EPA Science Advisory Board Peer Review
on
EPA Office of Research and Development Draft Report, *Assessment of the Potential Impacts of Hydraulic Fracturing for Oil and Gas on Drinking Water Resources* *(External Review Draft, EPA/600/R-15/047, June 2015)*

Preliminary Summary Responses to Charge Questions from Members of the EPA Science Advisory Board (SAB) Hydraulic Fracturing Research Advisory Panel

U.S. EPA Science Advisory Board
1200 Pennsylvania Ave., N.W.
Washington, D.C. 20460

October 30, 2015

Charge Question 1: Goals, Background and History of the Assessment:

> The goal of the assessment was to review, analyze, and synthesize available data and information concerning the potential impacts of hydraulic fracturing on drinking water resources in the United States, including identifying factors affecting the frequency or severity of any potential impacts. In Chapter 1 of the assessment, are the goals, background, scope, approach, and intended use of this assessment clearly articulated? In Chapters 2 and 3, are the descriptions of hydraulic fracturing and drinking water resources clear and informative as background material? Are there topics that should be added to Chapters 2 and 3 to provide needed background for the assessment?

Charge Question 1 Response:

- In Chapter 1, the goals and objectives should be stated more explicitly and clarified, and used consistently throughout the document.
- The background is described well.
- The scope is stated to be "defined by the hydraulic fracturing water cycle" and it is desirably broad, in particular not limiting it to solely the actual hydraulic fracturing step. Some additional explanation of the rationale for using the hydraulic fracturing water cycle would be helpful.
- The approach employed – review, synthesis, and analysis of scientific literature and information provided by stakeholders – should not be stated as the goal of the study.
- The use of EPA sponsored research projects, technical input from agencies, industries, NGOs and other stakeholders can be highlighted as part of the approach.
- The intended users range from policy makers and regulators to the industry and the public, but parts of Chapters 1-3 (and parts of the Executive Summary and some other chapters) are overly technical for most of those users.
- Chapter 1 is deficient in acknowledging the importance of experiences at individual sites, and needs associated with public outreach and education related to drinking water quality.
- As part of the background in Chapter 1, it would be helpful to discuss the differences in focus of the Clean Water Act and the Safe Drinking Water Act, and to provide a general description of authorities and responsibilities of the federal government and state government with respect to protection of surface water quality, ground water quality, municipal water supplies, and private wells.

Charge Question 1 Response (continued):

- The description of hydraulic fracturing in Chapter 2 is clear and informative. The temporal characteristics and differences of the hydraulic fracturing water cycle stages should be discussed.

- The description of drinking water resources in Chapter 3 is informative and generally clear.

- There needs to be more description and depiction of the three-dimensional nature of the subsurface environment and hydraulic fracturing activities within it. References to “co-location” of HF with surface and ground water may mislead about protection, as vertical separation may provide adequate protection of a drinking water resource.

Charge Question 2: Water Acquisition Step in the Hydraulic Fracturing Water Cycle:

The scope of the assessment was defined by the hydraulic fracturing water cycle, which includes a series of activities involving water that support hydraulic fracturing. The first stage in the hydraulic fracturing water cycle is water acquisition: the withdrawal of ground or surface water needed for hydraulic fracturing fluids. This is addressed in Chapter 4.

a. Does the assessment accurately and clearly summarize the available information concerning the sources and quantities of water used in hydraulic fracturing?
b. Are the quantities of water used and consumed in hydraulic fracturing accurately characterized with respect to total water use and consumption at appropriate temporal and spatial scales?
c. Are the major findings concerning water acquisition fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?
d. Are the uncertainties, assumptions, and limitations concerning water acquisition fully and clearly described?
e. What additional information, background, or context should be added, or research gaps should be assessed to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

Charge Question 2 Response:

2a) Does the assessment accurately and clearly summarize the available information concerning the sources and quantities of water used in the hydraulic fracturing process?

- The assessment regarding the water acquisition step in the hydraulic fracturing water cycle clearly summarizes the available information concerning the sources and quantities of water used from surface water, ground water, and treated wastewaters.

Charge Question 2 Response:

2b) Are the quantities of water used and consumed in hydraulic fracturing accurately characterized with respect to total water use and consumption at appropriate temporal and spatial scales?

- The assessment comprehensively characterizes the quantities of water used and consumed for hydraulic fracturing at multiple temporal and spatial scales. Though the national scale images of how water use is distributed across the country are useful and informative, the statistical extrapolation to describe average conditions at the national scale is not appropriate. The analyses at local scales (e.g., case studies) that were used to quantify how hydraulic fracturing water withdrawals affect short-term water availability were more accurate characterizations.

Charge Question 2 Response:

2c) Are the major findings concerning water acquisition fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?

- The major findings concerning water acquisition for hydraulic fracturing (from surface waters, ground waters, and treated wastewaters) were supported by the information and data presented in the assessment. Recent findings about the evolution of technologies to improve water re-use should be added.

- The finding that there were no cases where water use for hydraulic fracturing alone caused a stream or well run dry is not appropriate to consider severity of impacts. For example, a stream with substantially decreased water availability, or a well with drawdown as a result of water acquisition, may be impacted. Characterization of imbalances between water supply and demand, and localized effects, as affected by many interactive factors, may be better ways to consider impacts.

- The description of the frequency and severity of impacts is highly generalized and qualitative. Though the statements are reasonable, the report could be strengthened with specific and quantitative results.

Charge Question 2 Response:

2d) Are the uncertainties, assumptions, and limitations concerning water acquisition fully and clearly described?

- The uncertainties, assumptions, and limitations concerning hydraulic fracturing water acquisition are well described. There are important gaps in the data and information available to assess water use that EPA are acknowledged. Some findings relied on ptentially uncertain and incomplete information from the industry-supported FracFocus database and the USGS water use database. We encourage EPA to use additional available information from the well file study database to characterize water acquisition impacts, as planned in the 2012 progress report.

Charge Question 2 Response:

2e) What additional information, background, or context should be added, or research gaps should be assessed to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

- Given limitations in the availability of water consumption and use data, especially at local scales, and in the representativeness of the case studies used, the many factors contributing to effects of hydraulic fracturing on water availability -- such as climate, geology, water management, and multiple water sources -- could not be fully characterized.

- EPA should continue research on expanded case studies and long term prospective studies. Using additional data from industry (e.g., from the well file database) could strengthen the findings.

Charge Question 3: Chemical Mixing Step in the Hydraulic Fracturing Water Cycle:

The second stage in the hydraulic fracturing water cycle is chemical mixing: the mixing of water, chemicals, and proppant on the well pad to create the hydraulic fracturing fluid. This is addressed in Chapter 5.

a. Does the assessment accurately and clearly summarize the available information concerning the composition, volume, and management of the chemicals used to create hydraulic fracturing fluids?
b. Are the major findings concerning chemical mixing fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?
c. Are the uncertainties, assumptions, and limitations concerning chemical mixing fully and clearly described?
d. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

<u>**Charge Question 3 Response:**</u>

a. Does the assessment accurately and clearly summarize the available information concerning the composition, volume, and management of the chemicals used to create hydraulic fracturing fluids?

- This chapter endeavors to describe all aspects of this stage of the HF water cycle including: the mixing process, the chemicals involved, principles of their environmental fate and transport, and their potential impacts on the environment.

- The chapter contains some contradictory statements about the concentrations of additives in hydraulic fracturing fluids, possibly because of confusion between aqueous and non-aqueous fluids.

Charge Question 3 Response:

b. Are the major findings concerning chemical mixing fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?

- The data supports a routine occurrence of spills at fracking sites, which vary in cause, composition, and volume. The report often conflates spill frequency and spill volume with spill severity.
- Definitive data regarding the environmental impacts of HF related spills is scarce, but evidence from 'analogue' systems points to a reasonable likelihood of environmental impacts from a subset of such spills.
- The descriptions of the classes of chemicals and their range of uses are valuable. However, detailed chemical property information should be combined with similar information elsewhere (e.g., chapter 9). In this chapter it is sufficient to note that these chemicals "fully occupy" the chemical property space, minimizing the value of speculative transport scenarios.
- The section on fate and transport is not useful to this chapter because it does not narrow the uncertainty about severity of spills.

Charge Question 3 Response:

c. Are the uncertainties, assumptions, and limitations concerning chemical mixing fully and clearly described?

- Data limitations severely compromise the ability to develop definitive conclusions regarding the frequency and severity of spills. This does not constitute evidence that water resources are unaffected. Rather, it indicates the lack of routine monitoring at hydraulic fracturing sites,

Charge Question 3 Response:

d. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

- Spills during chemical mixing occur as part of an above-ground, engineered process. Emphasis should be placed on preventing spills and containing them when they occur. Once they enter the environment, the problems become much more complex, costly, and uncertain to assess and remediate. The precautionary principle should be invoked: what can be done to minimize spills?
- Monitoring before, during, and after hydraulic fracturing during the well's production life would provide a data source to assist in assessing the impacts of fracking and identifying releases to the environment that might go unnoticed.

Charge Question 4: Well Injection Step in the Hydraulic Fracturing Water Cycle:

The third stage in the hydraulic fracturing water cycle is well injection: the injection of hydraulic fracturing fluids into the well to enhance oil and gas production from the geologic formation by creating new fractures and dilating existing fractures. This is addressed in Chapter 6.

a. Does the assessment clearly and accurately summarize 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?
b. Are the major findings concerning well injection fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?
c. Are the uncertainties, assumptions, and limitations concerning well injection fully and clearly described?
d. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

Charge Question 4 Response:

General Comments and Introduction:

This is one of the most complex and pivotal chapters in the document. While chemicals used in HF may have various toxicities in varying concentrations, and, even newer, greener mixes may be safer, oil field fluids are still nothing you'd want to drink. The fluids coming out of the well (hydrocarbons and produced water) can be far more toxic than those being used for fracturing purposes. Therefore, the key is responsible well construction, operation and isolation of potable water. This includes inspection, testing and monitoring of the tubing tubing-casing annulus and other casing annuli, as well as monitoring and testing of the potable groundwater through which they pass.

In chapter 4 (Charge Question 2) the EPA used text boxes and case study summaries to illustrate concepts, which may be new or unknown to the public. More of this would be helpful in chapters 6 (and perhaps other chapters as well). The reason for this is that there have been some very serious concerns raised by the public and the public deserves the best explanation of what has happened and why. In order to understand any explanation, they need more information about borehole construction, geologic parameters and well integrity issues in language they can understand. Further, as the Agency attempts to inform public policy and lawmakers, it will be important to fix the problem that is broken, not condemn everything with a broad brush.

Charge Question 4 Response:

General Comments and Introduction (continued):

As a general point for this chapter in particular, but may be related to other chapters as well, anything improved, changed or accomplished since 2012 is not included in this study. There has been much good work done and many technological improvements. Incidents have not increased and may have decreased and it appears this may be due to newer technologies as well as better industry practices and better regulatory oversight. Whatever the reasons, this needs further elaboration.

Charge Question 4 Response: Thematic Areas:

1. Clarity; Accessibility to the Public: Charge question 4a.

The description of available data and information is well documented, but is geared toward a professional audience. The layperson needs much more help in understanding the intricacies of well design and of well integrity issues.

- The well construction discussion should include some mention of state oversight and testing of cement integrity at the time of initial completion, then indicate any subsequent monitoring after the many fractures are placed.

- Meaningful, accurate diagrams and charts to accompany the words would be helpful, and the relevant appendix should be expanded to include more design information. The chapter would be very much strengthened by clearer geologic illustrations, better figures to help understand heterogeneity (fractures, rock properties, layering etc.). Rock pictures should be added here or in Chapter 1 to help the public appreciate the scale and issues discussed. We attach a file of rock photos from Dr. Scott Bair for consideration.

- Please add more key illustrations, photos, graphs, charts etc., to accompany and break up the text would be helpful.

- Please eliminate the use of acronyms unless fully explained.

Charge Question 4 Response: Thematic Areas:

2. Case Studies: Charge Question 4d.

A discussion of the strengths and weaknesses of case studies is critical. We need to be clear what data is known, what is inferred, and how well remediated the issues have been.

- There are 2 case studies included in the chapter, Bainbridge, OH (which was a cement failure and not related to HF injection); and Kildeer, ND, (which was a blowout during HF injection).

- There are many public comments regarding missing studies, particularly those surrounding the most contentious issues such as Dimmock, PA; Pavillion, WY; and Parker Co., TX; As these seem to occupy the hearts and minds of much of the public, meaningful discussion of causes, conclusions and plans for remediation should be specifically discussed in the appropriate chapter.

- Mention is made of casing and cement issues causing gas migration behind pipe. We would like to see specific examples.

- We would like to see a discussion as to how well the regional geology of an area be understood prior to embarking on a well or a play where HF will be involved. By this we mean not only what are the rocks and the potential for hydrocarbon charge and maturation, but to understand the overall degree and complexity of deformation; the degree of separation from base potable ground water to the objective producing section; as well as geothermal and stress field gradients.

- We would like to see a diagram of an abandoned well with typical placement of cement. The footnote needs to include a note that abandoned wells are typically cemented.

<u>Charge Question 4 Response: Thematic Areas:</u>

<u>3. Cement and Casing Charge Question 4 b and c.</u>

Cement integrity is quite important and is critical to ensure well integrity. This has not been well defined in the report.

- Quality, placement and to some degree, type of cement is critical. There are various classes of cements used as well as types of casing used.

- Evaluation methodologies (Cement Bond Logs, Temperature Logs, Acoustic and Spectral Logs, Pressure testing etc. or their limitations) are not well explained or emphasized.

- Limit uncertainties by examining more/all of the 20,000 well files referenced in the report. Summary statistics would be better reported using graphs or tables.

- Design principles are absent and would help the public understand the issues.

- There is little information on aging, re-fracturing and use of acids in old wells…Does that degrade old cement? Can any statement be made in respect of this concern?

- Databases / data exist but may not be readily accessible, but this seems to be improving. Encouraging industry to share specific needed data would go a long way toward transparency.

- Much new research and technology has been, and is being, developed especially since 2010 with respect to cements, low thermal gradient setting times, swellable elastomers and flexible cements. How widespread are their uses? How available? This also relates to the question of temporal variation in certain problems. Have any/some/most problems been mitigated by newer technologies?

- Pressure diffusion in Karst limestone formations as well as in porous zones adjacent to shales can be critical in diffusing migration pathways. Pathways are complex and porous zones can help diffuse pressures. This concept should be better explained. Difficulty in cementing such zones should be noted.

- Please avoid use of words like conduits and pathways to describe cracks and fissures. Sounds like a superhighway.

<u>Charge Question 4 Response: Thematic Areas:</u>

<u>4. Water Measurements Charge Question 4 d.</u>

There is little mention of background or pre-drilling activity water data measurements. The people would like to understand what is/was in the water before human intervention. Colorado is now requiring sampling and measurement prior to and after all oil and gas drilling activity. Can we cite as best practice and include issues such as sampling techniques and quality.

- With respect to chemicals injected: The toxicity and mobility of various chemicals would be useful to characterize. Also, it is important to make the distinction between chemicals injected into a well vs. chemicals and hydrocarbons that come back out of the well in produced fluids.

- P. 6-56: Evidence of HF fluid movement can take years to identify. The statement is made with little back up. Can we say more about what is meant here?

- Why do we need to distinguish between flow-back and produced water? Is that important to the public? What is meant by produced water? From HF? From non-HF? Are there specific additional risks and leaks that are caused by HF or those activities? If not, why discuss this? This may be better suited to Chapter 7 and links between the two chapters better drawn. We would like to have a comment on un-recovered fracture fluids. Where does that go if it does not come back to the surface? Can we say anything about this that might help allay public concerns?

Charge Question 4 Response: Thematic Areas:

5. Modeling Charge Question 4b.

The Objectives, designs, limitations and conclusions of the models and simulations are poorly presented, described or explained.

- Need figures to illustrate each model/scenario.

- Focus more on describing assumptions, strengths and weaknesses of any modeling parameters. Models only provide insights on the basis of the quality of input data.

- Natural Fractures and the nature of induced vs. natural fractures is briefly mentioned, but this needs a lot more clarity. There is abundant data from industry, academia and service companies as to how fractures grow and what can likely reach the surface or not.

- We need to distinguish between induced fractures and existing natural fractures in a formation. Interactions between the two types of fractures are critical in terms of understanding local permeability. Shale reservoirs have different maturity levels, temperatures and pressures, which can impact permeability. Permeability of a fracture may change due to kergoen transformation in these zones.

- Figure 6-5 is good but as soon as we put faults there, then we have to talk about induced seismicity. Since 2009 we have noted significant increase in induced seismicity in TX, OK, OH, and other places. This is for high rate disposal injection wells, not HF wells. Need to more clearly distinguish these two types.

- 6.2.2 poor use of the word “evidence”. Models and observations are not evidence. Predictive models try to match something in nature. But interpretive models such as these have no data to ground truth. EPA should use typical geology, layers, heterogeneity, etc. Where micro-seismic is available, add more description. Add clarification statements to allow public to understand issues.

- Figure 6.5 does not describe the earth well. Distances and scale are misleading. Over simplified geology. Please revise.

- Please include a typical industry injection rate and pressure plot for a HF Treatment as a function of time. Please ensure it includes the entire fall-off period.

- Models such as “StimPlan” have tried to create conditions to allow a fracture to grow to intersect base potable water. No realistic scenario allows this.

- Figure 6-1 is misleading in that it shows what appears to be a fresh water zone not cemented behind intermediate casing string. This is NOT an industry practice.

- Please remove statement about increased opportunity for upward migration for fractures; unsupported by data.

Charge Question 4 Response: Thematic Areas:

6. Technology: Charge Question 4d.

A General comment for many chapters concerns need for better description of new technologies recently implemented, not to mention emerging technologies.

In addition to Cement Bond Logs we use acoustic logs to "hear" gas movement. Spectral noise testing . Is there more on cement development or monitoring?

Charge Question 4 Response: Thematic Areas:

7. Systems View: Charge Question 4d.

There is a lot of discussion about what is HF-related activity vs. what is not. But, what the Public wants to know: Is this problem caused by activity not far from my house?, regardless the label?

- It is an engineered system coupled to a heterogeneous natural system. We can identify leading causes of failures in pure engineered systems. Failures may be systemic and repeated.
- A description of the heterogeneities and site-specific variation in natural system is needed.
- It is important to list highest probability issues first. As well as what is naturally occurring and what is man induced. A systems look is needed. Findings should be discretely bulleted and clear as an actionable issue.

Charge Question 4 Response: Thematic Areas:

8. Spatial and Temporal Issues and Stray Gas; Charge Question 4b.

The addition of a summary of temporal and spatial variations in the observations may go a long way to address many of the public's concerns. One does not get that sense of possible temporal variation from the current draft. At a minimum, we suggest adding the dates of occurrence from the collected data and from the literature review, so that such conclusions may be drawn or inferred.

- Many time frames are mentioned but not fully differentiated or discussed: HF has a short time duration (hours/days). Waste Disposal and Produced Water are done over many years. Add the submitted bar graph from Scott Bair (see his comments).
- Information regarding the spatial proximity of wells to each other and to water sources and to known faults would be useful to help the public understand

- Need Expansion on stray gas migration discussion. If well is not properly cased and cemented you have problems. But we need to distinguish between fracture related gas vs. stray gas migrating naturally through formations. See John Fontana's write-up submitted.

- Stray gas is a big problem. Need to identify where that comes from. Recommend use of noble gasses as tracers. Still need to be sure what pathways you are talking about.

Charge Question 4 Response: Thematic Areas:

8. Spatial and Temporal Issues and Stray Gas; Charge Question 4b (continued).

- Well data summaries are not statistical in nature. Needs better 3D information needs better stress contrast information.

Charge Question 4 Response: Thematic Areas:

9. Regulatory Improvements Charge Question 4d.

Evolution of best practices has not yet been convolved into regulatory guidelines or even described in this report.

- There is little best or worst practice identification.

- A few key States such as PA, WY, TX, CO, CA have implemented new regulations since 2012.

- "Evolution vs. improvement" with respect to discussing regulatory progress. Avoid use of "improvement" as it implies a judgment.

- Wastewater injection and induced seismicity should be added to water disposal chapter. This will help public distinguish between HF and Long term disposal injections.

Charge Question 4 Response: Thematic Areas:

10. Findings and Conclusions Charge question 4 b, c and d.

In general, the conclusions are not well supported. Findings should be bulleted and conclusions should flow clearly from those findings.

- We would like to see a better hierarchy / prioritization of what are real worrisome 1st order factors and effects (like poor cementation or operator error), vs. 2nd and third order effects (like migration from the deep subsurface).

- Conclusions need to be better prioritized: high vs. lo probability as well as high vs. low impact.

- It is not clear from the chapter, nor from the summary of the data at the end of the chapter, that either the frequency or the severity have been adequately addressed, nor dismissed as unable to assess such impact or severity. The anecdotal data is not statistical in nature, and therefore conclusions as to severity and true risk are difficult to assess. The reader is left to wonder if anything can happen any where at any time. Given the millions of wells which have been hydraulically fractured, we know this is not the case, but there are issues which have arisen and for which the public demands answers. If not properly addressed and prioritized, we run the risk of solving the wrong problems and fixing what is not broken while leaving alone issues that do need improvement. The section on frequency and severity needs to have a much better focus on risk and probability than we have seen.

- The last conclusion sentence (quality of drinking water may have been affected by HF fluids escaping the well bore and surrounding formation…although conclusive evidence is limited.) is internally contradictory. We don’t always know the pathway so be careful about how this is phrased.

Charge Question 5: Flowback and Produced Water Step in the Hydraulic Fracturing Water Cycle:

> The fourth stage in the hydraulic fracturing water cycle focuses on flowback and produced water: the return of injected fluid and water produced from the formation to the surface and subsequent transport for reuse, treatment, or disposal. This is addressed in Chapter 7.
>
> a. Does the assessment clearly and accurately summarize the available information concerning the composition, volume, and management of flowback and produced waters?
> b. Are the major findings concerning flowback and produced water fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?
> c. Are the uncertainties, assumptions, and limitations concerning flowback and produced water fully and clearly described?
> d. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

<u>Charge Question 5 Response:</u>

Consensus Key Points

1) The assessment is a clear and accurate summary of the available information concerning composition, volume, and management of flowback and produced waters (response to 5a).

2) The major findings, found in Section 10.1.4, were supported but they should have been more explicitly quantified and clearly identified within the chapter itself (response to 5b).

3) Data gaps, especially with respect to baseline conditions and with respect to individual incidents, have been identified; however, it is not clear if the gaps are because the data are non-existent or not easily (i.e electronically) available (response to 5b).

4) The authors should consider including a specific finding that the two most important types of events on a volume basis are large severe incidents such as blowouts and smaller common incidents (usually containment leaks), and that blowouts are more severe in terms of impact due to the high-volume short-term characteristics of the release (response to 5b).

Charge Question 5 Response (continued):

5) The text describing the differences between flowback and production waters could be condensed because the distinction is somewhat arbitrary in the context of unconventional wells; however, additional information could be presented on changes in water chemistry over time (response to 5c).

6) More information should be included in the report concerning radionuclides in wastes (including new Pennsylvania Department of Environmental Protection research), bromide concentrations in wastes and in surface waters, best management practices (BMPs) for surface impoundments, and the natural occurrence of brines in the subsurface (response to 5c, 5d).

7) The chapter summarizes many types of incidents and refers to case studies that describe leaks and spills, but the assessment could be improved by providing additional detail describing the extent and duration of the impacts: how impactful are spills and releases when they happen? (response to 5a, 5c)

8) The chapter could be improved by additional discussion of pre-existing baseline chemistry of surface and groundwater, maximum contaminant limits (i.e., Table 7-4), and best management practices (response to 5d).

Charge Question 5 Response (continued):

9) While the assessment provides an overview of fate and transport of spills and the various components necessary to evaluate migration of a spill (i.e. amount of material released, timing of the release, response efforts, timing of response measures, soils, geology, and receptors) the report emphasizes the distance between spill and receptor without adequately indicating that fractures and joints in the shallow subsurface can allow fluids to migrate a considerable distance from the point of release (response to 5c).

10) To understand the likely probability of these events, the report should quantify in text and in a figure the frequency of the different types of release events, including whether the spilled material impacts groundwater or surface water (response to 5d).

Charge Question 6: Wastewater Treatment and Waste Disposal Step in the Hydraulic Fracturing Water Cycle:

The fifth stage in the hydraulic fracturing water cycle focuses on wastewater treatment and waste disposal: the reuse, treatment and release, or disposal of wastewater generated at the well pad. This is addressed in Chapter 8.

a. Does the assessment clearly and accurately summarize the available information concerning hydraulic fracturing wastewater management, treatment, and disposal?
b. Are the major findings concerning wastewater treatment and disposal fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?
c. Are the uncertainties, assumptions, and limitations concerning wastewater treatment and waste disposal fully and clearly described?
d. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

<u>Charge Question 6 Response:</u>

a. Does the assessment clearly and accurately summarize the available information concerning hydraulic fracturing wastewater management, treatment, and disposal?

- In terms of wastewater quantity, the summary of findings is properly brought forward based on the limited data provided. The introduction includes a statement regarding “billions of gallons of wastewater [is produced] daily” across the USA, but the basis for this number should be stated and consistent with other chapters. However, there is no validation of the approach proposed to predict future wastewater generation trends, or the uncertainty in these predictions. This should include a clear summary for the average and range of wastewater volumes generated per well, which varies by state.

Charge Question 6(a) Response (continued):

- There is a lack of description for regulatory oversight of CWTs. It is unclear if CWTs are exempt from NPDES permits, discharge permits to POTWs, etc. It is unclear how the discharges may relate to acute or chronic toxicity limits of receiving bodies, and which parameters (salts, organics, metals, radionuclides, etc.) control these discharges. A summary of regulations and common practices (e.g., salt loading, equalization of discharges, etc.) across the USA regarding discharges to surface waters and POTWs would improve the assessment. If wastewaters are discharged to POTWs, it is unclear how they might influence the sewage solids that would concentrate organics, radionuclides, and metals – because land application of sewage solids is common and can influence drinking water source waters as the result of infiltration or stormwater runoff. A summary of how CWTs are regulated by state, and by which agency, would be helpful. The summary should also address regulations of residuals (e.g., drilling materials, brines from CWT membrane systems, solids from CWTs, etc.), and if they are covered by RCRA or other rules. If landfill disposal of residuals is outside the scope, then stating this would be appropriate in the report.

Charge Question 6(a) Response (continued):

- The summary of treatment technologies is adequate, but requires more accurate wording of the unit processes (Chapter 6 and Appendix F). A limitation is the lack of discussion around complicating treatment issues such as mixed phase wastewaters (solids, solvents, water, surfactants, emulsions), complexing agents (e.g., binds metals that effects their removal efficiency) or formation of by-products upon oxidation/disinfection (bromate, iodate, HAA, NDMA) at the CWTs. Predicted removals for "organics" is too general and should be separated as particulate, soluble, volatile organics. The text should also address relative costs, energy consumption and green house gas production associated with each unit process (e.g., units of $, kWh, kgCO2 per million gallons).

- The report does not adequately describe past or future trends and impacts of produced wastewaters, and as such does not adequately address uncertainties into the future. This could be done effectively via scenarios (i.e., eastern vs western US practices). For example, in the western US large volumes of wastewater is injected into deep wells. There is emerging evidence these practices may lead to seismic activity, which may (and in some cases have already) close injection facilities. The current chapter does not mention anything about reporting of seismic activity discussed in the literature (Yeck et al., 2015; Weingartern et al., 2015; McNamara et al., 2015) related to deep well injection and should be raised to help guide appropriate rates and pressures that reduce these events if this management approach is selected. The scenario could explore what happens when deep well injection is no longer available, and if this would shift wastewater disposal to POTWs, surface waters or other locations. Changing technologies are also allowing greater reuse of wastewaters for fracking at the same, or new, well sites. This could lead to greater reuse shift discharge trends. Residuals from these reuse facilities will have >10x higher concentrations of many constituents; it is unclear where will these residuals go and how would they impact drinking water.

b. Are the major findings concerning wastewater treatment and disposal fully supported by the information and data presented in the assessment? Do these major findings identify the potential impacts to drinking water resources due to this stage of the hydraulic fracturing water cycle? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?

Charge Question 6(b) Response:

- The potential impacts of hydraulic fracturing wastewater treatment and disposal on drinking water resources are not adequately addressed, nor are factors affecting the frequency and severity of potential impacts adequately described. The available information does not support the conclusion that "no evidence" of impacts was found; for example, bromide … (Van Briessen). While estimated volumes and flowrates of wastewater, wastewater treatment processes, and wastewater disposal options are discussed in some detail, there is inadequate discussion of risk factors for impacts on drinking water sources (both groundwater and surface water sources). There is uncertainty in the surface water dilution models and release concentrations for bromide and organics. There is lack of discussion or modeling of the number of surface water intakes in counties or watersheds with active hydraulic fracturing, and their location relative to wastewater discharges. There is inadequate discussion or mapping of populations served by groundwater (municipal or private wells) in counties with active hydraulic fracturing. The specific conclusions that "As of 2014-2015, there is no evidence that these contaminants have affected drinking water facilities, but data are lacking for concentrations of these constituents at drinking water intakes in regions with hydraulic fracturing. " is not fully supported by the findings. These deficiencies lead to inadequate support of major findings related to known or potential impacts on drinking water.

c. Are the uncertainties, assumptions, and limitations concerning wastewater treatment and waste disposal fully and clearly described?

Charge Question 6(c) Response:

- Disinfection by-products (DBPs) are not adequately addressed in this draft report and impose a significant impact on drinking water resources. More than 40% of the US population uses chloramine disinfection, including large populations in Texas. The EPA includes NDMA in the Candidate Contaminant List (CCL4) and may regulate it in drinking waters. NDMA forms during chloramination in the presence of amine-based organic compounds, the type of which is present in fracking fluids. Assessing formation potentials of NDMA using chloramines and other DBPs using free chlorine (TOX, THM, HAA) or ozone (bromate) would help reduce uncertainty levels in impacts of fracking on DBPs at downstream drinking water treatment plants associated with inorganic salt consituents (Br, I) or organic constituents (amines). Since the amount and type of organics influence DBP formation, the ability of CWTs to remove total and dissolved organic carbon (TOC and DOC), color and ultraviolet absorbance at 254 nm are needed. Salt levels in wastewaters vary regionally and temporally as wells operate over time (e.g., TDS usually increases). Bromide and iodide are major salt constituents that indirectly influence municipal drinking water facilities (usually surface waters) that disinfect water. The EPA reported the use of modeling to determine how to reduce the impact of bromide on downstream users.

While a description of the model was not provided along with its assumptions, literature data mentioned in this report showed that significant dilution of waters containing bromide may not reduce levels to background concentrations. A limitation of the current report is the amount of Br and I data in wastewater over time or region (Appendix E has limited data); the report could normalize data by examining Cl/Br or Cl/I ratios and comparing to published ratios in seawater, surface waters and drinking waters.

- A key limitation is the chapter fails to draw clear identification of where are the highest risks for drinking waters. These may be drinking water treatment plants lower in a watershed than locations where hydraulic fracturing occurs, and where CWT waters are disposed (deep well injection, surface water discharge, reuse at well sites, discharge to POTWs). This may include drinking water surface intakes located downstream of POTWs receiving CWT wastewater, or CWT discharges. These may include private wells near sites where CWT wastewater may be spilled or reused. These may include municipal wells that serve many people. It might be possible to acknowledge that some readily measured inorganic parameters (bromide, iodide, radionuclides) may serve as indicators or surrogates of a broader range of more difficult, or costly, to detect pollutants. It would be extremely helpful to develop one or two scenarios to assess these types of impacts on downstream surface water intakes.

d. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize any potential impacts to drinking water resources from this stage of the hydraulic fracturing water cycle? Are there relevant literature or data sources that should be added in this section of the report?

<u>Charge Question 6(d) Response:</u>

- In the December 2012 preliminary plan a number of studies that were not included in this final report. For example, a DBP precursor study was proposed which included conducting experiments to simulate POTW processes to remove a range of pollutants present in fracking wastewaters (e.g., radionuclides, VOCs, anions, metals, inorganics, etc.) and DBP formation. Additionally, technical stakeholder input was shought (e.g., Technical Workshop 2011, Technical Roundtable 2012, Technical Workshop 2013), but not summarized in the final report. In general, outcomes of charge questions #11 and #12 from the May 2013 SAB meeting should be incorporated into the final report. Outcomes of other studies, or notation to which ones remain ongoing, should be discussed and summarized in this chapter.

Charge Question 7: Chemicals Used or Present in Hydraulic Fracturing Fluids:

The assessment used available information and data to identify chemicals used in hydraulic fracturing fluids and/or present in flowback and produced waters. Known physicochemical and toxicological properties of those chemicals were compiled and summarized. This is addressed in Chapter 9.

a. Does the assessment present a clear and accurate characterization of the available chemical and toxicological information concerning chemicals used in hydraulic fracturing?
b. Does the assessment clearly identify and describe the constituents of concern that potentially impact drinking water resources?
c. Are the major findings fully supported by the information and data presented in the assessment? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?
d. Are the uncertainties, assumptions, and limitations concerning chemical and toxicological properties fully and clearly described?
e. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize chemical and toxicological information in this assessment? Are there relevant literature or data sources that should be added in this section of the report?

a. Does the assessment present a clear and accurate characterization of the available chemical and toxicological information concerning chemicals used in hydraulic fracturing?

<u>Charge Question 7(a) Response:</u>

- EPA clearly articulates their approach for characterizing the available chemical and toxicological information, including listing some sources that did not meet their criteria. (a)
- The characterization of the toxicological information was not "accurate" because the criteria were too restrictive. (a)
- A tiered approach should be considered to populate missing toxicology information (a,b)
    - TERA/ MRL / MCL
    - QSAR Read Across approaches; Threshold of toxicological concern
    - FDA GRAS
- Understanding known likely exposure and potential concerns should guide what is included in this section. There is toxicological information for potential relevant durations and routes of exposure (a,b,c)
    - Duration: Acute, subchronic exposure
    - Route: Dermal and inhalation
    - *Endocrine Disruption (surfactants, characterization of levels of exposure)

Charge Question 7(a) Response (continued):

- There were some chemicals that pose hazards that should be discussed in greater detail (a,b,c)
  - o Methane – hazard to humans all thought no toxicological value (e.g. 10 mg/L in Wyoming)
  - o NORM – add regulatory levels (reference PENN regulation)
- CBI should be characterized with data EPA may have and/or information provided in FracFocus regarding chemical class, concentration, toxicity (e.g. read across) (a,b,c)

b. Does the assessment clearly identify and describe the constituents of concern that potentially impact drinking water resources?

c. Are the major findings fully supported by the information and data presented in the assessment? Are there other major findings that have not been brought forward? Are the factors affecting the frequency or severity of any impacts described to the extent possible and fully supported?

Charge Question 7(b) and 7(c) Response:

- The MCDA approach is a reasonable conceptual approach to prioritize chemicals of concern, but not as EPA prescribed it for a national level. In, addition, EPA SAB had concerns about the selection of specific factors in this example (c)
- A major finding was that "Agencies may use these results to prioritize chemicals for hazard assessment or for determining future research priorities". EPA SAB disagreed with this finding based on the current method and scope of their exercise. (c)

d. Are the uncertainties, assumptions, and limitations concerning chemical and toxicological properties fully and clearly described?

Charge Question 7(d) Response:

- See A,B,C.
- The assessment was based on FracFocus 1.0. It would be useful to evaluate FracFocus 3 to see how things have changed, and whether there's movement towards Greener chemistry (d).

e. What additional information, background, or context should be added, or research gaps should be assessed, to better characterize chemical and toxicological information in this assessment? Are there relevant literature or data sources that should be added in this section of the report?

Charge Question 7(e) Response:

- A more complete characterization of organics in wastewater is needed (d).
- Resumption of local case studies or prospective studies that were discontinued could provide understanding of exposure to constituents based on actual scenarios if there are adequate baseline data (d)

Charge Question 8: Synthesis of Science on Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, and Executive Summary:

The Executive Summary and Chapter 10 provide a synthesis of the information in this assessment. In particular, the Executive Summary was written for a broad audience.

a. Are the Executive Summary and Chapter 10 clearly written and logically organized?
b. Does the Executive Summary clearly, concisely, and accurately describe the major findings of the assessment for a broad audience, consistent with the body of the report?
c. In Chapter 10, have interrelationships and major findings for the major stages of the hydraulic fracturing water cycle been adequately explored and identified? Are there other major findings that have not been brought forward?
d. Are there sections in Chapter 10 that should be expanded? Or additional information added?

8a. Are the Executive Summary and Chapter 10 clearly written and logically organized?

<u>Charge Question 8(a) Response:</u>

• The executive summary is logically organized but unclear in presentation of major findings.

• The synthesis, as currently written, is a replication of major findings presented in the previous chapters. The synthesis should be revised to present conclusions, integrate finding from the various chapters, and make recommendations in light of the observations and evidence presented previously.

8b. Does the ES clearly, concisely, and accurately describe the major findings of the assessment for a broad audience, consistent with the body of the report?

<u>Charge Question 8(b) Response:</u>

• The executive summary should be oriented toward a general audience. Key concepts should be illustrated and clarified through use of figures and graphs.

• Some of major findings are ambiguous or are inconsistent with the observations/data presented in the body of the report. The statements of findings should be revised to be more precise and specific, and to clearly draw from the body of the report. Of particular concern is the statement of no widespread, systemic impacts on drinking-water resources. Neither the system of interest nor the definition of widespread is clear.

• Improve the focus by prioritizing the major findings in terms of likelihood of occurrence and severity of impact.

Charge Question 8(b) Response (continued):

- Explain the history of the ORD effort, including the research scoping plan, development of the Study Plan, the 2012 Progress Report, peer review by the science advisory board, and engagement with stakeholders.

- Potential impacts on drinking-water resources are site specific, and their explication is more important than national-level generalizations.

- Rationale for excluding prospective case studies should be addressed.

8c. In Chapter 10, have interrelationships and major findings for the major stages of the hydraulic fracturing water cycle been adequately explored and identified? Are there other major findings that have not been brought forward?

Charge Question 8(c) Response:

- Some of major findings are ambiguous or are inconsistent with the observations/data presented in the body of the report. The statements of findings should be revised to be more precise and specific, and to clearly draw from the body of the report. Of particular concern is the statement of no widespread, systemic impacts on drinking-water resources. Neither the system of interest nor the definition of widespread is clear.

8d. Are there sections in Chapter 10 that should be expanded? Or additional information added?

Charge Question 8(d) Response (continued):

- The synthesis, as currently written, is a replication of major findings presented in the previous chapters. The synthesis should be revised to present conclusions, integrate finding from the various chapters, and make recommendations in light of the observations and evidence presented previously.

- Improve the focus by prioritizing the major findings in terms of likelihood of occurrence and severity of impact.

- The synthesis chapter identifies several limitations and uncertainties that hinder evaluation of effects of hydraulic fracturing on freshwater resources. The report fails to make clear where we go from here. This report – the synthesis section in particular – could make an important contribution by using its findings to support recommendations for future research and steps that could be taken to mitigate the limitations and reduce the uncertainties.

Charge Question 8(d) Response (continued):

- Resolve inconsistencies between body of report and synthesis to avoid a drift in the tone and the way impacts are described and/or implied