen	EPA
Lipsky, Lipsky	No Affiliation Given
MacMillan, Hugh	FWW
Matthews, Lisa	EPA
McCleary, James	EPA
Meadows, Stephanie	API
Mintzes, Aaron	Earthworks
Newman, Colleen	AAPG
Noel, John	Clean Water Action
Orme-Zavaleta, Jennifer	EPA
Payne, Bryce	Independent Consultant
Penning, Trevor	University of Pennsylvania
Pepino, Rich	University of Pennsylvania
Ridley, Carson	EPA
Ring, Shari	The Cadmus Group, Inc.
Saunders, Nichole	EDF
Smith, Kelly	EPA
Stanek, John	EPA
Stevens, Craig	No Affiliation Given
Taccilo, Mary Ellen	The Cadmus Group, Inc.
Tatham, Elizabeth	No Affiliation Given
Thorp, Lynn	Clean Water Action
Todd, Jason	EPA
Tuccillo, Mary Ellen	The Cadmus Group, Inc.
Vera, Jaime	Telesur

Name	Affiliation
Weaver, Jim	EPA
Weber, Anna	The Cadmus Group, Inc.
Wiser, Nathan	EPA
Zimmerman, Jeff	Damascus Citizens for Sustainability and NYH2O