# Preliminary Comments from Members of the EPA Science Advisory Board (SAB) Panel for the Review of EPA's Hydraulic Fracturing Study Plan As Of March 22, 2011

**Purpose of Science Advisory Board Panel for the Review of Hydraulic Fracturing Study Plan:** To review and provide advice on the scientific adequacy and appropriateness of EPA's Draft Hydraulic Fracturing Study Plan that will assess the potential impacts of hydraulic fracturing on drinking water resources.

**<u>Preliminary Comments from Members of SAB Hydraulic Fracturing Study Plan Review Panel</u>**

**Comments from Dr. George Alexeeff**

**Charge Question 1: Water Use in Hydraulic Fracturing**

*EPA has used the water lifecycle shown in Figure 7 to characterize hydraulic fracturing and to identify the potential drinking water issues. Please comment on the appropriateness of this framework for the study plan. Within the context of the water lifecycle, does the study plan adequately identify and address the areas of concern?*

**General comments:**

The framework is useful since it is organized around water use in the hydraulic fracturing operations. However, such an approach does not highlight some overarching issues that affect interpretation of the research or help to identify general areas of concern.

One overarching issue is the lack of our knowledge on the expected contaminants and their toxicity. Since drinking water contamination is a key concern of this research, I suggest the extent of our knowledge on the type of chemical contamination should be included in each step as appropriate.

A second area is the uncertainty regarding our knowledge of each step. In the accompanying text it is stated that much of the information is propriety and may not be available. Much of the knowledge appears to be from internal reports or non-peer reviewed commentary, thus it is not clear to this reviewer how much of the inferences have been verified.

A third but related concern is the quality of information that leads to our current understanding of the issues. The EPA has been directed to rely on the best available science. The proposal developed by the EPA moves toward that goal. However, it is unclear if the quality of the literature on which the proposal is based meets the same standard. Many of the sources relied upon have not undergone peer review. Further, the data obtained even in the published reports do not appear to meet the same quality or transparency that is being undertaken by EPA.

A forth overarching issue is environmental justice. The proposal on pages 49-50 is incomplete in terms of evaluating environmental justice. While environmental justice may be important at each step, it would be useful to identify the environmental justice issues with each step. The proposal seems to focus on considering the association of demographics and location of well sites. Clearly demographics such as income or poverty level can be important in understanding environmental justice, yet a key factor is disproportion exposure. And it is unclear how this would be incorporated. Another concern is that correlation of sites and demographics may be skewed if many of the waste sites are in unpopulated areas. One method is to consider the disproportionate impact is the use of the cumulative impact. It would be useful to have the ORD to consider such an issue in their research. An important environmental justice concern is cumulative impact. This does not seem to be explored in this research project. There are two ways cumulative impact could be evaluated. One is the overall impact of the drilling operations on community, such as traffic, diesel pollution, landfills, contaminated water etc. A second potential measure is considering the impact of the drilling operations on top of other exposure burdens in the community. Both of these would also be considered in the context of demographics, sensitive populations, public health status of the community and general environmental degradation.

For these major reasons I have some concern that the research proposal may not be sufficiently focused on identifying likely drinking water contamination issues. Possibly, these have been addressed and considered in previous EPA documents. If so, maybe the research proposal should have a process diagram depicting major considerations leading to this report. It is not clear to me if an effort has been made to identify the gaps of knowledge at each step, and if the gaps are likely to prevent us from identifying drinking water contamination at each stage. For example, the lack of complete chemical analysis at existing sites prevents us from knowing if there is existing contamination.

**Specific comments:**

Under potential drinking water issues:

Water acquisition: I suggest adding "spread of an existing contaminant due to water withdrawal, lowering of water tables or dewatering of drinking water aquifers."

Chemical mixing: I would add, "what are the chemicals involved in mixing?"

Flowback and Produced water: I would add "what are the chemicals present in the flowback and produced water?"

Wastewater treatment: I would add, "are there processes to treat the wastewater?"

Page 4 states: "Based on stakeholder input and the expected growth in shale gas development, this study plan emphasizes hydraulic fracturing in shale formations." One concern is whether such an approach addresses the most vulnerable activities related to drinking water contamination. The maps provided suggest that shale gas extraction is not of interest in California. Yet, hydraulic fracturing is of interest in California. Thus by focusing on shale gas development are we missing opportunities to identify concerns in other formations and regions of the US?

Page 1:"independent sources of information." This term is an important one and there could be more discussion about the incorporation of such information. It could mean industry reports, community-based knowledge, or public comments.

Page 16: "Scenario Evaluation" the report discusses considering a typical case with typical management. The report also discusses a focus on the extraction from shale. However, there is little discussion of identifying worse-case or sensitive impact scenarios. Is it likely that most drilling operations are causing drinking water pollution? Or are there situations that are particularly vulnerable that need to be identified? My understanding would be that drinking water contamination does not usually occur but there may be situations in which it might occur.

**Charge Question 2: Research Questions**

*EPA has identified both fundamental and secondary research questions in Table 2. Has EPA identified the correct research questions to address whether or not hydraulic fracturing impacts drinking water resources, and if so, what those potential impacts may be?*

There needs to be some research questions to identify vulnerable drilling scenarios. Additional secondary questions:

Water acquisition:
- What are the impacts on the well-water resources on environmental justice communities?
- How are the needs for water acquisition considered in the context of the needs of the community?
- Is the water a sensitive resource? E.g., low availability, high demand by public and farmers, contaminated from other pollutants.
- What are unusually large water acquisition requirements?

Chemical mixing:
- What size of release could significantly impact water supply?
- Are the chemical constituents water soluble and likely to move throughout the geologic system?

Well injection:
- Is well injection likely to transform naturally existing compounds to more toxic ones? E.g., Cr+3 to Cr+6.

Flowback:
- What are the substances not recovered?
- What is the quantity of substances not recovered?
- What is the fate of the substances not recovered?

Wastewater treatment and disposal:
- What happens to the well, and what is the impact, after the end of its useful life?

**Charge Question 3: Research Approach**

*The approach for the proposed research is briefly described in Chapter 5. Please provide any recommendations for conducting the research outlined in this study plan, particularly with respect to the case studies. Have the necessary tools (i.e., existing data analysis, field monitoring, laboratory experiments, and modeling) been identified? Please comment on any additional key literature that should be included to ensure a comprehensive understanding of the trends in the hydraulic fracturing process.*

Case studies should consider not only a typical scenario, but also scenarios of greatest concern. There should be included scenarios of differing types of sources and approaches to fracturing. Retrospective case studies should focus on most vulnerable populations, sensitive drinking water resources, or situations of suspected contamination.

In addition to typical water requirements, there should be a consideration of unusually large water requirements?

Are there situations where water requirements change?

What factors can be used to identify a vulnerable or unusually sensitive hydraulic fracturing scenario?

**Charge Question 4(a): Proposed Research Activities - Water Acquisition**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Water Acquisition stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Regarding water acquisition:

- What are the impacts on the well-water resources on environmental justice communities?
- How can the needs for water acquisition be considered in the context of the needs of the community?
- Could one also assess any changes in flow or movement dynamics of the water?
- Water depth, for how long? If the water depth is lowered will some wells no longer have access?
- If all water is fully allocated, how does that affect the issue of water acquisition?
- Do transient effects matter?
- The role of timing is missing in the evaluation.
- How does water acquisition alter the existing or other water sheds?
- How do indicators of water quality change during water acquisition?

**Charge Question 4(b): Proposed Research Activities - Chemical Mixing**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Chemical Mixing stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Based on other statements in the document (page 25), it appears that only publicly known constituents will be considered. Further, even for the known constituents, the concentrations are unknown. That should be noted in the figure. It appears to be a significant limitation.

The Figure identifies characterization of toxicity and human health effects as an activity. The activity should be broadened beyond toxicity. The characterization should include any factor that impacts drinking water quality. What hazard properties are attributed to the compounds?

Look at existing trends of data quality.

What are the opportunities for mixing an exposure?

There should be a list of chemicals used in hydraulic fracturing. Also there is a need to add tracers or consider indicators to the hydraulic fracturing mixture. That will help to identify specific contamination of drinking water from hydraulic fracturing.

Apparently Wyoming and Nebraska require reporting of hydraulic fracturing fluids. Efforts should be made to obtain that information.

<u>Well injection:</u>
Additional questions regarding chemical mixing include:

- What size of release could significantly impact water supply?
- What are the chemical properties of the chemical constituents of hydraulic fracturing fluids that are most likely to move throughout the geologic system?
- Can markers be identified in hydraulic fracturing fluids or added to hydraulic fracturing fluids so that contamination of drinking water could be easily determined?
- How do the answers to the secondary questions help identify potential environmental justice impacts?
- If we can identify the chemicals in hydraulic fluids an effort should be made to know the basic hazard/chemical properties of the chemicals involved. This would be a first order hazard assessment.

**Charge Question 4(c): Proposed Research Activities - Well Injection**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Well Injection stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Research activities appear to be appropriate for the most part.

The Figure identifies characterization of toxicity and human health effects as an activity. The activity should be broadened beyond toxicity. The characterization should include any factor that impacts water quality such as aesthetic properties. The risk of explosions should be considered.

It seems that the issue of well construction is considered intertwined with well injection it would be good to differentiate between hydraulic fracturing versus well construction in prospective studies.

It may be helpful to clarify the distinction between vertical and horizontal wells.

It would be good to mention the knowledge of existing wells in the immediate area, as a new well is being injected. Ideally, mapping of existing well locations could help prevent intersecting problems with existing wells.

What size of release could significantly impact water supply?

What are the chemical properties of the chemical constituents of hydraulic fracturing fluids that are most likely to move throughout the geologic system?

Can markers be identified in hydraulic fracturing fluids or added to hydraulic fracturing fluids so that contamination of drinking water could be easily determined?

**Charge Question 4(d): Proposed Research Activities - Flowback and Produced Water**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Flowback and Produced Water stage of the water lifecycle? Please provide any suggestions for additional research activities.*

In general, the research activities appear to be appropriate.

The Figure identifies characterization of toxicity and human health effects as an activity. The activity should be broadened beyond toxicity. The characterization should include any factor that impacts water quality.

Another question is: Are communities with currently impacted water supplies being considered for hydraulic fracturing?

Wastewater treatment and disposal:

Do treatment and disposal methods differ among communities?

**Charge Question 4(e): Proposed Research Activities - Wastewater Treatment and Waste Disposal**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Wastewater Treatment and Waste Disposal stage of the water lifecycle? Please provide any suggestions for additional research activities.*

I suggest adding: "evaluate potential impacts of high bromide concentrations."

The Figure identifies characterization of toxicity and human health effects as an activity. The activity should be broadened beyond toxicity. The characterization should include any factor that impacts water quality.

The cost of treating the wastewater can result in greater costs borne by low income communities. This could be a variable included in the environmental justice evaluation.

Describe the treatment process of wastewater, where does it go?

When are contaminants likely to show up? Will they be methane and btex?

**Charge Question 5: Research Outcomes**

*If EPA conducts the proposed research, will we be able to:*

*a. Identify the key impacts, if any, of hydraulic fracturing on drinking water resources; and*

*b. Provide relevant information on the toxicity and possible exposure pathways of chemicals associated with hydraulic fracturing?*

Based on the current design and funding of the study, I do not think that the proposed research can identify the key impacts and provide relevant information and possible exposure pathways. If these two outcomes are the desired outcomes, the research could be more focused.

In the research plan a number of other research outcomes are mentioned. While it appears that the following numerous outcomes are important, it is not clear if the research would be able to address the following outcomes. The outcomes should be adjusted to more adequately follow the potential results of the study.

Identify possible impacts on water availability and quality associated with large volume water withdrawals for hydraulic fracturing.

Determine the cumulative effects of large volume water withdrawals within a watershed and aquifer.

Develop metrics that can be used to evaluate the vulnerability of water resources.

Provide an assessment of current water resource management practices related to hydraulic fracturing. Summarize available data on the identity and frequency of use of various hydraulic fracturing chemicals, the concentrations at which the chemicals are typically injected, and the total amounts used.

Identify the toxicity of chemical additives, and apply tools to prioritize data gaps and identify chemicals for further assessment.

Identify a set of chemical indicators associated with hydraulic fracturing fluids and associated analytical methods.

Determine the likelihood that surface spills will result in the contamination of drinking water resources.

Assess current management practices related to on-site chemical storage and mixing.

Identify the key conditions that increase or decrease the likelihood of the interaction of existing pathways with hydraulic fractures.

Evaluate water quality before, during, and after injection.

Determine the identity, mobility, and fate of potential contaminants, including fracturing fluid additives and/or naturally occurring substances (e.g., formation fluid, gases, trace elements, radionuclides, organic material) and their toxic effects.

Develop analytical methods for detecting chemicals associated with hydraulic fracturing events.

Provide a prioritized list of components requiring future studies relating to toxicity and human health effects.

Determine the likelihood that surface spills will result in the contamination of drinking water resources.

Evaluate risks posed to drinking water resources by current methods for on-site management of wastes produced by hydraulic fracturing.

Evaluate current treatment and disposal methods of flowback and produced water resulting from hydraulic fracturing activities.

Assess the short- and long-term effects resulting from inadequate treatment of hydraulic fracturing wastewaters.

I also have concerns that due to the number of unknown chemicals and likely lack of toxicity information, the relevant information on the toxicity and possible exposure pathways of chemicals may not be provided.

**Additional comments:**

The SAB recommendations of June 2010 as presented in Dr. Teichman's slides should be included in the Section 2.1 of the report.

Most of Table A4 should be in the major portion of the document. The columns "Year due" and "epa's role" can be in appendix.

**Comments from Dr. Tom Ballestero**

**General Comments**

1. The “Water Life Cycle” concept is okay, but it seems to completely ignore the hydrogeologic context. This is considered as a major flaw in the Study Plan. Specifically, case studies require thorough hydrogeologic characterization in order to determine if cause and effect exist. Without this, the Study Plan relies on inferior secondary metrics (chemistry, modeling, etc.) to make its inferences. If hydraulic fracturing wells or formation fractures create a direct connection between target formations and drinking water aquifers or surface waters, hydraulic connections will first be manifested before the chemical.
2. There is a general lack of hypotheses and testing methods. As a result, there is an overall lack of specificity to many of the tasks outlined in the Study Plan.
3. It is not clear how cumulative impacts are addressed
4. There is insufficient attention paid to treatment residuals management.
5. There should be a component directed at direct connections between hydraulic fracturing and surface waters.
6. Well abandonment issues need to be addressed in this study.

**Specific Comments**

Page 11 and 12, Figures 6a and 6b. Fracture mechanics and stress fields in rock generally dictate that at depths less than 200 m, hydraulic fracturing generates horizontal fractures and at depths greater than 3,000 m hydraulic fracturing generates vertical fractures. In between these depths, it is really site and formation specific; however it is self-evident that vertically driven fractures have the potential to intersect with shallower formations used for drinking water.

Page 15 under Section 4. Formation interconnections seem to be hidden or absent in the bullet list, when it should be at the forefront and obvious: complete hydrogeologic characterization of sites is imperative.

Page 17 Section 5, Field Monitoring. Geologic characterization is missing. Hydraulic setting and characterization is missing. Need to understand variability at each site. The modeling topic is terse and ambiguous. What is being modeled? What are the input parameters? How are models calibrated and validated?

Page 18 Table 2. Fundamental Research Question: even in light of the Congressional charge, drinking water resources do not occur in a vacuum…they are integrated with other users, instream flows, etc. Last column of chemical mixing row, first bullet, add: exposure, persistence. In the well injection row, last column, add: Controlling fractures and fracturing; add focus on the hydraulic consequences of fracturing (changes to formation connectivity, loss of low transmissivity buffer formations, etc.). This table needs another row entitled Hydrogeologic Characterization. The Fundamental Research Question is: what are the hydrogeologic impacts of hydraulic fracturing? The secondary research questions include; What are pre- and post-fracturing hydrogeologic characteristics of the setting?; what are the probabilistic and deterministic characteristics of fractures? How are aquitards impacted by hydraulic fracturing? Is it possible to develop a site screening tool to safeguard drinking water formations and permit hydraulic fracturing?

Page 20 Section 6.1.1. Surface water withdrawals upstream leave less clean water downstream for dilution. This could lead to violating NPDES permits or increased treatment for drinking water. Groundwater withdrawals can lead to induced recharge thereby effecting nearby groundwater supplies (lower water levels in wells, changes in aquatic chemistry (Fe, for example), as well as the reduced streamflow potential disadvantages.

Page 21 Section 6.1.4.1. Possibly also look at developing/mapping a classification for drinking water sources as good/fair/poor in relation to consequences of contamination from hydrofracturing. Develop a rubric for screening water supplies.

Page 22 Section 6.1.4.1. Evaluate the water balance method.

Page 22 Section 6.1.4.2. Evaluate data from an existing monitoring network or one that is enhanced/augmented? The original monitoring network was most likely not designed to test/study any potential consequences of hydraulic fracturing. A monitoring network needs to be very carefully designed and implemented. Hypotheses to be tested need to be clearly stated and the methods and conclusions of testing agreed upon before data is collected. If this is a research plan, then hypotheses and hypothesis testing should be at the heart of the scientific method.

Page 27 Section 6.3.1. The “Background” reveals a bias, and that is that contamination is only attributable to well design. That is one factor, but the fracturing of a formation and creating hydraulic connections to drinking water formations is also a major issue. It is not clear why this document is so silent on this issue. This is not just a concern, “…common to all oil and gas production activities.” This research plan does not fully embrace the uniqueness of each hydrogeologic setting and the need to fully characterize the sites at each Retrospective and Prospective case study.

Page 28 Figure 8. The depiction of a well here and elsewhere is idealized, this is fine, but it should be stated that wells are rarely straight and vertical/horizontal. Well alignment itself and how it could impact drinking water supplies is one potential variable of study.

Page 29 Section 6.3.1.2. The casing perforation step is one potential method that could lead to weakening of the casing seal. This should be studied.

Page 30 Section 6.3.2. “While EPA recognizes that fracturing or refracturing existing wells may pose a risk to drinking water resources, EPA has not been able to identify potential partners for a case study.” This is a very poor rationalization by EPA. Creating hydraulic connections between oil/gas formations and potable drinking water formations is the proverbial elephant sitting in the parlor that no one wants to talk about. There is absolutely no credible excuse for not studying the issue of how formation characteristics change as a result of fracturing or refracturing. By choosing not to focus on the hydraulic integrity of formations, the proposed EPA study then must rely on second tier, surrogate parameters. This is not even a poor substitute for studying formation connectedness. For example, if wells show contamination, how is that clearly tied to hydraulic fracturing unless there is one unique chemical signature upon which to make the case? This is the same issue that haunts superfund sites: because we do not know the exact path of groundwater, we can only make inferences about causality. This is fundamentally what has driven Congress and EPA to where they are now: we need to hydraulically connect the dots. Because contaminants travel at different velocities due to how each interacts with the formation, those that show up first may have many sources other than just hydraulic fracturing.

Page 32 Section 6.3.4. The issue of hydraulic fracturing chemicals increasing contaminant mobility is a moot point if no hydraulic connection exists between oil/gas and drinking water formations. All the more important to understand hydraulic fracturing effects on hydrogeology.

Page 33 Section 6.3.6.1. In the Retrospective studies, EPA plans to interpret data from wells at existing sites. In this case, to "…work to determine if well failure was responsible for the reported contamination…" As previously mentioned, it is quite likely that the monitoring network is ineffective at assisting with this goal since it was most likely not designed with that goal in mind. One of the first elements of the retrospective studies should be to assess the veracity of the monitoring network itself.

Page 33 Section 6.3.6.1. The Prospective case studies do not include sufficient detail to fully critique. There is no mention of the monitoring network to be constructed, sampling, or the tests to be performed. There are no metrics identified for statistical testing nor what indicates success or failure.

Page 33 Section 6.3.6.1. Scenario evaluation with modeling needs to address fracturing. Models need to be calibrated and verified. Ultimately these will become the industry (all involved in the subject area, not solely the oil/gas industry) standards for evaluating and assessing sites.

Page 33 Section 6.3.6.1. Does this include modeling the casing perforation technique? Estimating flowback? Need for restimulation?

Page 34 Section 6.3.6.2. Prospective Case Studies: the best "tracer" is the hydraulic signal. Long before any contamination is detected, the hydraulic signal defines connectivity. Insufficient effort is being invested in understanding the hydrogeology and hydraulic testing, and instead the emphasis is on a weaker indicator of impact: detecting chemical changes. The tracer works well for fluids that come back to the surface and have a surface fate. In the subsurface, the tracer may not move as fast as contaminants. In addition, because of the slow movement of groundwater in general, the tracer may have limited utility in the Prospective Case Studies.

Page 35. Section 6.3.6.3. The lab studies will be greatly enhanced in conjunction with time series data from field sites. The aspect of time is not clear: how does time in the lab relate to time in the formation? If it is 1:1, then EPAs studies can only assess the short term issues.

Page 35 Section6.3.7. The list of Potential Research Outcomes is noble, but unlikely to be achieved without the rigorous study of hydraulics. How can one determine fate and transport of chemicals (advection and dispersion) without understanding hydraulics?

Page 42 Section 6.5.3 – Analysis of existing data. This scope is too vague. For example, "…the impacts of the direct discharge of these waters in community wastewater systems." Lack of specificity paves the way for poorly defined goals, hypotheses, and objectives, with results often not answering anything but rather raising more questions. Retrospective studies should gather as much data as possible from WWTPs, etc, and not limit to a handful of sites.

Page 42 Section 6.5.3 – Prospective case studies. It is suggested that before any hydraulic fracturing waters be treated at a POTW, that the consequences first be estimated. Having a reliable predictive tool is a desirable outcome of this task so that future proposals have a screening tool.

Page 42 Section 6.5.3. Residuals management is a glaring omission of this section. Almost no effort is being put towards the ultimate disposition of treatment residuals and the ensuing consequences.

Page 42 Section 6.5.4. The second outcome seems to be poorly selected/developed. Why would we want to even consider the long term effects of inadequate treatment? Shouldn't the outcome rather be to develop guidelines for proper treatment and management?

Page 43. Table 6. Nomination Decision Criteria. The ability to adequately characterize and monitor the sites for the anticipated consequences is an important decision criterion. Not all sites are conducive to adequate characterization or monitoring.

Page 43. Table 6. Prioritization of inputs is needed. The ability to characterize sites should factor heavily in both input and the decision criteria. This is a major issue silent throughout most of the proposed study plan.

Page 45 Section 7.2 Table 8 Tier 2. This assumes that a suitable monitoring network already exists, which is difficult to believe since the original wells were not designed, constructed, and installed with the objectives of this study in mind. This tier should include assessment and enhancement of the monitoring network in order to make it sufficient to test the research hypotheses.

Page 45 Section 7.2 Table 8. There needs to be a Tier for formation hydraulic testing in order to determine if an hydraulic connection exists between hydraulic fracture wells and drinking water aquifers.

Page 45 Section 7.2 Table 8. One of the Tiers should address the modeling component and model development.

Page 46 Section 7.2. Hydrogeologic characterization with existing data should be performed here, with the intent of delineating the possible formation interconnections from the hydraulic fracturing process.

Page 46 Section 7.3. An important outcome of the Prospective Case Studies is to employ any predictive/assessment models that have been developed before the hydraulic fracturing occurs.

Page 47 Table 9. Hydraulic characterization and testing need to be added (relationship between formations, streambed seepage, etc.) Both before and after hydraulic fracturing. Three monitoring wells do not come close to what is necessary. A number should not be specified until specific hypotheses to be tested, as well as a conceptual hydrogeologic model, are proposed. "Calibrate hydraulic fracturing model" is too vague and needs more details. How will permits be handled?

Page 48 Section 8. Chemicals will be grouped by toxicity to humans, but where does that place TDS? Treatment consequences are also very important for something like TDS that may not pose as high toxicity to humans. TDS has been demonstrated in published EPA reports (mountaintop mining) to have dramatic effects on stream ecosystems.

Page 50 Section 9. This scope is too vague and needs more specific information to be considered as a "Study Plan".

Page 53 Section 10. Impacts of well injection on drinking water resources. This research question requires the need for hydrogeologic characterization. The supporting text states, "Scenario evaluations will use data obtained during case studies and will investigate the roles of various injection and geological conditions on drinking water resource contamination." The concern here is that without wells, as well as wells that exhibit contamination, the conclusion is that there is no impact. This gets back to the need for thorough site hydrogeologic characterization.

Page 78 Table B3. The need for hydrogeologic characterization is underscored by the fact that the most frequent public comment was about groundwater.

Pages 102 – 108. Many of the Stakeholder-nominated sites exhibit widespread or individual contamination not necessarily due to spills. This further supports the need for a thorough hydrogeologic characterization.

Page 111 Appendix G. The bullets on this page are a cry for hydrogeologic characterization, yet the text afterwards portrays a methodology intent on only looking at chemical evidence. The field sampling plan is severely flawed if it does not include water level and hydraulic data that support a thorough hydrogeologic characterization.

Page 112 Table G1. A suggestion is to include sample parameters that can be employed as geochronometers, for example CFCs.

Page 113 Figure G1 and text. How is water extracted from the sampler in the lab without creating the same offgassing biases?

Page 116 Appendix G Data Analysis. How is detection of butane, propane, etc. tied to the hydraulic fracturing process? Just because it is detected does not mean that it was caused by hydraulic fracturing.

Page 120 Appendix H. How are the models employed without hydrogeologic characterizations? Wheat is the basis for selecting parameters? TOUGH (and TOUGH2) are finite difference models, so at the heart of such models is a thorough hydrogeologic characterization. Hydraulics in TOUGH2 follow the double porosity concept of Warren and Root. In this formulation, it is incumbent to understand fracture characteristics in the continuum. As with other parts of this study plan, many details of the modeling phase are missing.

Suggestions for Elements of Hydraulic Characterization

Formulate a conceptual hydrogeologic model

A CHM is a simplified representation of a hydrogeologic formation, including hydro-stratigraphic units, hydrologic inputs (recharge), hydraulic parameter estimates, interconnections, boundary conditions, and flow directions.

Geologic characterization
- Observational
- Stratigraphy
- Structure
- Geophysics
- Drilling

Remote Sensing

Surface Geophysics

Water Balance Overview
- Sources
- Sinks
- Resident water/Residence time

Hydraulic Description
- Aquifers
- Aquitards
- Interconnectivity
- Fractures

Background Hydrogeochemistry

Drilling and Hydraulic Testing
Cores

Well Geophysical Logging

Design of a Well Monitoring Network – Paramount is to clearly delineate the monitoring objective(s). Objective examples include:

- Extend existing information
- Understanding the resource
- Maximum developable water
- Well interference
- Hydraulic characteristics
- Ground water – surface water interaction
- Source of water
- Well head area
- Radius of influence
- Basic water quality
- Location and extent of contamination
- Fate and transport parameters
- Ground water protection
- Insure to proper disposal of wastes
- Support/calibrate/verify numerical models
- Formation connectivity

Well Retirement Issues
Maintenance
Inspection
Integrity
Abandonment

**Comments from Dr. Mark Benjamin**

Overall, the Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources describes an appropriate agenda for achieving the stated goals of the study, given the constraints of time and resources. A general concern that relates to many aspects of the plan is that, although statements about accidental releases of HF fluids appear in several places in the document, the study plan does not seem to include any explicit assessment of the likelihood or magnitude of such releases, or of the topographic and hydrological features that would affect their impact. Research Topics 6.2 and 6.4 address this issue most directly, acknowledging that spills or leaks could occur in a variety of scenarios, and pointing to general scientific literature that addresses the fate of released contaminants. It may be that a broad survey of past releases of HF fluids is planned as part of the research, but that is not clear from the draft plan. The same can be said with respect to an assessment of potential system failure scenarios that would lead to HF fluid releases. If no such surveys or scenario analyses are currently planned, it may prudent to consider adding them.

Similarly, the plan to include at least one case study where an accidental release has occurred is laudable, as is the plan to monitor and assess current chemical management practices. Clearly, though, no small group of retrospective case studies, let alone a single case study, can provide the breadth of information needed to make informed policy decisions about how to minimize the adverse impacts of accidental releases in general. Fairly detailed assessment of hypothetical release scenarios that are not known to have occurred, or did occur but were not documented well enough to serve as a good retrospective case study, might therefore be appropriate additions to the research plan, if they are not already implicitly included.

In Research Topic 6.5 (Wastewater Treatment and Waste Disposal), the plan to assess the DBP formation potential of HF fluid additives and their degradation products, and from released components from underground formations, seems prudent. The potential for increased chloride concentrations to exacerbate corrosion in water treatment plants or water distribution systems can probably be assessed based on existing literature, and probably cannot be evaluated with any confidence via short-term bench- or pilot-scale studies, so that part of the research plan can probably be simplified; the same is true for the effect of increased bromide on DBP formation. Many of the problems caused by increased salinity in wastewater treatment plants and drinking water sources can also be evaluated based on simple mass balance calculations and do not require experimental studies. The challenge associated with such problems is that, although they are relatively easy to predict, they are very difficult to overcome in a cost-effective manner.

**Comments from Mr. David Burnett**

*1.* It would be easier for EPA to carry out the charge of Congress is this was a more focused study. A major advantage of a more focused study would be to (a) make it more affordable, (b) make it more likely that good relevant information would be developed, and (c) results would be timelier. *Recommendation - The EPA should clearly state the breadth and depth of the study – i.e. the study is designed to examine the conditions related to* ***hydraulic fracturing*** *that may be associated with the potential contamination of drinking water resources, and to identify the factors that may lead to human exposure and risks.*

2. *Recommendation - There needs to be a statement clearly defined that hydraulic fracturing is a TEMPORARY operation lasting days.*

3. P. 9 - The Figure # is missing from the text

*4.* P. 10 - 3.1 - *Recommendation - The first paragraph should perhaps state "The Drilling process" not hydraulic fracturing process. Companies* ***evaluate*** *possible well sites would be a better statement than* ***exploring****.*

*5.* P. 12 - last paragraph of 3.2 - *Recommendation eliminate "contain the contents of the well in an effort" with "ensure zonal isolation of the formations being fractured stimulated" - at the end of the next to last sentence add - "and ensuring well bore integrity".*

6. P. 12 - 3.3 – In 2010 and 2011 very few sites require large volumes of water to be transported to the site. In most instances, this water can be supplied from nearby water wells or impoundments. And many companies are now drilling into brackish water aquifers, rather than tapping into fresh water zones. *Recommendation – The report should state that water management technology is evolving rapidly and that any surveys and research activities should specifically define what type of strategy is being documented.*

*7.* P. 13 - 3.3 - *Recommendation - add (i.e. injection into permitted UIC Class II wells) after disposal. Class II wells specifically regulate O&G underground injection for brine disposal into non-potable salt water bearing formations.*

8. P. 13 - 3.5 - *Recommendation add to end of first sentence - "or federal land management agencies such as the US Bureau of Land Management for activities on federal onshore leases". Add to end of second sentence - "and maintains primacy on Indian reservations.*

9. P. 14 – Fig. 7 *Recommendation Fig. 7 should somehow acknowledge that wastewater treatment might well allow potential re-use of the water*

10. P. 16 - 5.1 - *Recommendation Retrospective case studies should look at* ***alleged*** *instances of drinking water resource contamination. Prospective case studies should be about* ***probable*** *impacts.*

11. P. 16-17 Existing Data Evaluation. *Recommendation The paragraph should state that many companies are now making fracturing fluid chemical makeup information public.*

*12.* P. 17 - *Recommendation EPA should list the models that are expected to be used. Specifically we recommend that models used by the U.S. DOE. The two-dimensional models they have used to calculate fracture dimensions are the GDK (Geertsma- DeKlerk), the PKN (Perkins-Kern/Nordgren) and "ellipsoidal frac" models. Each has a slightly different theoretical basis, but the results from such were reported to be in close agreement with regard to induced fracture height in this exercise. The use of these models is recommended because they will produce worst-case scenarios. These models assume that planar fractures are always created reaching the longest distance from the point of fracture propagation and do not consider kinked, curved, or branched fracturing that is common in shales.*

13. P. 18 The table asks what are the toxic effects of hydraulic fracturing constituents? The same thing could be said for naturally occurring substances. Recommendation – *report should ask how might possible toxic effects occur under various conditions and situations and at what concentrations?*

14. P. 19 – *Recommendation- the study should employ the newest 5 year update to the 50 year plan of the Texas Water Development Board to be released in 2011 as this document will have the latest and best information available on this subject*.

15. P. 19 Paragraph 6.1.1 The statement "the total volume of water used in fracturing varies with depth and porosity" is not true. Frac volumes are based on the mechanical characteristics of the shale, the well trajectory, the number of stages, and the field development plan. In addition, the porosity numbers in the table provide an inaccurate portrayal of the play. It is the permeability of the shale that determines the rate of flow of the gas to the well. Matrix permeability of shales are in the nanodarcy range. *Recommendation - The report should be reworded to reflect standard fracturing design practices.*

16. P. 20 - the first paragraph states the concerns on "high" rate water withdrawals from small streams without consideration of the rules that are in place by the various river basin commissions. *Recommendation – report should properly acknowledge river basin current rules and permits.*

17. P. 21 - 6.1.4.1 - The key question should be whether water withdrawals for hydraulic fracturing have a long-term deleterious effect on ground water or surface water flows. Withdrawals for any purpose will impact flows.

18. P 22 – Prospective Case Studies-- the figure number is missing from the text.

19. P. 22 - What basis is being used to assume that the future scenario work done for the Chesapeake Bay Program and the ORD Futures Midwest Landscape Program will be useful to the charge of this study? *Recommendation – either remove the references or state how such studies are relevant to fracturing studies*.

*20.* P. 23 – Potential Research Outcomes. The intended scope of work does not seem significant enough to provide for an assessment of current water resource management practices related to hydraulic fracturing. Gas shale plays with significant technically recoverable resources now cover millions of square miles of the U.S. Gas shale development is unique for each shale play. Drilling and fracturing practices vary considerably by geography and geology. In addition, rapid advances in technology make any study based on early data suspect. (Like studying the differences between vertical and horizontal wells.) A useful assessment is somewhat doubtful. *Recommendation - The study would be better served by limiting its scope to the key issues at hand.*

*21.* P. 26 - How is it intended to differentiate between fracturing fluid degradation products and similar products that may be derived from other sources? In the natural environment, many organic chemicals have similar or nearly similar breakdown products and it is difficult to determine the actual parent source. *Recommendation – the report should limit its scope to a realistic study scope and make use of research compiled by energy companies over the past 50 years.*

*22.* P. 26 - 6.2.5.2 - What risk assessment methodologies are planned to be applied to the research on the fate and transport of hydraulic fracturing fluid additives in order to determine the potential relative impact of such? *Recommendation- identify models and model requirements.*

23. P. 26 – Retrospective Case Studies. Surface fluid releases. In the past EPA has sponsored many detailed studies of industrial sites and of the fate of chemicals at those locations. Doesn't this effort repeat that process –except now the industrial site is a well pad? *Recommendation- require consistency with prior models*

*24.* P. 27 - 6.2.6 - Industry trends and methods are changing rapidly. Fracturing technology of the 1990's have been superseded by today's practices. *Recommendation- classify statistical data by era.*

*25.* P. 27 - Will this information be summarized by formation injected into; geographic area; depth of injection; volumes used under various conditions, etc? What value is expected to be gained from this summary? Will time trend analysis of such summarized information be conducted? How will this information be useful+. *Recommendation - The methodology to be utilized to summarize data on the identity and frequency of hydraulic chemicals injected should be clearly stated and the value of that data weighted against the expense and quality of data collected*

26. P. 28 - It is not always necessary to treat drill cuttings - especially those from inert formations that have been drilled on air or with water-based mud.

27. P. 28 - The principal function of a cementing program is to ensure effective **zonal** isolation.

28. P. 30 - 6.3.2 - A more specific approach such should be considered. How long after hydraulic fracturing are the effectiveness of well construction practices to be evaluated? *Recommendation - suggest 5 years.*

*29. Recommendation It is suggested that since the focus of this study is supposed to be around hydraulic fracturing, that the primary well construction practice that should be studied is what methods are employed to ensure and confirm that casings and well cements are properly placed to contain hydraulic fracturing fluids and pressures*

30. P. 31 - The issues of well age and maintenance would seem to be out-of-scope for the purposes of this study and evaluations of such issues have already been conducted by many of the state regulatory agencies. *Recommendation - The best way to ensure well integrity over time is to conduct periodic bradenhead testing*.

*31*. P. 31 - 6.3.3 - The premise of the entire first paragraph is highly speculative and is not supported either by either available theory or evidence as measured in the field through a number of means (e.g. microseismic). *Recommendation – omit this paragraph.*

*32.* P. 31 - Contrary to the statement made in the second paragraph under 6.3.3, there is no clear scientific evidence that leak off from hydraulic fracturing has ever migrated into drinking water aquifers. One of the references cited mentions the possibility of gas migration - not fluid leakoff. One of these references is a news story - not a science article. One of the other references is simply a collection of allegations without any supporting evidence. This is stated as a conclusion rather than a question to be investigated and is not consistent with accepted scientific methods. The citation from Yang is correct as this is what hydraulic fracturing is intended to do. However, this citation is inappropriate in the same paragraph as the preceding sentences as its context is entirely different. *Recommendation – omit this paragraph.*

33. P. 31 - The characterization of all coalbed methane reservoirs as shallow could be misconstrued as the use of the word shallow is a relative term. While some such formations currently produced occur at only hundreds of feet in depth, others are many thousands of feet below the surface. *Recommendation –use qualifiers in the statements*.

*34.* P. 31 - The last paragraph on this page appears to have nothing to do with hydraulic fracturing operations but is more related to production operations. In fact, many of the statements made in this paragraph are in direct contradiction to the conclusions of this study. Allegations are not good scientific data upon which to base preliminary conclusions or to direct further study. *Recommendation – rewrite paragraph to simply state that there are many ways that groundwater may have encroachment from other zones.*

*35.* P. 32 - All of the references provided for the statements in the first paragraph are textbooks the contents of which are primarily directed at soil and near surface conditions. They are inappropriate references for the purposes of this study. *Recommendation –use qualifiers in the statements that state that fracturing shale rock more than 10,000 ft below the surface is not the same as near surface hydrologic or geochemical processes.*

36. P. 32 - 2nd paragraph - What the statements in this paragraph fail to take into account is that a number of methods are utilized to neutralize microbes before they are placed into the formation through hydraulic fracturing operations in order to prevent microbialgrowth that can be deleterious to production operations. The currently employed methods for such include: the use of biocides, chlorine dioxide, ultraviolet light, and ultrafiltration. *Recommendation – state that fracturing operations use disinfection agents to prevent bacterial contamination*.

37. P. 32 - 3rd paragraph - The purpose of this paragraph is not understood. It is indeed the objective of hydraulic fracturing to increases the mobility of methane from the surrounding media into the production well not into the surrounding media. *Recommendation – omit this paragraph*.

*38.* P. 32 - 6.3.6.1 – *Recommendation - EPA would only require those portions of the well files that relate to hydraulic fracturing as intended for this scope of study.*

39. It is not clearly stated as to the criteria that will be employed for retrospective case selection. It would be recommended to ensure that there is good geologic and geographic distribution of such.

40. *It is recommended that probable modes of failure of cement to be modeled rather than any possibility. This should be modeled on a properly risked basis*.

41. P. 34 - 6.3.6.2 - Will the study be examining whether any reported contamination may have been pre-existing? Likewise, could any reported contamination have come from alternate sources? *Recommendation –any studies should include an evaluation of any pre-existing condition prior to any drilling, completion, and fracturing operations*.

42. P. 34 - What chemical tracers would be employed? Will they be non-toxic?

43. P. 34 - What models are planned to be employed? How will the inputs for such be calibrated and determined? Any modeling needs to be compared to known conditions for truthing purposes. There is a high probability that there are too many variables to gain the level of precision needed for good prediction of conditions. *Recommendation - Contaminant fate and transport hypothesis testing should be performed by an objective scientific organization to ensure that modifications to the model are not simply made to fit the case.*

44. P. 35 – The laboratory testing described in this paragraph is extremely complicated. Reaction vessel tests have been conducted in the past – and reaction kinetics are 1st order in surface area of the rock species. Only by relating experimental conditions to real life flow in fracture surfaces would this type of study be relevant. As an example, Dr. Martin Chenevert (U.T. Austin), an internationally recognized expert on fluid rock interactions has more than 90 publications on shale chemistry i.e. **Chemical and Thermal Effects on Wellbore Stability of Shale Formations, Society of Petroleum engineers 2001)** *Recommendation – reduce the scope of this study to literature review of previous research on rocks, shales, and mineral structures.*

45. Where are the cores and cuttings and samples of aquifer materials to be obtained? How will it be determined if these are representative? What methods will be employed for such testing? Who will conduct these tests? How will the validity of any testing methodology be employed? *Recommendation – The report should clearly state that only limited "restored state" studies would be commissioned and that the bulk of the research would be data "mining" from current literature.*

*46.* P. 35 - 6.4.1 - The "flowback" period is generally considered to be the time following hydraulic fracturing until the well is brought into production. The current statements in this section do not demonstrate a proper understanding of this term. *Recommendation – The report should be edited to include a more precise description of flow back period.*

*47.* P. 36 - Flowback is generally not required to be reported because this information is of limited value for regulatory purposes. "Flowback" is a mixture of injected fluids and formation water that changes in chemistry and flow volume over time and is difficult to characterize. High flowback rates will only be found where large volumes of fluid have been injected. There is no **normal** rate of produced water flow. This will always depend upon the formation characteristics in any one area and the success of the hydraulic fracturing operation*. Recommendation - It is suggested that the term post-fracturing produced water be employed for this study as it can be difficult to distinguish between what has been injected and what is being derived from the formation. The stabilized chemistry for such flows can easily be determined though testing of TDS levels.*

48. P. 37 - It should be noted that produced water from well locations is piped rather than trucked for treatment and/or disposal at some locations. Also, the statements on this page do not take into account onsite recycling that may occur at multi-well pads. *Recommendation – The report's statements should be corrected*.

*49.* P. 37 - 6.4.3 - Operations and regulations surrounding such are much better based on probabilities - not all possibilities. *Recommendation- It is suggested that this study should utilize the water well quality database that has been compiled by the Colorado Oil and Gas Commission as this is likely the largest such database that contain information on water quality from both pre-drilling and fracturing operations and post such operations over a period of a couple of years.*

*50.* P. 38 - 6.4.4 - Most states already have requirements for such practices and would be the best source of existing information concerning such. Best practices surrounding such are also documented in API guidance documents*. Recommendation – The report should reference the effort known as STRONGER – an industry effort to coordinate state regulatory practices (http://www.iogcc.state.ok.us/Websites/iogcc/docs/September_2005.pdf) and earlier work Review of State Oil and Natural Gas Environmental Regulations Final Report DOE Interagency Agreement No.: DE-AI26-01BC15320*

*51.* P. 38 - 6.4.5.1 – *Recommendation - The term* ***potential*** *toxic effects should be used here as the toxicity of any chemical will vary not only with the volume of such but its interactions with* *other constituents that may be present and with the actual environmental conditions present at any one site.*

52. P. 38 – *Recommendation - The study should properly state that any research project would need to include a large number of samples from many different vendors and areas to gain any conclusive data*.

*53. Recommendation - that information on the DOE NETL ongoing project concerning isotopic signatures of flowback and produced water be included in the EPA study.*

*54. Recommendation - that the report should include the use of risk assessment and risk analysis methodologies to more realistically reflect the risks and hazards of the practices being evaluated.*

55. P. 39 - 6.4.5.2 – It is not clear that the methodology proposed here will contain sufficient data to produce useful conclusions that can be widely applied. *Recommendation – require cost benefit analysis to evaluate potential studies in this area.*

56. P. 39 – *Recommendation - that the scenario evaluation should focus on methods for verification of proper cementing - not just speculation on what could happen.*

*57.* P. 39 - 6.4.5.3 - How is it planned that the potential for leaking from storage pits will be evaluated? What forms or types of treatment are planned to be evaluated? There are hundreds of vendors of water treatment technology and many new players coming into this field all the time with new ideas and improvements. What is the plan for sorting through such as this may take a considerable amount of effort in order to properly conduct such an analysis? *Recommendation – The EPA advisory panel should consider a more limited study where "best practices" are documented – even if such practices may be chronologically organized to show the change in technology as better practices are adopted.*

58. P. 39 6.4.6 - How has it been determined that there is any need to develop analytical methods to identify and quantify flowback and produced water components beyond that which already exists? For the most part, chloride is the single most reliable indicator of flow from producing horizons. The planned effort appears to create a lot work that may prove interesting but is unnecessary for accomplishing the objective of determining whether there is cross formational flow from producing horizons. The objectives of this section sound more like preparation for regulation rather than any kind of unbiased scientific study. In order to determine the likelihood that surface spills could result in the contamination of drinking water resources, considerable information would be needed on soil types, vegetative cover, slope present and distance to such resources. Because such factors are primarily site specific, this would not appear to be a most efficacious course of action for this particular study as gaining meaningful data would require considerably more resources than are currently available. *Recommendation – The EPA recommended program should define a more limited, but practical approach to the development of analytical methods that will provide useful data.*

*59.* P. 40 - 6.5.1 - The basic premise of this section would appear to be flawed. Post-fracturing produced water is already regulated by a number of entities and intentional disposal and discharge of such that does not meet discharge standards to surface waters is already illegal. Where underground injection is not a viable option, treatment and reuse or transportation of such waters to adequate disposal facilities that meet regulatory discharge standards are the favored options. *Recommendation – This section should be omitted or at the very least acknowledge that state and federal regulatory practices are already in place for this activity.*

60. P. 41 - 6.5.2 - The effectiveness of treatment and disposal methods will vary with the nature of the water at hand and the planned use (if any) of the water that may be treated. Changing the nature of the fluids utilized during the hydraulic fracturing process would have significantly more impact in reducing environmental risk than anything that could be contemplated for post fracturing treatment and disposal. *Recommendation - the study could benefit from taking a course of action that follows such a pathway. Given the current actions taking place in the hydraulic fracturing service industry and using the current plan, the study risks being well out of date before the interim report is done.*

61. P. 42 - 6.5.3.1 - Any potential use of treated post-fracturing produced water should be considered from a sustainability perspective. Any gas well will have a finite life and the water and beneficial use associated with such will disappear when the well is properly closed and plugged as per existing regulations. The suggested laboratory studies may well prove interesting but it would seem that there is some overemphasis on this aspect of hydraulic fracturing as the well integrity issues would seem to be more important. *Recommendation - there is a considerable body of data on the effectiveness of current water treatment technologies and that this could be utilized without the need for significant additional study.*

62. P. 42 - 6.5.4 - The proposed study efforts would appear to be inadequate for the stated purposes of this section. *Recommendation – consider striking this section or modifying it so that the work scope is possible.*

*63.* P. 44 - Table 7 - The Retrospective case studies would seem to be overly focused on methane as this is not used during the hydraulic fracturing process. Potential – underemphasized in the study scope. *Recommendation – refocus the study on well integrity issues and transport of fluids to ground water aquifers.*

*64.* P. 46 – *Recommendation – if literature reviews and preliminary studies show this type of work to be of benefit, then t would be more meaningful if the degradation rate of the chemicals under study were to be known under the various temperatures and pressures found under different hydraulic fracturing conditions. Will the potential of alternate sources of contamination be reviewed and methods for differentiating such as part of the study? Again, in order to gain meaningful information from the retrospective cases that can be widely applied, we recommend that a broad range of conditions be considered and included as part of the study.*

*65.* P. 47 - Table 9 - *Recommendation – report should note that the results achieved from prospective cases may only be applicable to the particular areas and formations being studied.*

*66.* P. 47 - The basic premise of this section is disputed as most practitioners would assert that there is very limited potential for such substances to be introduced into drinking water resources as such has not be found to be true by any of the current regulatory agencies. *Recommendation – use qualifying statements such as "it is possible that" or in some instances".*

*67.* P. 48 - Although hydraulic fracturing has and does take place in a number of different types of formations, it would appear that the primary focus here is mostly on shale plays. *Recommendation – The report should state that the intent of this study is to evaluate multistage hydraulic fracturing in gas shale, if indeed that is the aim.*

68. P. 49 - How relevant are these methodologies proposed to aquifer situations? Will there be any consideration of dispersion and adsorption phenomena within various types of aquifers? Will there be consideration of the solubility and density of any particular constituent and how such might impact transport and concentrations within various aquifers*? Recommendation –Risk probability assessments are needed that are related to such also need to incorporate data drawn from actual conditions - not just theoretical evaluations and calculations*.

*69.* P. 53 - It is believed that potential degradates identified during laboratory studies may not accurately reflect what will occur in geologic formations due to the pressures and temperatures found as well as geochemical reactions that may occur within the formation being fractured. As such, the conduct of such laboratory studies is considered to be of limited use. Such methodologies are believed more useful to surface studies at ambient temperatures and pressures. *Recommendation – the report should acknowledge that water withdrawals for hydraulic fracturing operations are temporary in nature and there is considerable potential for any water source utilized to recover in flow and volume.*

*70.* P. 54 - How will this list of chemicals be used prospectively if they are, in fact, no longer employed in the hydraulic fracturing process? What sort of research is planned to determine what chemicals are currently employed and which ones are no longer utilized? *Recommendation –the report should define chemicals currently used and differentiate them from chemicals no longer used. (The re-use of saline frac brine for subsequent well operations has made early chemicals obsolete. The report should acknowledge that a majority of the frac fluid chemicals already meet environmental conditions for offshore use and discharge.*

*71.* P. 54 - It would be useful for the purposes of this study if it were to focus on likely or actual known risks instead of all potential risks to drinking water from hydraulic fracturing activities. The current scope as presented simply goes far beyond looking at hydraulic fracturing related issues and instead encompasses the entire natural gas exploration and production cycle. *Recommendation –It is again repeated that the study be more focused and prioritized on those key issues that are of most concern to the public and which are in alignment with the charge from Congress.*

72. P. 54 - There does not seem to be a compelling need for Section 11 as these areas are outside of the scope of study and there is no clear reason why they should even be mentioned within this document. It is agreed that routine disposal of wastewaters in Class II UIC wells is well known

and regulated and does not need further study within this scope. *Recommendation –do not include this section in the report.*

73. The use of non-peer reviewed materials and numerous citations from newspaper and magazine articles would not appear to set a solid scientific basis for future study as such documents often contain unsupported allegations and demonstrate a poor knowledge of the processes, practices, and conditions involved in hydraulic fracturing. *Recommendation –use commonly accepted standards for citations in the report – and omit unsubstantiated newspaper reports and blogs.*

*74.* Table A2 - *Recommendation –this proposed research in Table A2 should be made more relevant by focusing on the most recent suite of chemicals employed by hydraulic fracturing service providers to ensure that the information produced is as up to date as possible.*

*75.* Table A3 – Why is injection being mentioned on this table as it was stated previously that such was not to be part of this study *Recommendation –omit the reference to injection in the Table.*

76. P. 77 - Many of the previous commenters may disagree with EPA interpretation that their intent was to support the need for additional study. *Recommendation -EPA should establish a verification process to provide assurance around the real intent of each and every commenter to ensure that the presupposed support for this study is real.*

77. Table B3 – *Recommendation - It is suggested that the most efficacious way forward would be for the study to focus on the top 3 concerns of commenters that are consistent with the charge from Congress for this study.*

*78.* Table D2 - It should be noted that many of these constituents have been found at minute levels as would be expected as they are added in small quantities and much may be left behind within the target formation. It should also be noted that this is a much smaller list than Table D1 which lists those constituents used during hydraulic fracturing operations. It is also puzzling that this is a list of chemicals identified in flowback/produced water while many of the constituents listed would not be considered as chemicals in a scientific sense but are simply naturally occurring elements. *Recommendation – identify naturally occurring elements and differentiate them from fracturing chemicals.*

*79.* 2-butoxyethanol is listed on Table D1 as a chemical identified in hydraulic fracturing fluids. Table D2 of this document lists both 2- butoxyethanol and 2-butoxyethanol phosphate as chemicals identified in flowback/produced water. Indeed, 2-butoxyethanol has sometimes been used in hydraulic fracturing fluids. However, it is also found in a host of other materials including solvents, cleaning products, inks, acrylic resin formulations, asphalt release agents, firefighting foam, leather protectors, degreasers, photographic strip solutions and is a primary ingredient in whiteboard cleaners, liquid soaps, cosmetics, dry cleaning solutions, lacquers, varnishes, herbicides and later paints. The reference source for these listings is EPA's expanded site investigation-analytical results report - Pavillion area groundwater investigation prepared by URS Operating Services. The original report found 2-butoxyethanol phosphate and speculated that 2-butoxyethanol may have reacted with phosphate in the rock to produce what was found. The expanded report (referenced in the draft study scope) stated in its results and conclusions that 2-butoxyethanol phosphate was found at low concentrations (less than 5 ppb) in eleven water wells but did not speculate as to the source of such. Table 9 that accompanies this report only lists Tris (2-butoxyethanol) phosphate as a target analyte. While this is just a synonym for this compound, this could easily lead to confusion. 2-butoxyethanol by itself was not even a target analyte for this part of the study and should not have been referenced in the draft study scope as part of Table D2 as this is inaccurate. *Recommendation – re-write the list and qualify the included chemicals with knowledgeable analytical chemists consulting opinions.*

*80.* Table D3 - Neither of the reference sources for this table are from peer-reviewed journals and should not be considered completely accurate. For instance the reader might note that "chlorine" is not a lubricant as reported in the Table. It is an oxidant and if any frac fluids contain residual chlorine, it is because it was used as a disinfectant – just as in the municipal water treatment industry. *Recommendation –the report could properly put a disclaimer on the list saying that the material may be present only as trace contaminants from a manufacturing process.*

*81.* P. 99 - It should be note that the reference by Ravi (2002) is nearly a decade old and that the example wells used in this paper included only: high-pressure high-temperature wells, deep water wells, gas storage wells, weak, unconsolidated formations, steam injection wells, and producing wells converted info water injectors. None of these types of wells are the primary targets of this study. It should also be noted that most relevant regulatory agencies have requirements around cementing program design and confirmation of such following well completion activities. *Recommendation – use information from STRONGER files to augment and serve as a model information source.*

*82.* Appendix F - It is noted that nowhere is industry mentioned as partners in any of the planned studies. One would think that having such industry involvement would be crucial to the success of any such endeavor as this is where the greatest expertise currently resides. *Recommendation- include specialists from industry with experience in (a) oilfield produced water management, (b) laboratory rock mechanics and core flow studies, and (c) reservoir modeling.*

**Comments from Dr. Shari Dunn-Norman**

**OVERARCHING CONCERNS**

The EPA HF Study Plan will be read by many individuals, activist groups, coalitions and corporations and, as such, must be as comprehensive, factually correct, and informative as possible. The first draft study plan has been written by authors who have little to no hydraulic fracturing experience, and their focus is almost exclusively on the Marcellus Shale. The next draft of the document should be more comprehensive, include much more information about hydraulic fracturing and how the process varies across the United States. In preparing the final draft, it would be very helpful to obtain input from at least a Petroleum Engineer, but at least from individuals experienced at pumping HF treatments.

Section 3.0 (Overview of Unconventional Natural Gas Production) is misleading in the sense that it gives the uninformed reader the impression that HF technology is applied solely in unconventional reservoirs, i.e. shales or tight sands. Many wells are stimulated in high permeability environments (especially offshore) and in those cases the fractures are created to have high leakoff, short lengths, and high fracture conductivity. It is simply impossible to extrapolate findings of this HF proposed study to those types of formations regardless of any approach taken. This should be noted in the study plan.

All sections of the report related to proposed research activities lack any description of the procedures currently employed by industry, and their strengths or shortcomings. The review panel discussed this issue at length with respect to “chemical mixing”. Instead of describing how chemicals are currently mixed, the document makes vague statements about “many spills” without any information about the spills, severity, frequency, etc. This approach within the study plan must be corrected in the next draft, because this document will be reviewed by many people who have little oil and gas experience. It is strongly suggested that the ORD provide this information in the second draft of the study.

Specifically, Sections 3 and 6.3 should discuss relevant practices within each of the shale areas (and high permeability fracturing areas), and their wellbore and fracturing differences. Otherwise, it should be stated that this study plan is focused on *only* the Marcellus Shale.

The document would be enhanced by incorporating some information from the DOE NETL study (http://www.netl.doe.gov/kmd/CDs/Disk2/PWGuideExtras/Sec5-8PWGuideFinal-LowRes.pdf) on water quality, use and disposal differences for the various shale plays and the US. Many areas have Class 2 injection wells, which are excluded from this study plan as they are already regulated. This point should be emphasized.

Figure 6a shows a horizontal well, but Figure 6b and Figure 8 show vertical wells. The differences between the two well geometries should be noted, and the concern areas for multi-zone horizontal HF completions versus vertical wells.

The EPA HF study plan specifically disregards all current regulatory practices of the States, and this seems to be a major shortcoming of the plan. To disregard a large body of experience seems illogical, as it would help to potentially address the *frequency* or *severity* of any issues, and identify if State regulations are currently adequate.

The timing of this HF study is extremely aggressive - it seems impossible that any agency could expect meaningful, well researched results for a study of this type to occur in one year, particularly since it will be months before the work is awarded. It seems unlikely that the timeline will be maintained as proposed.

The next draft should avoid citing environmental activist groups such as "Earthworks" as this reduces the credibility of the study plan. Cite textbooks, or original sources for fundamental technology points related to hydraulic fracturing. Use peer review literature to describe fracturing technology, not internal company memos.

Finally, there is a tremendous amount of detail in the Appendix of this study that really should be included in the main discussion document, rather than tabulated at the end as this may be overlooked by the reader.

## CHARGE QUESTIONS

### 1. <u>Charge Question 1: Water Use in Hydraulic Fracturing</u>

*EPA has identified the water lifecycle shown in Figure 7 to characterize hydraulic fracturing and to identify the potential drinking water issues. Please comment on the appropriateness of this framework for the study plan. Within the context of the water lifecycle, does the study plan adequately identify and address the areas of concern?*

The framework of the study is useful and appropriate since it is organized around water use in the hydraulic fracturing process.

However, in Figure 7 well injection should be separated into well construction versus the fracturing process, i.e. the bulleted points should reflect the three pathways of concern:

- Accidental release to groundwater from the wellbore pathway (e.g. faulty well construction)
- Fracturing fluid migration into drinking water aquifers by direct propagation of hydraulic fractures upward into overlying drinking water formations
- Mobilization of fluids (frac fluids, formation brine) into drinking water aquifers through hydraulic fractures intersecting other existing subsurface flow paths (faults, fracture pathways)

There should be text included with this section to indicate which shale plays have limited numbers of Class 2 injection wells. Pennsylvania and New York (?) may be unique in this context, and therefore the water treatment and disposal discussion should note that. Otherwise the general public may be misled to think frac water is disposed of in POTWs across the United States.

**With respect to all overall lifecycle, the real goal should also be to determine if the impacts, if any, are *significant* and *permanent.***

## 2. Charge Question 2: Research Questions

*EPA has identified both fundamental and secondary research questions in Table 2. Has EPA identified the correct research questions to address whether or not hydraulic fracturing impacts drinking water resources and if so, what those potential impacts may be?*

Under the section on water acquisition, the fundamental question seems acceptable. The secondary questions on water availability should address quality and characterizing existing contamination. The research question should address how changes in water availability or quality will be linked to hydraulic fracturing rather than general contamination mechanisms. **Throughout the document it is unclear how contamination from HF will be differentiated from other sources of contamination.**

Chemical mixing should address the likelihood of an accidental release and expected severity.

I recommend the well injection section be separated into to subsections – one for wellbore construction and the other for the completion process of hydraulic fracturing. The fundamental research questions could be revised as:

- What are the ways in which wellbores fail, and what are the best practices that will protect sources of drinking water?
- What are the possible impacts of injection and fracturing processes on drinking water resources?

From these fundamental questions, the secondary questions could be:

- Could contamination occur if the surface casing shoe is set in a permeable zone instead of an impermeable layer?
- Are there significant risks associated with a liner type completion versus full production casing to surface?
- Should all casing strings be cemented to surface?
- Do industry fracturing models adequately predict fracture morphology and, if so, then under what conditions (net treating pressure, leakoff, formation lithology) could a fracture propagate into an overlying source of drinking water. Do microseismic data from treatments show any such treatments are currently being pumped?
- Is there any evidence to suggest that hydraulic fractures have ever intersected existing subsurface flowpaths? What is the likelihood of this occurrence and how can this be mitigated?

The question "What are the toxic effects of naturally occurring substances" seems impossible to answer from 4 case studies. A toxicology study is beyond this time frame.

While the fundamental and secondary questions of the remaining sections seem acceptable, they should really reflect the need to characterize the frequency and severity of suspected problems, not just a single occurrence.

## 3. Charge Question 3: Research Approach

*The approach for the proposed research is briefly described in Chapter 5. Please provide any recommendations for conducting the research outlined in this study plan, particularly with respect to the case studies. Have the necessary tools (i.e. existing data analysis, field monitoring, laboratory experiments and modeling) been identified? Please comment on any additional key literature that should be included to ensure a comprehensive understanding of the trends in the hydraulic fracturing process?*

Appendix F contains 41 stakeholder cases forwarded for study. Assuming that these cases capture the realm of potential problem water wells, it seems hard to understand why only 4 of these would be selected for forensic investigation. Selecting only 10% of the cases to study (based largely on the availability of data or self imposed time constraints), will almost certainly provide misleading results or information that cannot be extrapolated. If 2 of the 4 cases find contamination, exactly how would that finding be used?

Meaningful results might be determined by studying all cases, and comparing the fractured wells around these potentially contaminated water wells, to fracture treatments in the same field where no contamination occurred. Are management practices to blame? Well construction?

The research approach proposes modeling, but the modeling seems to focus on ground water models in which researchers will embed a fracture assuming who-knows-what with respect to the fracture height, length, width and conductivity. Standard industry fracturing models are not even mentioned in this draft study. Output of industry fracturing models would necessarily be the input of any other model for the results to have any validity.

Laboratory studies seem premature for this work.

## 4. Charge Question (4a): Proposed Research Activities – Water Acquisition

Studying 4 cases in limited areas cannot adequately address this issue. Each shale play and geographical area is unique with respect to water sheds, rainfall, climates, vegetation, groundwater hydrology, etc. Each shale play will have a typical practice of water use (impoundment, withdrawal) and disposal (POTW vs Class 2 injection). I do not see how this can be generalized beyond the sites selected.

## 5. Charge Question (4b): Proposed Research Activities – Chemical Mixing

This section seems overly ambition and needs to focus on the chemicals most frequently used in the industry in hydraulic fracturing treatments. A toxicity study is beyond the scope of this work and it is not possible for 4 retrospective cases to provide insight into the likelihood of a spill occurring. The EPA should coordinate with States to obtain a more comprehensive idea of spill occurrence.

## 6. Charge Question (4c): Proposed Research Activities – Well Injection

Section 6.3 should to be rewritten to separate well construction from the completion process of hydraulic fracturing. Illustrate the range of well bore geometries and construction methods, and a comparison of the relative risks between them noted (or at least their major completion differences). It is likely that well construction may be the culprit for any potential contamination found, and from reading this document it is not clear how this will be identified.

The discussion regarding surface monitoring during treatment should be rewritten to note this is a standard practice. Include a diagram of a typical treatment pressure record, with pumping rates. Include credible peer reviewed references about surface monitoring and its value in determining fracture morphology.

The paragraph on leakoff has been written to create an impression that leakoff is beyond control of the industry. Hydraulic fractures occur because the fluid is incompressible, and applied pressure breaks the rock through the applied hydraulic pressure **(there is NO subsurface explosion involved in hydraulic fracturing).** In *high permeability environments*, or conventional reservoirs, the pad fluid leaks off to the pore space of the formation as the fracture propagates through the subsurface. When the pad is fully leaked off (spent) the fracture can no longer grow. In shales, there is such low permeability that leakoff to the main formation is negligible and the fluid pumped is opening (perhaps even dissolving material with) natural fractures within the formation. Leakoff may seem high because of this, but the fluid is not entering the matrix rock – it is opening fracture pathways. This paragraph needs to better reflect the process and cite sources from textbooks and industry experts (not grey sources).

Other comments are noted above.

The outcomes for this section are not attainable with only a 4-well study. It is simply not possible to broadly assess the integrity of wells with respect to casing, and cement placement by looking at only 4 examples. Similarly, it is impossible to determine the frequency and severity of well failures, and factors that contribute to those failures, by studying only 4 cases. Without a broad study which includes State level information, it is also not possible to indentify key conditions that increase or decrease the likelihood of the interaction of existing pathways with hydraulic fractures.

What should be possible is to model fracture height growth and input parameters (pressure, fluid type, distance to overlying USDW) and then compare the model conditions that might create a pathway to the treatments being pumped. Microseismic data should be used to verify actually treatment heights.

This section also includes a determination of water quality before, and after fracturing for prospective case studies. This includes chemical studies, fate of potential contaminants, etc. This seems to be an overly ambitions outcome for the time, resources and state of technology.

In the "Area of Evaluation" paragraph it should be noted if States are already using this oversight. Isn't North Dakota doing this? The paragraph reads as if this is not being done at all.

## 7. Charge Question (4d): Proposed Research Activities – Flowback and Produced Water

The text gives the impression that the primary concern is flowback water from the Marcellus Shale and it proper handling and disposal. This section would be greatly enhanced if the reader were informed of how many areas of the country use Class 2 injection wells compared to disposal through POTW. Again, this document will be used as a resource by many layman who know little about hydraulic fracturing, so it is especially important to correctly convey if the primary concern is the Marcellus because Pennsylvania (and New York and ? ) have limited Class 2 injection.

What percentage of the loadwater is typically recovered for each (a) treatment type and (b) play area. It would be helpful for the reader to know this.

Tracers are used to identify when flow back stops (or salinity curves with time). Tracers are used in waterflooding by the oil industry, but since hydraulic fracturing is a reversal of flow, it is unlikely that tracers will provide meaningful (definitive) characterizations of subsurface flows from a fractured well to a USDW.

## 8. Charge Question 5: Research Outcomes

Most of the research outcomes are overly ambitious and are unlikely to achieve meaningful results by studying 4 retrospective cases over a one year period. Prospective cases will have a longer period of time but must be designed more carefully to produce meaningful results

Use modeling where it makes sense and include geology more extensively in the studies.

## Environmental Justice

These comments are provided after the panel review. The committee discussed environmental as a "cost" to POTW end users who would be forced to pay the escalating costs for retrofitting their water treatment facilities to handle higher salinities, etc, from the inclusion of treating hydraulic fracturing water. As I understood it, this term is not a socio-economic issue unless the increased burden would unduly burden lower income water users. Although many present committee members felt that this was an important part of the study, I feel that its inclusion is premature at best and that, in general, societal issues should not be included until the results of this study are finalized.

**Some specific comments (from initial review):**

P 12. In all wells casing and cement **are installed to provide structural integrity and zonal isolation.**

The sentence "As injection pressure is reduced, the fluid is returned to the surface, leaving the proppant behind to keep the fractures open." This sounds like a gradual reversal of flow and is not correct. Rewrite this with help of knowledgeable person.

P 16. Retrospective case studies should look at **alleged** instances of drinking water contamination…

P18 - Chemical Mixing

The question should be whether there are possible toxic effects from chemicals used in certain typical concentrations during hydraulic fracturing treatments in a range of geological conditions.

P19 **–** How will the study differentiate companies who construct purposeful impoundments versus those who withdraw from the subsurface? This aspect of the study should clearly differentiate the two, for each major shale play basin. This entire section implies that the focus will be on large scale withdrawal with no attempt made to determine the magnitude of withdrawal versus impoundment. The study approach is too general, and should be made more specific to regions, water management practices being used in specific shale plays, etc.

P23. Section 6.2 ff
In general, how will the study differentiate correlation from causation? If chemicals are present in water, how will the study trace their origin to a definitive source?

P 25. It would seem important to quantify the frequency and severity of any spill failures as part of the study.

P 26-27 Does EPA plan to create a database of chemical used, concentration and frequency? If so, how will this information be useful? Will the toxicity of every chemical be tested at varying concentrations? For humans? Fish? Wildlife?

P26. It is stated that one of the retrospective cases selected includes a potential spill release. One, or even two cases, would be too limited for general conclusions.

P28 ff

Correct the word “wellhead” in Figure 8 to “tree”. Include pictures of surface pump trucks on location and more detailed information about the fracturing process.

It is important to examine setting surface casing in highly permeable zones compared to impermeable formations.

Not all production casing strings are cemented back to the surface casing. Formations exposed to the annulus could be sources of inflow, rather than hydraulic fracturing. An example are coal seams above the shale plays.

Aging effects on casing strings is outside the scope of this study.

p. 30. The statement “Some or all of these substances may find a pathway to USDWs as a result of fracturing activities…” This seems to be a conclusion of the study that hasn’t yet been conducted.

p. 31 Leakoff is a purposeful phenomena of the fracture treatment design. The pad is intended to leakoff to the formation to propagate fracture growth. When the pad is spent, the fracture stops growing, and pumping stops. The amount of pad (leakoff) is determined by the type of rock to be stimulated.

There is no evidence that leakoff has ever contaminated drinking water. Are all references cited on p31 scientific references?

Well abandonment for the protection of drinking water is a separate topic and, if the relationship between abandoned wellbore and hydraulic fracturing is to be studied, it should be stated clearly.

p. 32. Shallow soil surface studies are not relevant to deeper formation flows. Have there been relevant studies at reservoir depth?

To be relevant, EPA will need to study a statistical sample of wells for construction failure frequency and severity. Studying only a few, select cases will lead to erroneous perceptions of the well construction process.

P.33 How will EPA gather annular samples in wells with surface casing cemented to surface? Or will sampling occur in the tubing-casing annulus in wells with packers?

Fracture modeling/treatment simulation software, such as STIMPLAN, should be specified for the study. Study should include fracture, height, length, width. Post fracture pressure transient analysis should be completed to identify fracture morphology.

In addition to studying well case history, a comprehensive study of cement/casing bonding and differential expansion/shrinkage pre-and post frac should be considered. The differential behavior of cements, steel and rock should be studied.

p.34 part 6.3.6.2 This is an extensive modeling effort which leads to many questions. Who will conduct these studies and with what data? How will the results be validated?

Is "Area of Evaluation" a new term defined for hydraulic fracturing with the same intended meaning as AOR for Class II injection wells? This is what is implied and it seems presumptuous to have this term already in place.

p. 35 Nothing in the proposed study will indicate the frequency or severity of well failures. To do this will require a statistical sampling of wells from each shale play.
Similarly, the proposed activities are unlikely to answer key conditions that increase or decrease the likelihood of the interaction of existing pathways with hydraulic fractures.

p. 35 Flowback – the purpose of flowback is to unload the well from the frac water so that hydrocarbons can more readily enter the wellbore. Rapid recovery of load water is preferred to prevent clay swelling. The document should convey the purpose of flowback.

Industry does not report flowback water because it is of little interest. TDS is often monitored simply as an indication when the majority of flow is from formation water, thus signaling that a majority of the load water has been recovered. The discussion about flowback rates seems irrelevant to the study.

P 37. 6.4.2 Implies a national level study of flow back water compared to either water well or ground water quality. This seems beyond the scope of this study.

p. 38 Add the work "potential" toxic effects….final sentence of 6.4.5.1

What is the scope of the DOE NETL flowback water study? Is that study sufficient as to simply support the EPA work without additional sampling. The sample size for this to be meaningful would seem very large.

The disposal of post fracturing water load is already regulated by states and so the purpose of this section is unclear. Any spillage would be illegal. So, the need for additional study in this area is less clear than other areas.

p.41 What is the frequency of use for POTWs? It would seem that the study would need to evaluate a wide range of waters, and bromide/chloride combinations in numerous POTWs to answer the question at bottom of page 41. This does not seem feasible. Due to the stochastic nature o f hydraulic fracturing, it is unlikely that any two load waters will be the same.

p. 42. The proposed study is not adequate for the bulleted points under 6.5.4.

p. 46. ff In general, it would be more useful to understand how chemicals used in hydraulic fracturing were altered in-situ, post treatment, for each geological basin/depth/pressure/etc. The proposed study does not address this.

The number of case studies proposed throughout the DRAFT plan are too small to provide any meaningful conclusions about the frequency or severity of any potential contamination issues. Again, it would seem more meaningful to study other hydraulically fractured wells around the proposed study wells, for comparison.

p. 47 ff – If EPA evaluates hundreds of chemicals as part of this study, will there be minimum toxicity levels released that have application to other E&P activities, or only hydraulic fracturing?

**Comments from Dr. John P. Giesy**

The answer to the charge question is NO. There will be too much uncertainty. But that does not mean that it will not be useful to conduct the exercise to gain knowledge and experience and a proposed method of monitoring for and keeping a national registry of dverse outcomes.

I would start out by commending ORD for an excellent analysis of issues and suggested approaches to study the issue in a short period of time. All of the study questions are appropriate and all of the proposed studies will bear fruit. However, some of the proposed studies would be more useful for completion during the next two years.

There is no easy way to approach the problem and no approach will be perfect, but the study might result in a set of standard practices that will improve safety and decrease the risk of contaminating groundwater.

In general I thought the questions being asked were appropriate and likely the most relevant and of immediate concern.

The decision to look at both direct and indirect effects by releases of chemicals and effects of water removals on drinking water quality and quantity is well articulated and appropriate to do.

It is appropriate to look at natural products in return and produced water as well as the chemicals added in HF.

All three approaches, retrospective, prospective and scenarios will be useful in obtaining information that can be sued to address the potential risks and to develop guidelines for HF. However, both the retrospective and prospective studies suffer from a lack of resources. The sample sizes will be small and the greatest utility of these types of studies will be to develop empirical experience for a cadre of US EPA experts to continue working on the topic.

The case studies will be useful but not indicative of all situations. However, it is good that they will be sited in different geographic regions to give some indication of the range of possible effects.

Partnering with industry and with other agencies is mandatory and ORD has done on excellent job of doing both of these.

It is suggested that a national monitoring program be instituted as soon as the target chemicals have been identified and when methods are available. But this is a long-term goal beyond the scope of this set of studies.

The initial focus should be on surface contamination (spills) and treatment which is where the primary pathways of exposure likely lie.

Focusing on retrospectives is an excellent idea, but will not be perfect.

In general the proposed studies will be useful and result in valuable information that can be used in the national policy debate. Most of the studies and approaches laid out by ORD are appropriate and the proposed methods will likely result in useful information.

The most useful information will come from the literature review and then assembling and critiquing what is known and what is not known. Development of a data gaps analysis will be most useful.

The use of retrospectives will be useful, but the information available might be limited.

Before any accurate studies can be planned a complete list of materials used in HF needs to be generated.

Once a list of chemicals used in HF has been generated then it is suggested that a Risk Assessment paradigm be followed to determine the probability of adverse effects.

Human toxicity data will not be available for most HF compounds so cannot do a complete risk assessment. Suggest simply prioritizing compounds to look for based on amount used, mobility and a first cut a know hazards.

It is going to be difficult to determine exposure in a risk assessment so should just focus on the probability of contamination occurring. It will be difficult to conduct a risk assessment for the more than 300 compounds that could be used in HF.

The first step would be to determine potential—site-specific, of interaction between HF and drinking water. Just studies of the accuracy of predicting and then monitoring for the lengths of fractures will be very useful. If there is no overlap between fractures and groundwater aquifers then there will be no need to look at the hazard side of the risk equation.

The risk assessment should focus on the exposure side of the equation. If contamination of groundwater does occur, the public will not want to use surface or groundwater for drinking regardless of the level of risk. So from a perception perspective the EPA should focus on exposure and if there are instances of exposure documented or predicted, then the potential for adverse effects should be assessed secondarily. There will be spills so focus on this first.

In a risk assessment, the hazard component is almost irrelevant since people will not want water that is contaminated regardless of the risks. So focus on probability of contamination occurring.

Treatment of return water and cleanup of spills is the most pressing need. Most treatment plants will not be prepared to treat many of the listed compounds used in HF.

It is suggested to spend no time or resources on conducting toxicity testing to develop information.

The use of quantitative Structure Activity (QSARs) will not assist in the risk assessment.

It is suggested that methods development for identified compounds not be conducted. The time required to develop and validate methods is too long to be achieved in the near term.

Focusing on treatment methodologies is a reasonable approach.

Measuring the water quality of surface waters such as streams and rivers in regions where HF is occurring will likely not provide useful information. This will take a lot of resources if measurements are made and it will be difficult to link changes directly to HF.

Determining effects of HF on water quantity in areas of HF will be more useful. But even this will be difficult to link to HF unless good information is available on removals.

The use of USGS data on water quality is a good one, but may be limited by lack of overlap between where HF occurs and data is collected by the NWQA data is available.

How will mixture effects be addressed?

It is going to be difficult to compare to standards because they do not exist for most of the compounds.

Adding a tracer to HF wells is not suggested. Use site-specific knowledge of what is added as a tracer.

The studies of mobility under laboratory conditions while not perfect, will be useful in predicting mobility in the environment and these tests can be done fairly quickly and cost effectively.

It is suggested that a matrix be developed for the chemicals added in HF and likely natural products to occur in produced water. The develop a matrix of what is needed to be known about each chemical. From this develop a list of data gaps to be filled.

It should be possible to conduct a screening-level risk assessment to determine some obvious “bad actors” based on persistence, mobility and toxicity. Perhaps an index could be developed to rapidly score chemicals. I liked the proposed classification of chemicals based on low, medium and high probability of effects in humans. This would be the equivalent of doing some crude risk assessments based on volume of the chemical used, probability of migration, persistence and inherent toxicity.

It is suggest using a system such as (SCRAM) to score chemicals. This has the advantage of developing a chemical score based on its properties and an uncertainty score based on what is not known. The aggregate score then ranks the chemical. In this way instead of ignoring chemicals for which little is known, there is an incentive for industry to gather the missing information to reduce the overall score. This spreadsheet model (Excel) model was developed jointly by US EPA and the State of Michigan and available from the authors (Snyder et al., 1999a,b,c,d; Mitchell et al 2002).

The major issue will be surface contamination and volumes that need to be treated before release to the environment. This is where effort should be focused first.

Basing the assessment of retrospective studies might allow calculation of probabilities of effects and to identify those specific sets of conditions that lead to an adverse outcome, but will not relate to site-specific conditions or alleviate concerns of the public

Can use probabilistic modeling, but need to remember that this always allows for some probability of effect and cannot predict which wells are likely to be an issue.

Focus on monitoring spills and treatment of wastes and develop adaptive and remediation plans to deal with these situations in a rapid response to minimize contamination of surface water and groundwater.

References

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**Comments from Dr. Jeffrey Griffiths**

**Charge Question 1. "…. *Within the context of the water lifecycle, does the study plan adequately identify and address the areas of concern?"***

In large part, yes.

Having stated that:

1) In figure 7 there should be a feed-back loop from the "flowback and produced water" box which returns to the water acquisition and chemical mixing boxes. It is clear that there is substantial recycling of "flowback and produced water" for re-injection which is not represented.
2) In a more minor comment, I found the word "water availability" to be a somewhat inadequate descriptor for: (1) water *quantity* and (2) the *timing* of removal during the hydro-ecological cycles, both of which are aspects of availability. [I am unclear the research strategy addresses this issue of temporality explicitly, although there are some references suggesting that spatial and temporal issues will be examined].

**Charge Question 2. Research Questions.**

I believe the US EPA has identified key research questions to address impacts on drinking water resources.

A number of the research areas listed in Appendix B on pages 78 and 79 are relevant to drinking water resources, and issues such as long-term impacts from abandoned or aging wells, effects on drinking water wells, and the recycling of water appear to be highly relevant. I will request justification during the meeting why the recycling of water, for example, is not more highly ranked. Please note that I believed the hydrological lifecycle of figure 7 is incomplete as it does not include this component.

The charge question, relating to potential impacts on drinking water resources, is narrowly drawn, and thus many of the questions of interest to the public and scientific community – air quality, for example – are not within the charge to the committee. The statement (page 5) that the EPA will announce requests for applications for extramural research projects related to this study, and that it is in dialogue with other governmental bodies, may require clarification as to what will actually be funded, and which of the lower priority issues will be in part or wholly addressed through those mechanisms.

Understanding this focus on drinking water sources, there is a major opportunity during the conduct of this project to identify "low hanging fruit" for other important research questions which the SAB has already recommended be conducted, albeit with less urgency than the studies outlined in this draft plan. The majority of my comments regarding this are listed under Charge Question 4 – however the concept is outlined in the example below:

The list of known chemicals used in the fracturing process includes known carcinogens. During this water resources study, the safety and monitoring practices used during the mixing of chemicals, for example, could be noted for the design of a future or concurrent separate study on the occupational hazards this poses to the persons involved in fracturing who have exposure to these mixtures and fluids.

**Charge Question 3. Research Approach**

1) In the description of the research plan, I believe that one potential problem is that the US EPA does not currently know what the spectrum of chemicals / proppants actually are. Appendix C details the request for information sent to a number of companies, and Appendix D details some of the reported compounds found in injected fluids, flowback, and released by the process. It may be prudent to *archive some samples* for later testing. This activity may lie within the purview of several of the suggested research questions.
2) Managerial practices are important throughout the fracturing cycle. It is mentioned in the prospective case studies but not so explicitly in the forensic retrospective studies, nor as a factor that may influence the likelihood of a contamination event (table, page 73). It may be the intent to have these practices examined, as suggested at times in the retrospective studies, however I think this should be more clearly delineated as an outcome of interest.

**Question 4. Research Activities.**

**As a lead discussant on mixing of chemicals(4b, scheduled for 8 am Tuesday morning), I note that there is no current description of examining how the mixing vessels and transport trucks will be cleaned either on or off site, and the potential for contamination of drinking water resources. Furthermore, the actual process of mixing is not well described – perhaps because of variations in how it is conducted - and I would like to know more about the process or processes in order to discuss this question more fully.**

1) I have some concerns that the prospective case studies mentioned in the research plan will be conducted at sites managed with "best practices" strictly enforced, e.g. the outcomes may not be representative of the average site. During the meeting I would like to hear some discussion about how the prospective case studies will adequately represent the full spectrum of events that can occur during fracturing.
2) The SAB recommended engagement with stakeholders throughout the research process. Is there a way the EPA can make this engagement more concrete and functional …. Having enunciated and defined a set of concerns and research questions, can the EPA then engage stakeholders in identifying or creating sources of information which will inform the research process? ….. two examples are provided below:

    2a) For example, the research questions around the effectiveness of treatment and disposal include identifying the effects of HF wastewaters on drinking water utilities. In the research approach, it is possible for drinking water and wastewater utilities to be engaged and actively participating in a data collection process where they voluntarily report effects they note when dealing with hydraulic fracturing water? This particular activity is not a case study, rather it is active engagement with participating stakeholders.

2b) Ambient air may be subject to releases of gas at fracturing sites which contain benzene and similar compounds. Lupo et al (Environmental Health Perspectives, 119(3):397-402) have reported that in Texas, maternal exposure to benzene is associated with neural tube defects, such as spina bifida. During the proposed analysis of existing data, the suggestion is made (e.g. Appendix A, page 70) that HF sites be surveyed and mapped. Once this has been done for the purposes of studying water resources, the geo-coded data set of HF sites could be used by the US EPA or others to pursue questions relating to air quality.

In reviewing the research questions, I tried to imagine how the questions and following approaches and activities would use information about a fish die-off. I see little emphasis on the utilization of obvious ecological information. By this I specifically do not mean the US EPA should necessarily focus on the acquisition of ecological data, rather, that a place for the incorporation of ecological data should remain in the research design and conduct process.

**Question 5. Outcomes.**

The proposed research does have the potential to "identify key impacts, if any, of the HF process on drinking water resources," and provide at least some relevant information regarding toxicity and exposure pathways. Care will need to be taken to carefully choose the sites for retrospective and prospective studies. It is unclear that in the absence of more exhaustive epidemiological studies that the full range of potential toxicities will be identified through this approach; however, identifying exposure pathways may serve as an initial starting point for preventing future exposures and possible harm to the public from those exposures.

**Comments from Dr. Phillip Gschwend**

**<u>Charge Question 1: Water Use in Hydraulic Fracturing</u>**
*"EPA has used the water lifecycle shown in Figure 7 to characterize hydraulic fracturing and to identify the potential drinking water issues. Please comment on the appropriateness of this framework for the study plan. Within the context of the water lifecycle, does the study plan adequately identify and address areas of concern?"*

<u>Gschwend comments on Question 1</u>

1. The figure chiefly suffers from a common "life cycle" problem: where should the boundaries of the system be placed? As unfortunately, often occurs, this figure shows the boundaries only reaching to the edges of the particular industry represented and chiefly provides a list of potential inputs of toxic substances to drinking water supplies from hydraulic fracturing activities. This framework fails to show that this hydraulic fracturing use of water should be seen as imbedded in the larger hydro-biogeochemical cycle of a region AND that it has a good chance to substantially alter that cycle (at least locally or regionally). We know that changes in such longstanding natural cycles can have major impacts on water supplies. For example, by instigating groundwater pumping at ~30 m in Bangladesh a few decades ago, the natural hydrological cycle of that region was changed as surface waters were newly induced to infiltrate. This ultimately caused new contact of water with relatively high organic loads with uncontaminated subsurface solids that had previously not experienced such conditions, and the result was the exposure of the population to extremely unhealthy arsenic levels in the drinking water supply! Hence, I suggest the water lifecycle shown in Figure 7 should be expanded so we are sure to ask: "will the proposed fracturing water usage substantially change local/regional water fluxes and cause new biogeochemical conditions at important places and times in our natural water supply systems?

2. The figure also fails to represent the unique chemistries present at thousands of feet below the ground surface. For example, we know that the entire 238U decay series, including 222Rn, will be represented in the formations' waters. By pursuing the natural gas resource extraction technology, we will simultaneously be short-circuiting connections in the hydrosphere that had little chemical exchange previously. One cannot simply focus on the chemicals used by the hydraulic fracturing industry (and relatively "traditional" water quality parameters like chloride, bromide, and BOD) as emphasized in the Figure.

3. One of the greatest impediments to anticipating unhealthy water supplies is the fact that "we" allow industries to utilize "proprietary" substances with no assurance that they will not adversely affect our water supplies. Since natural waters effectively serve as the Earth's vascular system, this situation is comparable to allowing individuals, untrained in biochemistry and physiology, to introduce "unidentified" drugs into our bloodstream to achieve a particular health-related goal. And we are simply left to trust that there won't be unwanted side effects. The bottom line, Figure 7 needs to capture a huge area of drinking water issues that are regulatory (and perhaps economic in the sense of still enabling companies to garner advantage from there materials choices). And perhaps in a related sense, the figure gives no indication of what we will do when

(not if) we experience something akin to the unfortunate Deepwater Horizon blowout in one of our Hydraulic Fracturing wells; we need to plan (?regulate) for the impacts of such a hopefully very rare, but potentially catastrophic, event now.

**Comments from Dr. Nancy K. Kim**

**Charge Question 4(c): Proposed Research Activities – Well Injection**

***Proposed research activities are provided for each state of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Well Injection stage of the water lifecycle? Pleas provide any suggestions for additional research activities.***

***How effective are well construction practices at containing gases and fluids before, during, and after fracturing?***

The activities EPA intends to undertake will provide information to help answer this question. However, without additional information, it isn't clear how well this question will be answered.

Analysis of existing data: well files
EPA asked for information for sites where hydraulic fracturing operations occurred within the past year. EPA is going to select a representative sample of sites and request the complete well files for these sites. Limiting the information request to the past year has the benefit of reducing the number of sites that EPA must review for selecting the sites on which to focus. Limiting the data call to sites with hydraulic fracturing operations occurred within the last year could exclude older sites that might have a higher potential for being associated with well failures. If drinking water contamination was occurring at newer sites, the possibility of it not yet being detected might be higher than at older sites. Has EPA selected criteria for selecting sites for obtaining complete well files?

The potential product from this activity is: "Data on the frequency, severity, and contributing factors leading to well failures." It isn't clear that accurate information on frequency will be obtained and may depend on the information required in the spreadsheet. EPA should provide limitations or uncertainties in describing its findings.

Retrospective case studies
This activity is expected to produce "Data on the role of mechanical integrity in suspected cases of drinking water contamination due to HF" and that should be achievable at least for the retrospective cases that are studied. EPA should provide information about how these data can be related to other HF sites.

Prospective case studies
These studies are to: provide data on changes (if any) in mechanical integrity due to HF and identify methods being used (if any) to monitor mechanical integrity after HF.

These potential products should be achievable although EPA also provide information about how these data can be related to other HF sites.

Scenario evaluation

The potential product for this activity is:
Identification and assessment of well failure scenarios during well injection that lead to drinking water contamination.
If the models can be appropriately calibrated and validated, they may provide some useful insights that might lead to further investigations.
– What is meant by unexpected situations?

**<u>What are the potential impacts of pre-existing man-made or natural pathways/features on contaminant transport?</u>**

<u>Retrospective case studies</u>
The potential products for this activity are:
Assessment of the role of pre-existing pathways in the transport of HF fluids, natural gas, or naturally occurring substances to drinking water resources
Data on the location of hydraulic fractures and their potential connection to other pathways

Depending on the specific case studies, this activity may or may not be able to provide an answer that can be generalized to other sites although it is likely to provide some useful information.

<u>Prospective case studies</u>
The potential products for this activity are:
Identification of processes and tools used to determine fracture location and properties
Data on water quality before, during, and after injection (possibly using chemical tracers)

The prospective case studies are probably more likely to provide useful data than the retrospective case studies.

The following are questions related to tracers that may be used. How will the tracers be selected? Will there be any toxicity or fate and transport criteria for the tracers? How will nearby communities react to adding tracer fluids? Why would these be better than indicator chemicals for fracturing fluids or substances that may be released?

<u>Scenario evaluation</u>
The potential products for this activity are:
Assessment of key conditions that affect the interaction of pre-existing pathways with HF fractures
Identification of the area of potential impact

The models may provide some useful suggestions that should be further investigated. I have general reservations about models being able to provide definitive results by themselves alone, but could lead to useful information when combined with additional work, e.g. field investigations.

Question for clarification: Early on in the document, EPA used the term "site." How is the definition of site related to the area of evaluation.

**What chemical/physical/biological processes could impact the fate and transport of substances in the subsurface?**

The potential products of this activity are:
Assessment of fate of HF fluid components and naturally occurring substances
Assessment of the identity, physical and chemical characteristics, mobility, and concentration of potential drinking water contaminants

The laboratory experiments are likely to provide some useful data. However, it isn't clear how laboratory studies of core samples alone will be sufficient to characterize and evaluate chemical, mineralogical and microbiological degradation products. The number of variables that may affect the formation of degradation products in the environment seem to be too numerous to reproduce in the laboratory using core samples alone. How is EPA going to select the core samples, the specific HFs, the conditions for the experiments, etc.? EPA is likely to have to be careful about how it describes the limitations and usefulness of the results. However, in addition to what is already know about possible degradation products from the literature, industry, etc., this activity is likely to expand our knowledge of these products. EPA should compare these results with the results from field work.

Is EPA adding by-products formed when these chemicals are treated with disinfection agents?

**What are the toxic effects of naturally occurring substances?**

The potential products from this activity are:
Compilation of information on the toxicity of naturally occurring substances
Prioritized list of chemicals requiring further toxicity study
PPRTVs for chemicals of concern

The first product can be produced, and EPA is using SAR and predictive toxicology tools to estimate what the hazards may be from chemicals with no or little data. This is a reasonable approach and will provide more information that only using what is in the literature. EPA's plan for prioritizing chemicals for hazard needs to include some measure of data quality (human data vs. SAR information). It also has to include some data quality measure if PPRTVs are developed. EPA's approach to assessing hazard is good and takes advantage of new tools.

EPA prioritizes chemicals using hazard (and perhaps potency data) to identify which chemicals may need additional testing. EPA does not discuss how it is going to use occurrence data (both frequency and concentration) in prioritizing chemicals. A chemical with the potential for high concentrations in drinking water that may not be extremely toxic may be more of a concern than a more toxic chemical that has little occurrence potential. This needs to be added.

EPA learned from developing its most recent CCL and should apply those lessons to this exercise.

EPA needs to consider risk and not just hazard. EPA should also consider other types of risks (explosions) that these some of the chemicals might pose and not just toxicity. EPA should also consider including aesthetic impacts on drinking water. It is appropriate that EPA consider the possible impacts of disinfection practices as it mentions in Chapter 8.

In 6.2.5.1, EPA mentions it "expects to identify a short list of 10 to 20 chemical indicators to track the fate and transport of hydraulic fracturing fluids through the environment."
The criteria for selecting these indicators includes frequency of occurrence in fracturing fluids, the toxicity of the chemical, the fate and transport of the chemical and the availability of detection methods. For the purpose stated, tracking fate and transport of HF fluids in the environment, toxicity is not an obvious factor that would influence an indicator's behavior in the environment.

**Comments from Dr. Cindy M. Lee**

**Charge Question 1: Water Use in Hydraulic Fracturing**
*EPA has used the water lifecycle shown in Figure 7 to characterize hydraulic fracturing and to identify the potential drinking water issues. Please comment on the appropriateness of this framework for the study plan. Within the context of the water lifecycle, does the study plan adequately identify and address the areas of concern?*

The use of the water life cycle is an appropriate organizing framework for determining the issues that are likely to affect drinking water. The EPA is charged with protecting current and future drinking water supplies, which requires that a systems approach be used to ensure that this charge can be fulfilled.

**Charge Question 2: Research Questions**
*EPA has identified both fundamental and secondary research questions in Table 2. Has EPA identified the correct research questions to address whether or not hydraulic fracturing impacts drinking water resources, and if so, what those potential impacts may be?*

The EPA has proposed a relatively comprehensive set of research questions to be examined. Under the Chemical Mixing and Flowback and Produced Waters sub-headings, a question is posed about the mitigation approaches for reducing the impact of spills. Spill prevention should be explored as well and included in the research questions to be considered.

**Charge Question 3: Research Approach**
*The approach for the proposed research is briefly described in Chapter 5. Please provide any recommendations for conducting the research outlined in this study plan, particularly with respect to the case studies. Have the necessary tools (i.e., existing data analysis, field monitoring, laboratory experiments, and modeling) been identified? Please comment on any additional key literature that should be included to ensure a comprehensive understanding of the trends in the hydraulic fracturing process.*

The combination of retrospective and prospective case studies is a sound approach to take. But will there be enough cooperation from current operations to develop the prospective case studies? The proposed retrospective case study locations appear to include a range of the issues such as aquifer and surface water contamination. The explanation of the scenario evaluation approach is not as clear as the case study approach. Elaboration of how it will inform the research would be useful. The tools that have been described are certainly the ones that are necessary for the proposed research.

**Charge Question 4(a): Proposed Research Activities - Water Acquisition**
*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Water Acquisition stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Any expected changes in water resources due to climate change must be factored into the scenario evaluation for this part of the water lifecycle.

**Charge Question 4(b): Proposed Research Activities - Chemical Mixing**
*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Chemical Mixing stage of the water lifecycle? Please provide any suggestions for additional research activities.*

The challenge will be in identifying the range of composition of the fluids. If the challenge is met, there is likely to be many unknowns in the toxicity of many of the components since there are still major efforts underway to develop an understanding of the toxicity of the high volume production chemicals in use in the U.S. Spill prevention is an area that should be explored. Given the nature of the drilling operations, it will be challenging to design systems that will prevent accidental releases in a cost effective manner. Although many sites in the western U.S. may be more isolated, as the boon continues more drilling sites will be located in more populated areas with private or municipal wells as well as surface water sources of drinking water that can be affected by accidental releases of the hydraulic fracturing chemicals.

**Charge Question 4(c): Proposed Research Activities - Well Injection**
*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Well Injection stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Although there is considerable experience in injection, the wide use of horizontal wells has less history. The effects of the horizontal bore holes on the well operation and integrity will be of considerable research interest. What is known about the failure history of horizontal drilling? The data from the microseisemic monitoring from the small percentage of fracturing sites could be of considerable help in understanding the fracturing process and the likelihood of affecting drinking water aquifers.

**Charge Question 4(d): Proposed Research Activities - Flowback and Produced Water**
*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Flowback and Produced Water stage of the water lifecycle? Please provide any suggestions for additional research activities.*

It would be useful to have some perspective on the amounts of flowback and produced water due to conventional gas or oil production. The draft plan indicated that a spill of flowback and produced waters into surface waters that cause ecosystem disturbance is outside the scope of the study. However, if high salinity affects the ecosystem in such a manner as to encourage the growth of noxious algae, there could be a significant effect on drinking water.

**Charge Question 4(e): Proposed Research Activities - Wastewater Treatment and Waste Disposal**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Wastewater Treatment and Waste Disposal stage of the water lifecycle? Please provide any suggestions for additional research activities.*

The ability of wastewater treatment plants to deal with high ionic strength wastes is of significant concern. Most municipal wastewater plants were not designed to treat brines. Is there a role for passive systems such as constructed wetlands to handle the anticipated volumes? The presence of the naturally occurring radioactive materials is also of concern and not in the typical treatment scheme for municipal wastewater treatment plants.

**Charge Question 5: Research Outcomes**

*If EPA conducts the proposed research, will we be able to:*

a. *Identify the key impacts, if any, of hydraulic fracturing on drinking water resources; and*

   The plan appears to provide coverage of most of the critical areas that will affect drinking water resources.

b. *Provide relevant information on the toxicity and possible exposure pathways of chemicals associated with hydraulic fracturing?*

   The ability of the proposed plan to provide the needed information on the toxicity of the chemicals is of more concern because of the questions about the full list of components used in hydraulic fracturing fluids and the limitations of knowledge about the toxicity of chemicals in commerce. On the other hand, it is likely that the plan will provide the necessary information about potential exposure pathways.

**Comments from Dr. Duncan Patten**

Comments on Charge Questions related to the EPA ORD Draft Plan to Study the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources from Duncan Patten

Note: All of my questions or comments on Charge Questions are in italics while the text or actual charge questions are not italicized.

**Charge Question 1.** ***Comment on the appropriateness of using the water life cycle as the framework for the study plan?***

The HF water life cycle appears to be a very logical approach to investigating effects of HF on drinking water resources; however, at no point does the Draft Plan demonstrate the interrelations (i.e., interception) between the HF water lifecycle and the "natural water cycle" (i.e., local to global hydrological cycle) which overall is the source of drinking water? This connection, or overlap in "processes", one man-made and one "natural" is necessary to justify the importance of the HF water cycle as the foundation of the HF study.

In Figure 7, Drinking Water Issues are listed. Each of these may have sub-issues which are not obvious in this Figure. For example, under Chemical Mixing the issues mention "release to surface and groundwater", while under Water Acquisition "water availability" does not separate the sources into surface and groundwater as it does in the text (perhaps this is a simple editing issue) but it is an important point relating to the actual sources of water used for HF.

Although the issues listed for Water Acquisition points out the "impact of water withdrawal on water quality", it should be made clearer that what really is being addressed here is not necessarily the process of water withdrawal on water quality but rather the reduction in water quantity (availability) which may or may not be a consequence of water withdrawal (this needs to be shown) and its direct effect on water quality.

**Also, and importantly, the five basic research questions do not include impacts of HF locations per se and their construction and maintenance on water quality (discussed below under Charge Question 2).**

**Charge Question 2.** ***Has EPA identified the correct research questions?***

The Research Questions are listed below, both Fundamental and Secondary. Basically, the questions posed in this study address the primary aspects of the HF water cycle issues; however, the text and the abbreviated secondary questions may miss some points. Thus, following the secondary questions and associated comments below, in italics, are questions on more detailed issues that might be considered. In some way, these more detailed questions also lead to research approaches that may or may not be addressed in the Study Document. Not all secondary questions have added italicized questions or issues. If they do not, then I had no additional question to add at this time.

One Fundamental Question that is not asked as it may be considered outside the HF water cycle and water use questions, is:

*What are the impacts on water availability and quality resulting from construction, maintenance and removal of HF well locations?*

This is a critical question because runoff from these locations may carry sediment and other compounds that will contaminate rivers and lakes in the region of the well activity. Many rivers and lakes in potential HF locations are clear resulting from a stable forest or vegetation cover in the areas (Marcellus shale locations in upstate PA and NY are prime examples of this). Removal of this vegetation along with site construction can alter runoff patterns and sediment loads.

Also, the research program should always keep in mind a statement made on page 21 of the Study document. That is "Furthermore, it is important to recognize that ground water and surface water are hydraulically connected (Winter et al., 1998); any changes in the quantity and quality of the surface water will affect ground water and vice versa." This connection between ground water and surface water is critical to addressing many of the questions and issues of hydraulic fracturing impacts. Basically, stated another way, there is no such thing as an identifiable drinking water resource that is distinct from other water sources.

*1. Water Acquisition: How might large volume water withdrawals from ground and surface water impact drinking water resources?*

*A. What are impacts on water availability?*

What are the depths of functional groundwater wells in the area of HF? In some states where HF occurs groundwater wells may be as deep as 9000 ft. This goes beyond just determining local groundwater depths as wells may tap much deeper water sources.

What are the relationships between surface flows and groundwater recharge in areas of HF? Groundwater is often being overdrafted in arid and semi-arid regions and reductions in surface flows (availability) may exacerbate groundwater storage.

The report makes the following statement: "The sustainability analysis will reflect minimum river flow requirements and aquifer drawdown for drought, average, and wet precipitation years." (pg 22).

Minimum river flow requirements need to be determined as suggested, but not only what is minimum but more importantly "what are the environmental flow requirements". Minimum flows and environmental flows are quite different concepts. Also, these requirements must be determined based on hydrological processes in the areas of HF (i.e., climate, usage, etc. as suggested for minimum flows.)

Dealing with both impacts on quantity and quality, the study should ask, " how different will impacts of water withdrawal be on different stream types (e.g., perennial, intermittent) and their different base geologies." Hydrology of the HF sites include headwater streams which may be perennial, intermittent or ephemeral, as well as larger lower elevation perennial streams.

*B. What are impacts on water quality?*

For different locations, how will reduction in water availability (i.e., quantity), especially surface flows, affect water quality? As the potential for dilution decreases, the potential for increased contaminant levels increases. This relationship is mentioned in the report but this relationship is critical to looking at the relationship between the HF water cycle and the natural hydrological cycle.

The following question is tied to the impacts of the hydraulic fracturing process not just water withdrawal.

If the hydraulic fracturing process influences the upward migration of deep aquifer, low quality water (e.g., brine), how will acquisition of large quantities of ground water influence the continued upward migration of these low quality (e.g., brine) into drinking water resources? And, secondarily and mentioned later, what are the upward pathways of this low quality water?

*2. Chemical Mixing: What are the possible impacts of accidental releases of hydraulic fracturing fluids on drinking water resources?*

*A. What is the composition of hydraulic fracturing fluids and what are the toxic effects of these constituents?*

*B. What factors may influence the likelihood of contamination of drinking water resources?*

The report (6.2.3) addresses mainly potential accidents on the surface and the resulting contamination of surface water or shallow groundwater. If the term accidental release is strictly surficial then the concerns in 6.2.3 are correct to address. If accidental release can also happen well below the surface than concerns of migration to drinking water sources should be addressed. Again, these raises the issue of pathways of contaminants (natural or man-made). These may be addressed more completely in research on well injection (see question 3.B below).

*C. How effective are mitigation approaches in reducing impacts to drinking water resources?*

*3. Well Injection: What are the possible impacts of the injection and fracturing process on drinking water resources?*

*A. How effective are well construction practices at containing gases and fluids before, during and after fracturing?*

The Report mentions naturally occurring substances (6.3.1.3) which may be affected by HF. One such substance is brine (water with dissolved "salts"). This implies some connectivity between surface and deep groundwater, albeit, probably over geological time. Analysis of the water in the brine might illuminate its source and thus some indication of natural pathways for contaminant transport (see next question). Discussion of possible pathways of contamination of groundwater of these natural occurring substances is appropriately discussed in 6.3.4.

*B. What are the potential impacts of pre-existing artificial or natural pathways/features on contaminant transport?*

This section needs to ask more detailed questions and put more emphasis on geological studies of overlying rock strata which are assumed to protect or prevent migration of chemicals to groundwater sources.

This section discusses man-made intrusions into formations where water exists such as wells but it does not address the natural occurrence of connections between deep groundwater and surface flows (e.g., artesian wells and springs) but rather only mentions natural fractures that might connect HF locations and groundwater. This section needs to ask questions about these connections to the surface because in some places they extend very deep into groundwater that may form warm springs. Chemistry of the spring water often is an indicator of the groundwater geological location.

Related to the above questions, EPA should ask what types of natural and man-made fractures and/or intrusions into subsurface strata are (1) more susceptible to contamination by HF and (2) most probably as pathways to shallow groundwater and surface water sources.

The whole issue of pathways is brought up again below under toxic effects of naturally occurring substances, indicating the connectedness of the issues and questions.

*C. What chemical/physical/biological processes could impact the fate and transport of substances in the subsurface?*

*D. What are the toxic effects of naturally occurring substances?*

What naturally occurring substances that may be toxic occur at different spatial locations relative to well site location and fracturing activities? Do these natural occurring substances have temporal cycles, that is, do they exist continuously or do they have some process (or are part of a process) that changes over time? Location and occurrence of these substances relative to different groundwater sources (both useful and not useful sources, e.g., deep brine which may be connected to shallower water sources) need to be addressed to determine the potential magnitude of their toxicity.

In Section 6.3.1.3 the report states "Some or all of these substances (i.e., naturally occurring substances) may find a pathway to USDWs as a result of hydraulic fracturing activities." If this is of concern, than identification of or study to determine the pathways should be a major question. The report should ask, what are the potential pathways for migration of naturally occurring substances as well as HF chemicals to drinking water sources (surface or ground water)?

Section 6.3.3 (page 31) does address the above question, but the concern for migration of natural or created chemicals through geological pathways should be brought into other discussion, not on the CBM discussion where HF processes may be shallower but also the shale discussion.

*4. Flowback and Produced Water: What are the possible impacts of accidental releases of flowback and produced water on drinking water resources?*

*A. What is the composition and variability of flowback and produced water and what are the toxic effects of these constituents?*

If the produced water is water that occurs in the subsurface region of the gas production HF activity, especially in CBM activity but also shale, what is (or was) its natural source and is that source connected (spatially and temporally) to potential drinking water resources?

How much of the water coming from the well is combined flowback and produced water and is there any way to separate or distinguish the different sources? This is asked because in some cases produced water may be used for other productive uses (e.g., irrigation, livestock water).

*B. What factors may influence the likelihood of contamination of drinking water resources?*

What is the fate (movement over time) of flowback water that is not recaptured? Is there a method to track this water in transport through geological or man-made fissures (pathways)? This assumes that flowback water is separate from produced water which is water that originated subsurface and does not include and injected water.

*C. How effective are mitigation approaches in reducing impacts to drinking water resources?*

*5. Wastewater Treatment and Waste Disposal: What are the possible impacts of inadequate treatment of hydraulic fracturing wastewaters on drinking water resources?*

*A. How effective are treatment and disposal methods?*

**Charge Question 3. Research Approach. *Please provide any recommendations for conducting the research outlined in this study, particularly re: case studies and necessary tools.***

On page 17 the study mentions "Field Monitoring" at the study sites. No mention in this section of monitoring layout or details whether it is a retrospective or prospective site. It may well be in another section.

If one goes to Case Studies in the Appendix G – Field Sampling and Analytical Methods it mentions (page 111) monitoring wells and monitoring points at Case Study locations.

There is not enough detail of how the monitoring scheme will be designed and how the design might differ between retrospective and prospective study sites. The Study Design should have a schematic of a "typical" well location with examples of what water source and soil locations will be sample. Granted, some sampling will be from existing ground water wells in the location and also from water taps (in houses for example), but the study should include "new" monitoring wells and their placement. Also, soil monitoring locations relative to the well site should be designated on some "master research design" plan.

A Research Design should also include "typical" sampling locations of surface water sources in a hypothetical Case Study location.

The Research Design should also include not only the spatial arrangement (as above) of sampling locations, but also the temporal schedule (i.e., timing of various sampling activities relative to the developmental and/or active processes at the well locations).

Table 9 (page 47) covers research approach for prospective wells. It is proposed to "Sample all available existing wells, catalogue depth to drinking water aquifers, gather well logs". What is missing in this approach is determination of depths of potential drinking water aquifers. These may be deeper than existing wells and may well be future drinking water sources if ground water withdrawal for the HF process lowers existing water tables.

Table 9 also mentions "Sample any adjoining surface water bodies". This needs to be expanding beyond just adjoining surface water bodies to water bodies that potentially are connected hydrologically to aquifers that may be influenced by the HF process, especially that which includes water acquisition.

**Charge Question 4. Research Activities.** ***Will the proposed research activities for each stage of the HF water cycle adequately answer secondary questions proposed under Research Questions?***

*A. Water Acquisition*

In Section 6.1.4.1 under proposed research activities, the report states "These data will include ground water levels, surface water flows, and water quality as well as data on hydraulic fracturing operations, such as the location of wells and the recorded water used during fracturing."

This section appears to omit several hydrological data. These include short and long term precipitation data for the study sites but as importantly, the whole study tends to ignore lakes and emphasizes surface water sources as primarily streams. Lakes are a critical water source to sample. In some cases they are the drinking water source but many lakes are ground water fed. For example in the Marcellus Shale area of up state Pennsylvania and New York, many of the small lakes (as well as large) are primarily ground water fed with little surface water input and thus crystal clear. If ground water sources are impacted, either in quantity or quality, by the HF process, then these lakes should be inventoried for levels (volume) and quality. These lakes should also be of concern relative to runoff from HF locations (an issue tied more to establishment and maintenance of HF well locations.

*B. Chemical Mixing*

*C. Well Injection*

*D. Flowback and Produced Water*

*E. Wastewater Treatment and Waste Disposal*

**Charge Question 5.** ***Will the proposed research allow EPA to (a) identify key impacts of HF on drinking water resources and (b) provide information on toxicity and possible exposure paths of chemicals associated with HF?***

The response to this question essentially falls back on the question, approach and research sections. If they are properly designed, and obviously some weaknesses have been identified, then the proposed research should fulfill the two questions above. Unfortunately, the research misses some hydrological connections, water sources, etc.

## Comments from Dr. Stephen Randtke

This document does not include all of my comments during the panel meeting, nor does it reflect all of my thoughts regarding this matter; and these comments do not necessarily reflect the consensus of the panel.

### Charge Question 1: Water Use in Hydraulic Fracturing

*EPA has used the water lifecycle shown in Figure 7 to characterize hydraulic fracturing and to identify the potential drinking water issues. Please comment on the appropriateness of this framework for the study plan. Within the context of the water lifecycle, does the study plan adequately identify and address the areas of concern?*

The water lifecycle framework is an appropriate one for organizing the study plan. However, it should be noted that Figure 7 shows the water lifecycle for water used in hydrofracking (HF), as stated in the title of the figure, rather than the natural hydrologic cycle. So various adjustments to the figure, such as feedback loops, may be needed if the figure is intended to comprehensively address all potential impacts on drinking water resources. For example, acquiring HF water from a groundwater source (USDW) in a given area and discharging the flowback water to a river may impact the availability of both groundwater and surface water in that area.

### Charge Question 2: Research Questions:

*EPA has identified both fundamental and secondary research questions in Table 2. Has EPA identified the correct research questions to address whether or not hydraulic fracturing impacts drinking water resources, and if so, what those potential impacts may be?*

One question that does not appear to be adequately addressed is what impacts might occur over longer time periods as HF fluids not recovered as flowback or produced water (i.e., those lost as “leakoff”) begin to diffuse away from their source, especially when the nearest confining layer (aquitard) has just been fractured. Will the various constituents they contain eventually degrade, adsorb, and diffuse to the extent that detectable or toxicologically significant concentrations never show up in nearby drinking water sources, or do they pose a long-term threat to future generations? This issue could be addressed, perhaps reasonably well, using scenario modeling techniques. (This comment is also directly related to Charge Question 4c.)

### Charge Question 3: Research Approach:

*The approach for the proposed research is briefly described in Chapter 5. Please provide any recommendations for conducting the research outlined in this study plan, particularly with respect to the case studies. Have the necessary tools (i.e., existing data analysis, field monitoring, laboratory experiments, and modeling) been identified? Please comment on any additional key literature that should be included to ensure a comprehensive understanding of the trends in the hydraulic fracturing process.*

Conducting a limited number of case studies (5 to 8) will not fully address the broad range of geologic and other conditions associated with HF activities. However, time and resources are limited, and a good combination of retrospective and prospective case studies at carefully selected sites will provide much good information. Since a key charge is to determine if HF activities are impacting drinking water resources, it is advisable to focus on worst case scenarios in diverse areas, especially areas where there is already credible evidence of impacts on drinking water resources. It is also important to select sites where it is feasible to conclusively link any contamination that may be found to HF activities. In retrospective case studies it may be difficult to prove that certain impacts that may be observed, such as elevated levels of naturally occurring contaminants, are caused by HF activities.

If, as EPA expects, it does not "address the efficacy of the regulatory framework as part of this investigation" (p. 13), this will significantly diminish the usefulness of the study. There may be good reasons for taking this approach, e.g., pending litigation, but the study results will be more meaningful in a regulatory context. As noted in the presentation by EPA, it is anticipated that the results of the study will be used to "inform decision makers regarding the key factors that may drive potential impacts of hydraulic fracturing on drinking water resources." If adverse impacts are identified, decision makers will want to know as much as possible about the regulatory framework that allowed such impacts to occur so they can consider what changes might be appropriate to prevent future occurrences of such impacts. The fundamental research questions focus on "possible" impacts, but most of the possible impacts are probably already known, and the study is not designed to find impacts that are not thought to be possible. The real value of this study lies in its ability to answer the secondary questions, which are best addressed in the context of the existing regulatory framework rather than in a vacuum. For example, one secondary question is: "What factors may influence the likelihood of contamination of drinking water resources?" Obvious factors include the existence of regulatory constraints (or lack thereof), exemptions from existing regulations, the adequacy of existing regulations, the level of monitoring and enforcement, and whether any mitigation or remediation efforts have been or may be required. Similar arguments can be made for various other secondary research questions. For example, if drinking water is found to be contaminated by constituents of HF fluids that passed through a wastewater treatment facility, a reasonable question to ask is whether the fluids were discharged in compliance with the facility's NPDES permit and local sewer use ordinances. The plan states that "EPA may assess existing state regulations in a separate effort" (p. 13). If so, any such effort ought to be closely coordinated with the research activities outlined in the study plan so that each study can benefit from the other.

**Charge Question 4(a): Proposed Research Activities - Water Acquisition:**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Water Acquisition stage of the water lifecycle? Please provide any suggestions for additional research activities.*

The proposed research activities will address the secondary questions reasonably well. Some refinements are recommended, and some aspects of the secondary questions may prove difficult to answer definitively without additional research. The research activities to study the impacts of HF on water availability and water quality need to be carefully coordinated since water quality can be strongly influenced by water availability. These research activities also need to be closely coordinated with: 1) research activities addressing wastewater treatment and disposal, since the availability of water for dilution and the quality of the dilution water are of critical importance in assessing the adequacy of treatment and impacts on drinking water quality; and 2) any research activities that are part of a separate effort to assess the regulatory framework (Sect. 3.5, p. 13).

In some areas, much of the basic background information needed to address the secondary questions (e.g., water use, stream flow data, groundwater levels, and baseline water quality data) may be readily available. In such cases, it should be possible to answer a number of questions by evaluating existing data (e.g., examining trends and performing mass and material balances), by scenario modeling, and by conducting prospective case studies. However, some impacts will be more difficult than others to examine, quantify, and attribute to a specific cause. As the study plans are fleshed out, EPA should make a concerted effort to identify opportunities to determine, as definitively as possible within time and budgetary constraints, whether HF is or is not causing specific adverse impacts on drinking water resources.

Water availability is usually viewed primarily in terms of the quantity of water available, overall and for a given set of uses. Other aspects of water availability that are also important, but that may be more difficult to quantify, include: the cost of obtaining and treating the water (economic availability); water depth (hydraulic availability); legal availability (impacts on local and regional water rights issues); environmental availability (considering such things as local and regional environmental flow needs); availability to dilute waste discharges (including those associated with HF as well as other municipal and industrial discharges); and availability to dilute naturally occurring drinking water contaminants. (Evaluation of the last two aspects will require close coordination with the elements of the study plan addressing water quality and wastewater treatment and disposal, respectively.) Some of these aspects of water availability have been noted in the research plan, but as the research plan is further developed and implemented, EPA should look for opportunities to more thoroughly address them and to more conclusively show that adverse impacts are or are not occurring. Some impacts will be difficult to examine in a meaningful way without carefully describing applicable state and local regulatory frameworks.

Water withdrawal results in water movement and therefore has the potential to significantly influence the migration of brackish waters and brines and to mobilize soluble salts. The proposed research activities are appropriate for identifying, monitoring, and evaluating such impacts; and existing water flow and water quality models can be used to quantitatively forecast future impacts. However, some potential water quality impacts of considerable interest to the public and policy makers can arise from more complex physical and chemical processes such as stream–aquifer interactions, stimulation of biological growths, redox reactions (such as those associated with arsenic mobilization and acid mine drainage), and upwelling of water from deeper formations (bromide). Some potential impacts involve naturally occurring contaminants that are rarely monitored (e.g., methane, radium, and radon), which will make it difficult to demonstrate that a change in water quality has actually occurred. For example, if a high level of methane or radon is found in a well but no historical data are available, it may be difficult or impossible to determine whether the methane or radon concentration has changed as a result of HF activities. EPA is clearly aware of such difficulties and will need to carefully look for opportunities to conclusively determine whether such impacts are occurring or may occur in the future.

To further complicate matters, only a fraction of the withdrawals in a given area are likely to be associated with HF activities; and there may be significant natural variations in rainfall and runoff, large variations in the rate of withdrawal by various users, regional movement of groundwater in the area, and significant temporal and spatial variations in water quality. For these and other reasons, even where significant water quality changes are documented, they may not be attributable to a single cause and it may be difficult or impossible to assign an exact portion of the change to HF activities. Prospective studies and modeling efforts may be of significant help in addressing such issues, but some of study results are likely to be inconclusive, or inconclusive without further study. Some of these complications and limitations are noted in the draft plan, but they are not explicitly addressed in the section (6.1.4.2) describing the proposed research activities to address impacts of withdrawal on water quality. In further developing and implementing the research plan, EPA should identify opportunities to circumvent or resolve such problems.

The list of analytes considered in studying the impacts of water acquisition (and other HF activities) on water quality (Table G1) should explicitly include: 1) hydrogen sulfide, a toxic and corrosive substance that also imparts a strongly offensive odor to air and water, exerts an oxygen demand in streams, and exerts a high oxidant demand (e.g., chlorine demand) when present in a public water supply; 2) ammonium, a compound naturally present in many alluvial aquifers and some deeper formation that exerts a large chlorine demand and is also toxic to many aquatic organisms; 3) radon (Rn), a radioactive gas that could potentially be released into drinking water by HR activities; 4) iron, manganese, arsenic, and selenium, metals and non-metals that may be mobilized by HF activities, including water withdrawal; and 5) bromide and other disinfection by-product precursors, mentioned in the draft but not explicitly listed in Table G1.

Research on topics of importance to the public should be conducted with due consideration of the potential policy implications and the information decision makers will need to address problems that are identified. One of the desired outcomes of the study plan (p. 23, Sect. 6.1.5) is to "allow EPA to … provide an assessment of current resource management practices related to hydraulic fracturing." The plan makes several references to management or management practices, but it does not explicitly state what practices this includes or how they will be addressed in the study. To adequately assess the impacts of water management practices on water availability and water quality in a given area, and to help decision makers identify changes in management practices that are needed to address any problems that are identified, it is important to know such things as how water rights are obtained and enforced; whether groundwater withdrawals are managed or regulated (and, if so, how and by who); if problems are occurring because appropriate regulations or other management tools are lacking; and if existing regulations or management practices have actually made the situation worse. Therefore, relevant regulatory information should be collected at the same time background information and water quality and quantity data are collected, and in conjunction with all case studies.

The research plan does not explicitly address the obstacles private well owners and small public water supply systems (PWSSs) may encounter if they experience adverse impacts on water availability or water quality that they believe are related to HF activities. Unlike larger users, they will generally lack the financial resources to hire experts to prove that their water resources have been adversely impacted. This problem is related to both management practices and environmental justice (Sect. 9). To address this problem, if would be helpful if the research plan included development of recommendations regarding the baseline data that ought to be collected in a given area, before HF activity begins, so that significant changes in water availability or water quality can be more readily documented.

The plan states (p. 1) that EPA defines "drinking water resources" to include underground sources of drinking water (USDWs), which are defined in the glossary as aquifers capable of supplying a public water system and having a TDS concentration of 10,000 mg/L or less. It may be appropriate to reconsider this definition given recent advances in membrane desalination and current and future water shortages in many parts of the U.S. It is reasonable to consider very deep, highly saline aquifers isolated from drinking water resources as potential sites for waste injection, etc., but shallower brackish waters are increasingly being considered as potential sources of supply. Furthermore, some relatively saline aquifers could potentially be used for future "aquifer storage and recovery" operations, and it would behoove state and federal regulatory agencies to take appropriate measures to prevent them from being polluted.

The plan states (p. 20) that large volume withdrawals for HF are unique in that much of the water may not be recovered, but consumptive use is neither unique nor uncommon. Some energy-related used of water, such as hydro-electric power generation and single-pass cooling, are largely non-consumptive; but irrigation, which accounts for the majority of water use in many areas of the U.S., is usually highly consumptive. Withdrawals for HF may be consumptive, e.g., if the water is withdrawn from an aquifer and the flowback is discharged to a stream; but they may also be largely non-consumptive, e.g., if the water is used in close proximity to the withdrawal point and then recycled.

Figure 6b (p. 12), which "illustrates the relative depths of a gas well and a water well" (p. 11), shows the water well going to a depth of about 300 feet. It is worth noting that public water supply wells can be much deeper. Water well depths of 1000 ft or more are common in Southeast Kansas, in the vicinity of the Excello-Mulky shale gas play. Water availability and water quality are already being influenced by high regional withdrawal rates in this area.

**Charge Question 4(b): Proposed Research Activities - Chemical Mixing:**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Chemical Mixing stage of the water lifecycle? Please provide any suggestions for additional research activities.*

EPA's plan to identify 10 to 20 chemical indicators to track fracturing fluids (Sect. 6.2.5.1, p. 26) is an excellent one. The list of potential ingredients is very lengthy. It would not be a wise use of time and resources to attempt to determine all analytes for which methods currently exist, nor would it be a wise use of time and money to develop new analytical methods for many of the compounds listed. The composition of HF fluids can be well characterized by determining the ingredients used; and the concentrations of individual constituents in fluids that may find their way into the environment through various pathways can be conservatively estimated by applying appropriate dilution factors. The research plan should focus on those compounds that are most likely to be found in water in concentrations that are measureable at the levels of concern, using existing methods and, where appropriate, indicator chemicals. Given the rapid rate at which HF activities are expanding, time is of the essence, and it is not reasonable to allow methods development activities to hold up other elements of the research plan. Nevertheless, it would be appropriate to identify chemicals for which new methods are needed and to begin, on a separate track, to develop the methods, which could then be employed as they become available.

One of the desired outcomes of the research on chemical mixing (Sect. 6.2.6, p. 27) is to enable EPA to "assess current management practices related to on-site chemical storage and mixing." To meet this outcome it would be helpful to explicitly identify the management practices that will be included. Spill prevention and certain "mitigation practices" (Sect. 6.2.4, p. 25) will evidently be included, but it might be appropriate to explicitly include any soil and aquifer remediation practices currently recommended by API or used by the industry. It might also be appropriate to assess the effectiveness of mitigation practices and emergency response plans by examining cases where spills have occurred. Two well known oil spills (in Alaska and in the Gulf of Mexico) illustrate the need for adequate response plans under difficult circumstances.

**Charge Question 4(c): Proposed Research Activities - Well Injection:**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Well Injection stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Please see the earlier comment in response to Charge Question 2.

The study plan indicates that nitrogen gas is commonly used to fracture coal beds (p. 23), high pressure pumps are used to send HF fluids into wells (p. 24), compressed air is sometimes used in drilling (p. 27), and "the production casing is perforated using explosive charges" (p. 29). The study plan notes that microseismic monitors are sometimes used during fracturing, so fracturing evidently produces tremors large enough to be instrumentally detected; and seismologists have linked certain natural tremors to the release of underground gases. Moreover, there are anecdotal accounts of increased methane levels in water drawn from wells near HF activities. Therefore, a reasonable question to add to the study plan is: "Do HF activities produce pressure pulses of sufficient magnitude to cause natural gases such as methane and radon to be released into nearby drinking water sources?" In one or more of the case studies, it might be appropriate to select a few deep water supply wells in an area where HF will commence and to monitor water quality, and especially dissolved gases, to see if any noticeable water quality changes occur.

Table 5 (p. 30) lists examples of naturally occurring substances. The list is not intended to be exhaustive, but it might be wise to add radon to the table so it is not overlooked as the research described in the study plan moves forward.

The scenario evaluations should include cases where abandoned wells are located nearby but their existence is not known and they have not been plugged. There are literally thousands of abandoned oil and gas exploration and productions wells in Kansas alone, and good records were often not kept in the past. Pumping HF fluid into a formation penetrated by abandoned wells could dramatically impact nearby drinking water sources. Management practices for identifying or preventing such situations, and for mitigating them in the event of a release, should be evaluated as part of this study.

The use of chemical tracers is an excellent idea; but instead of using components of natural gas, such as methane, as tracers, EPA should consider, in prospective case studies, adding chemicals such as CFCs to HF fluids so that the tracer can be conclusively linked to injected HF fluid. The tracer should be conservative (not adsorbed, biodegradable, etc.), rapidly transported (e.g., a low-MW compound, perhaps a gas), and readily detectable in brackish water when highly diluted. To obtain useful data by 2014, the monitoring wells will need to draw water from depths close to that of the fractured formation, or from nearby faults or other natural or man-made pathways.

The laboratory studies described in Section 6.3.6.3 (p. 35) appear rather unfocused and for the most part unnecessary. A reasonable amount of information on the fracturing characteristics of gas-bearing formation should already be available in peer-reviewed publications; and, given the great variability of geologic conditions and HF fluid compositions, it seems unlikely that the tests described would produce much information useful to EPA. The tests to simulate exposure of HF fluids under simulated subsurface conditions seem pointless, since such samples can be readily obtained in the field by collecting flowback water; so it might be appropriate to limit such tests to important questions that cannot be answered by analyzing samples of flowback water. It does not seem logical to conduct lab tests to identify possible components in flowback water, and to then place these components on a list of components for which analytical methods are needed. How will they be identified in the lab tests unless existing methods are able to identify them? If the goal is to develop more sensitive methods, methods for various groups of contaminants, less expensive methods, etc., this should be clearly stated.

Section 6.4.1 of the study plan summarizes estimates of the percentage of HF fluid recovered as flowback water. It might be worthwhile for EPA to assess the quality of these estimates and to also determine, perhaps using prospective case studies, the recovered fractions of the various chemicals used to prepare HF fluids. Recovery of the water in the fluids is pertinent to questions regarding water availability, but recovery of the chemicals is more directly related to various water quality issues, including the potential for "leakoff" to eventually migrate into sources of drinking water. In this regard, it is also important to note that chemicals not withdrawn with the flowback water could potentially be withdrawn with the produced water.

**Charge Question 4(d): Proposed Research Activities - Flowback and Produced Water:**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Flowback and Produced Water stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Development of analytical methods is noted as a potential outcome (Sect. 6.4.6, p. 39), but as noted earlier in response to Charge Question 4b, methods development activities should not be allowed to hold up other elements of the research plan.

The daily volume of produced water is described as typically low (e.g., 50 gal/day, p. 36). It would be good to know more about exceptions, i.e., whether there are sometimes flows of produced water large enough, individually or collectively, to adversely impact water availability or, by inducing ground water movement, to adversely impact water quality.

**Charge Question 4(e): Proposed Research Activities - Wastewater Treatment and Waste Disposal:**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Wastewater Treatment and Waste Disposal stage of the water lifecycle? Please provide any suggestions for additional research activities.*

The study plan indicates that flowback "water treated on site may also be used for irrigation" (p. 41). Use of flowback or produced water used for irrigation would perhaps not require NPDES or other permits, but could potentially cause significant deterioration of drinking water quality. This practice merits careful scrutiny as to its extent and possible current or future impacts on drinking water quality. The current regulatory framework for this practice needs to be described.

Laboratory studies to assess the potential of HF fluids to produce DBPs should consider not only currently regulated DBPs but also other DBPs that might be formed. Samples of HF fluids that are chlorinated should be analyzed for total organic halogen (TOX) to assess the extent to which unregulated chlorinated DBPs may be formed. Total organic carbon (TOC) and DBP formation potentials should also be determined, as some drinking water treatment plants are now required to monitor and perhaps control DBP precursors, typically measured as TOC. Toxicity and mutagenicity tests should also be considered.

A great deal is already known about the ability of various treatment process to remove some of the contaminants present in HF fluids, especially "conventional" contaminants such as BOD and suspended solids. Much is also known about treatment processes that could potentially be used to treat various constituents present in HF fluids. For example, various desalination technologies could potentially be used to remove or concentrate salts, and activated carbon adsorption and advanced oxidation processes could be used to treat various organic constituents. However, the study plan should focus on the ability of currently used processes to remove constituents of interest and not on processes that could potentially be used if current processes are deemed to be inadequate.

For some constituents, the primary effect of current treatment practices on some constituents (e.g., chloride and bromide) will be dilution rather than removal. In such cases, the key question is whether these constituents are being diluted sufficiently to avoid adverse impacts on drinking water quality. This question can be addressed by evaluating existing data, by analyzing samples collected as part of case studies, and by scenario modeling using simple mass balances and applying the appropriate dilution factors. The prospective case studies should focus on treatment of potentially important contaminants whose fate in current treatment processes is not already well understood or readily predicted.

**Charge Question 5: Research Outcomes:**

*If EPA conducts the proposed research, will we be able to: a. Identify the key impacts, if any, of hydraulic fracturing on drinking water resources; and b. Provide relevant information on the toxicity and possible exposure pathways of chemicals associated with hydraulic fracturing?*

Some or all of the potential key impacts of HF activities on drinking water resources, as well as possible exposure pathways associated with drinking water, have already been identified. If EPA conducts the proposed research, it should find evidence of such impacts if they are occurring frequently enough in the study areas, and the evidence may in some cases be conclusive.

Regarding toxicity, the study plan indicates that EPA will develop a prioritized list of chemicals and conduct screening tests. In prioritizing the chemicals, EPA should consider the amounts of chemicals typically used in HF fluids and apply appropriate dilution factors to determine the likelihood that a given chemical will reach drinking water resources at a concentration high enough to be detected and to be toxicologically significant. Future research efforts should be directed toward the chemicals likely to pose problems.

**Comments from Dr. Connie K. Schreppel**

**Charge Question 1: Water Use in Hydraulic Fracturing**

*EPA has used the water lifecycle shown in Figure 7 to characterize hydraulic fracturing and to identify the potential drinking water issues. Please comment on the appropriateness of this framework for the study plan. Within the context of the water lifecycle, does the study plan adequately identify and address the areas of concern?*

The use of the water life cycle appears to be an appropriate framework for the study. All stages of the lifecycle can play a significant role in the pathway of contamination of drinking water supplies. It should be recognized that the life cycle is not truly a vertical process and that it should be portrayed as a feed-back loop type diagram to demonstrate that there are interactions and feedback between the 5 identified processes.

Given the time constraints and the resources available the project may be too broad to fully achieve all of the intended goals of the study.

**Charge Question 2: Research Questions**

*EPA has identified both fundamental and secondary research questions in Table 2. Has EPA identified the correct research questions to address whether or not hydraulic fracturing impacts drinking water resources, and if so, what those potential impacts may be?*

The EPA has generally identified the key research questions to address the impacts on drinking water. However, it is unclear if the cumulative impacts are considered in relation to the combination of chemical mixing, well injection, flow back and produced water and disposal and/or treatment. The cumulative impacts from all HF activities have the potential to be more serious than the study may indicate when each parameter is examined individually.

**Charge Question 3: Research Approach**

*The approach for the proposed research is briefly described in Chapter 5. Please provide any recommendations for conducting the research outlined in this study plan, particularly with respect to the case studies. Have the necessary tools (i.e., existing data analysis, field monitoring, laboratory experiments, and modeling) been identified? Please comment on any additional key literature that should be included to ensure a comprehensive understanding of the trends in the hydraulic fracturing process.*

The use of case studies is a logical approach to take. A balance needs to be established between the time and resources allocated to the retrospective and prospective studies. It is questionable if the time frame and the resources of the study will lend itself to producing meaningful data from the prospective studies. There was some discussion in the plan of methods development and if this is also factored in to study it appears the study will definitely be hampered by time constraints.

Again because of the time constraints and the small number of case studies that are being considered meaningful conclusions about the frequency, severity and duration of contamination issues might not be captured and general conclusions will not be accurate.

**Charge Question 4(a): Proposed Research Activities - Water Acquisition**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Water Acquisition stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Concerns associated with the acquisition of large volumes of water for the HF process include both the quantity of water and the resulting quality of water once those volumes of water have been removed from the aquifer. EPA's decision to choose representative areas across the country to study and the process of comparing control areas with similar baseline water demands is sound.

Modeling should be employed to simulate extreme weather conditions in each test area as extreme drought and excessive precipitation can occur in any area. Analysis of long and short term precipitation must be included. Surface water studies seem to be focused only on streams and headwaters. Since some lakes can be heavily influenced by groundwater they should be incorporated into the study in some fashion.

**Charge Question 4(b): Proposed Research Activities - Chemical Mixing**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Chemical Mixing stage of the water lifecycle? Please provide any suggestions for additional research activities.*

The most important factor here is the determination of the compounds in the HF fluid. In the study areas the HF fluids should be inventoried in regards to the entire composition of the HF fluid and the use of the term "proprietary mixture" should not be acceptable. Until the industry is totally forth coming with this information there will be definite gaps in the study process.

Spills associated with chemical mixing should also be investigated as part of the retrospective case studies. The transportation of chemicals is an important factor that could contribute to the contamination of water resources. Western areas of the country are more remote but as hydrofracking practices become more and more frequent in more heavily populated areas in the East spills and the safety of transportation of chemicals near water resources become more and more important.

References have been made that this study is not associated with regulatory aspects but it is important to review the current regulations that are in place to see if they are sufficient and protective of water supplies.

**Charge Question 4(c): Proposed Research Activities - Well Injection**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Well Injection stage of the water lifecycle? Please provide any suggestions for additional research activities.*

Again the case studies are an important component to this research activity. It may serve the study better if wells of an older age are inventoried rather than ones that are approximately one year old. A portion of the case studies should be devoted to older wells where problems with the HF process have been documented.

A comparison of well construction and sealing practices versus known well failures would be helpful in the analysis. Again the inclusion of older wells would prove useful.

Modeling and the use of tracers could be used as a tool to provide insight into the probability of well failure during injection.

An inventory of the HF fluid is again an important piece of the information needed to achieve results in this area of study. A database of chemicals used, concentrations of these chemicals and frequency of use should be compiled.

A partner for a study of repeated fracturing of a well over its life time should be secured by EPA.

**Charge Question 4(d): Proposed Research Activities - Flow back and Produced Water**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Flow back and Produced Water stage of the water lifecycle? Please provide any suggestions for additional research activities.*

The study plan appears to be appropriate. However, it is important to compile data from the case studies and obtain existing data from hydraulic fracturing companies and state environmental agencies to assess the quantity of the flow back and produced water. Again the use of non-toxic tracers would lend themselves useful in the prospective case studies.

The probability of spills due to failure of pumping activities, holding vessels, or pipeline failures is high during this stage of the process. A history of documented past spills and the circumstances associated with these spills should be compiled. It is important that the studies evaluate the risks posed to drinking water resources by current methods for on-site management of the HF flow back and produced waters.

## Charge Question 4(e): Proposed Research Activities - Wastewater Treatment and Waste Disposal

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Wastewater Treatment and Waste Disposal stage of the water lifecycle? Please provide any suggestions for additional research activities.*

The following comments are made in reference to conventional WWTPs rather than the deep injection wells. Most public WWTP are not equipped to deal with receiving HF wastewater. High TDS fluids that contain elevated levels of chlorides and bromides which are not removed by the WWTP can pose many problems to WTPs downstream.

One can easily draw a comparison with the HF wastes to the detections of personal care products (PCP) that have recently been shown to easily pass through conventional sewage treatment plants. Recent drinking water treatment research has been focusing on the occurrence of PCPs that enter the water treatment plant and cannot be removed with their conventional treatment processes. Research has focused on what processes will remove PCPs and it has been shown that only advanced treatment is effective and in most cases a combination of advanced treatment techniques is needed for removal. This can become very complicated, very expensive and exert a heavy burden on water systems especially the medium and small systems (economic justice issues). The same parallels can be drawn with the disposal of HF fluids at the conventional WWTPs.

The issue of radiological contaminants as reported in the press recently raises more issues for this study. Most public water systems, especially the systems that utilize surface water sources, have never dealt with the detection of radiological contaminants. Safe Drinking water regulations also do not require frequent radiological testing and some monitoring is only required every ten years. Radiological contaminants could go undetected for long periods of time under this framework.

It would be useful to collect data from continuous radiological monitors placed at the influent and effluent of WWTPs that receive HF wastes and compare monitoring that is collected at WTPs downstream of the WWTP receiving those HF wastewaters. It would also be useful to collect radiological data when receiving the bulk HF fluids on the receiving side of the WWTP.

The study makes mention of the investigation of the formation of disinfection by-products. It is important to investigate the formation potentials of these by-products that may be increased in a PWS due to the presence of increased chlorides and bromides that may be present in the HF wastewater. The levels of chlorides and bromides should also be addressed due to the issue of corrosion of plumbing materials.

While drinking water systems are focused on a small group of DBPs such as trihalomethnes and haloacetic acids the research should collect data on total organic halide (TOX) potential so there are no surprises with potentially more toxic DBP's somewhere down the road. It is also important to monitor changes in the total organic content of the water.

Again it comes back to what additives are in the HF fluid and the subsequent wastes. It would be helpful to the investigation if records are kept as to where the wastewater is being processed. It would also be useful if EPA could catalog what public WWTPs are receiving these wastewater fluids and what compounds they contain.

The study should examine the recent cases of occurrences of brominated DBPs above the MCLs that have been detected in SW Pennsylvania and ask that partnerships be established so that this data can be included in some fashion to the study. The use of a retrospective study to evaluate the impacts of untreated and/or partially treated wastewater that are impacting community water systems in western Pennsylvania is warranted.

Although out of the scope of this project there seems to be a need for regulatory framework that would require SOPs, BMPs, standardization and cataloging of fluids in regards to proper disposal of HF fluids at WWTPs.

**Charge Question 5: Research Outcomes**

*If EPA conducts the proposed research, will we be able to:*

*a. Identify the key impacts, if any, of hydraulic fracturing on drinking water resources; and*

*b. Provide relevant information on the toxicity and possible exposure pathways of chemicals associated with hydraulic fracturing?*

The scope of this research document is ambitious but perhaps too broad and time constraints and funding will hamper the over-all effort and results. After reading the study plan several times the areas seemed to be overlapping and care must be taken that efforts are not duplicated in areas of the study

The use of case studies both retrospective and prospective appears sound but again time constraints may hamper completion of the prospective studies. The use of tracers and modeling will be an important part of this study.

**Overall Comments:**

The water life cycle is an appropriate framework for the study but it is important that the following areas are addressed:

1. Well drilling procedures and well maintenance practices: The study needs to address if these practices are safe and sustainable for protecting water quantity and water quality. The methods of drilling and sealing need to be evaluated and standardized. There needs to be planning so that a catastrophic failure event similar to the deep water oil well rupture well does not happen in this arena.

2. The HF fluid: It appears that the greatest obstacle to studying the impacts of hydrofracking on water resources is the fact the drilling industry is not forthcoming with the “proprietary” substances contained in the HF fluid and there is no assurance that these substances will not adversely affect

water resources. A complete catalog of all constituents and concentrations used in the HF fluid should be compiled for each individual well and a spill history at each well should be documented. If this is not possible in retrospect it should be standard practice for all future wells. The industry should be compelled to standardize the fluids and limit the number of possible additives that could cause adverse health effects and should limit the toxic chemicals used on the side of precaution. This most likely will not happen without regulatory framework. The EPA should encourage the drilling industry to investigate the alternative use of "green" HF fluids.

3. To determine the effects of hydrofracking on drinking water resources it is also important to determine the cumulative effects of drilling. While one fracking procedure or failure may not cause a problem the cumulative effects of multiple wells, multiple chemical injections and/or spills may pose a completely different problem.

It seems that the objectives of this study would be more obtainable if industry was engaged further as partners in any or all of the planned studies. Partnerships should include both the oil and gas industry and both the drinking water industry and the wastewater treatment industry.

**Comments from Dr. Jeanne VanBriesen**

**General Comments:**

The document lacks cohesive presentation of the research plan. The approach is covered in multiple locations, with many necessary details relegated to the appendices in ways that make it difficult to follow the linkages among the different research questions and the specific approaches to answer each question. Further, the research questions described lack sufficient specificity to evaluate how they will be addressed and how answering these questions will address the desired outcomes. Also, in each section, potential research outcomes are listed, but it is difficult to evaluate if these are outcomes EPA is committed to achieving or if these are outcomes that 'could' 'potentially' be achieved. If they are potential outcomes, what will determine whether they are met, and which outcomes are expected, which are possible but unlikely, which are absolutely necessary in order to move to the next steps of the research? Increased clarity on the prioritization of the specific outcomes is needed.

The lifecycle shows in Figure 1 of the executive summary (also Figure 7 of the main report) is a good approach; however, the figure is visually and conceptually too narrow. It gives the impression that this is the water use in a single operation – a single well or a series of wells on a pad, rather than water use in an entire shale basin or watershed. This leads to concerns that cumulative effects and specific watershed effects (e.g. small stream withdrawals) might not be adequately addressed in this structure.

Section 2.3 suggests that research prioritization based on uniqueness will ensure that resources are provided for the areas that potentially pose the greatest risk to drinking water resources. It is difficult to see how this is a valid assertion. The fact that extensive research is already taking place on a given research question or potential drinking water impact does NOT suggest that it is of less potential risk than areas that are being less studied. Quite the opposite. The presence of a number of existing research projects in an area suggests that many scientists and engineers consider it a critical unanswered question. It does not seem wise for EPA to avoid studying areas that are the focus of existing expert attention. Rather, EPA should leverage this existing work to inform additional research questions in critical drinking water effects. I would recommend a series of workshops with experts to brainstorm on critical issues and identify the most important issues (this may be what the plan is for the workshops taking place concurrently with this SAB review). This could be followed with a formal expert elicitation and analysis.

Section 2.5. It is not clear to me why certain federal agencies provide comments through interagency review, while others sent comments through the public review process. It is difficult to understand how the interagency review comments have been incorporated into the plan without seeing these comments. I would recommend EPA summarize comments from the interagency review process and the response that was taken in the study plan development.

The data management for this large a study will be complex and require a high degree of coordination among the participants. A description of the plan for this data management should be included in the research plan. The data, metadata, analysis, model simulation results, etc.

must all be stored in a manner that allows access and utilization by the full scientific community as quickly as possible. The study plan indicates EPA's QA/QC will be used. During questioning in the public hearing, Dr. Briskin confirmed that level 1 QA/QC, the highest standard, will be used in this study. The extent to which this QA/QC incorporates data management is not clear in the document, and this detail should be added to the study plan.

**Charge Question 1: Water Use in Hydraulic Fracturing**
*EPA has used the water lifecycle shown in Figure 7 to characterize hydraulic fracturing and to identify the potential drinking water issues. Please comment on the appropriateness of this framework for the study plan. Within the context of the water lifecycle, does the study plan adequately identify and address the areas of concern?*

As mentioned in the general comments the framework in Figure 7 is clear and suitable, but the figure is visually and conceptually too narrow. It gives the impression that this is the water use in a single operation – a single well or a series of wells on a pad, rather than water use in an entire shale basin or watershed. This leads to concerns that cumulative effects and specific watershed effects (e.g. small stream withdrawals) might not be adequately addressed in this structure. A minor restructuring to the labeling in this figure may be sufficient to avoid this impression or an outside box showing that this conceptual plan is within a larger basin-level analysis. I would also recommend and added note about natural water cycle issues into the first orange box. Further, there are missing linkages in the figure, such as the reuse of flowback and produced water for the next fracturing activity. These produced waters are part of the water acquisition and chemical mixing when water is reused. Water storage should be included in the water acquisition section as well; impoundments of transported water or rainwater and water storage of flowback and produced water are widely used as part of water acquisition.

It is critical that this study address how *cumulative* withdrawals might affect quantity and quality and how withdrawals might affect quantity and quality differently at different times of year. The spatial temporal uncertainty associated with water resources and with water withdrawals must be considered in the analysis of existing data and in the modeling of scenarios. Also, the study should include evaluation of the potential effects under unstable climate conditions. The development of shale gas resources will span decades during which significant changes in water resources may occur. The use of Q710 withdrawal restrictions may be limited due to changes in the hydrological cycle that are not well predicted through historical records that inform Q710 and similar flow calculations.

It is critical that water movement around a basin and through inter-basin transfers be considered for its affects on basin level water resource. Water movement can also affect ecological systems in ways that impact downstream drinking water sources (e.g., changes in water salinity and temperature affect algal growth that may cause taste and odor problems in finished waters).

Water withdrawal is regulated in different ways in different parts of the country. Some areas have basin commissions that permit all withdrawals (like the Susquehanna River Basin). Others have state regulatory authority that is not basin-specific (like the western third of Pennsylvania in the Ohio Basin). These different regulatory structures lead to significant differences in how water is managed. These differences must be acknowledged and incorporated into planned studies of the effect of water use on drinking water resources. It would be reasonable to include these different regions in the prospective case studies.

Clearly, a water basin approach is needed, and yet, that would require sophisticated knowledge of water resources. For the most part, we do not have extensive water resource information in many basins in the US, particularly where water is abundant. Insufficient water quantity and quality data for a baseline will severely limit the usability of the models for the scenario evaluation suggested in this study as well as limit the conclusions that can be made from the case studies and scenarios evaluated.

**Charge Question 2: Research Questions**

*EPA has identified both fundamental and secondary research questions in Table 2. Has EPA identified the correct research questions to address whether or not hydraulic fracturing impacts drinking water resources, and if so, what those potential impacts may be?*

The fundamental research questions are sufficiently broad as to cover the objectives. The secondary research questions do not provide enough detail to evaluate if their answers will be sufficient to inform policy decisions. For example, what is meant by "water availability?" Does this refer just to quantity or to accessibility or both? As with Figure 7, "water availability" should encompass ecological flow. The composition of hydraulic fracturing fluids is not a single thing as suggested in the questions on this topic. Hydraulic fracturing fluids are varied in response to formation conditions, and thus, the questions on the characteristics and toxicity of these fluids must include a statistical approach to deal with the variability and uncertainty regarding these materials. Further, water reuse at a well pad or from well pad to well pad will affect the composition of the hydraulic fracturing fluid used in subsequent fracturing activities.

A set of questions that are ANSWERABLE in the time frame and budget available would be a significant value added in Table 2. A set of questions about which you could have hypotheses and provide input in order to answer them would be very useful in narrowing the scope and determining the actual steps necessary to address these questions. The specific planned activities for each research area (as described in Tables in Appendix A) are not clearly outlined as research questions that can be answered. This should be expanded to enable better planning of the research study and better review of the research activities by the SAB and by other scientists outside of EPA.

One area that is not adequately considered in the research questions is the role of multiple layers of gas resources. Are there any additional effects from hydraulically fracturing a layer under an already fractured layer? Is there prior information on fracturing multiple layers of hydrocarbons? Many areas that have fossil fuels have multiple types – coal seams, coal bed methane extraction, conventional natural gas, shale gas, oil. And, thus, the research questions should address how these different layers are accessed and how they are separated.

Another area insufficiently considered is the role of re-fracking at a well or collection of wells. The study specifically states it will NOT consider this due to lack of a partner for a prospective study. This should be re-considered as this activity within the life cycle of a well could have a considerable effect on drinking water resources, particularly if the fracking is taking place on older wells. If this cannot be included due to resource limitations or time frame, a paper study of the likelihood of refracturing in recent wells and in aging wells should be undertaken to ascertain the importance of restricting the study.

**Charge Question 3: Research Approach**
*The approach for the proposed research is briefly described in Chapter 5. Please provide any recommendations for conducting the research outlined in this study plan, particularly with respect to the case studies. Have the necessary tools (i.e., existing data analysis, field monitoring, laboratory experiments, and modeling) been identified? Please comment on any additional key literature that should be included to ensure a comprehensive understanding of the trends in the hydraulic fracturing process.*

The plan specifically calls for a transdisciplinary research approach that includes the integration of expertise inside and outside EPA. No specifics are given for how experts across multiple disciplines or from agencies or organizations outside of EPA will be engaged in the study. Since significant expertise exists in the private as well as public sector, the report should explain how such expertise will be engaged in the study.

The scope of the study includes the full life cycle of water use, which is good. But, the full life cycle of the *process* and its affect on drinking water sources is not included. For example, the fate and impact of the disposal of drilling tailings is not included and the fate and affects of liquid or solid waste produced during treatment of produced water (which can be road applied for deicing and dust control) is not included. If these are specifically excluded, that should be made clear and the boundaries for the life cycle should be clarified.

The approach includes retrospective case studies, prospective case studies, and scenario analysis. It is unclear that the specific case study approach will be sufficient to capture all potential problems. The scenario analysis approach “may” be able to capture issues such as dilution in large rivers, cumulative effects of multiple discharge points, and the effect of treatment choices in downstream drinking water plants. However, whether or not it DOES capture these issues is dependent upon the scenarios selected, and the study plan provides insufficient details about the selection of scenarios. Who will be involved in selection? Who will evaluate the scenarios once selected?

Retrospective case studies are a good idea, but this is difficult for large scale drinking water effects on surface water users as it is more difficult to identify “cases.” In a large basin, there are multiple inputs that ‘could’ be the cause of ‘cases,’ thus complicating the identification of case/control systems for comparison.

Prospective case studies are a good idea, but the site selection methodology is unclear. After a site is selected, what boundaries will be placed? Will it track that wastewater to ALL the places it might go or just to all the places it actually goes for these selected sites/wells? Once a site is selected, it will be difficult to ensure that management of water at the selected sites will be representative of average industry practice rather than best practice under observation. Thus, a case study should include a basin-wide wastewater management system so that all aspects of this can be included in the study.

Since the full water cycle is complex and there are multiple aspects within a single basin, a comprehensive water balance approach should be used to evaluate the potential pathways.

The tools described begin with existing data evaluation. One concern I have is that data needed for a comprehensive water balance may not exist. Water management, at least within Pennsylvania, appears to be lacking in closure of the water mass balance and complete tracking of the wastewater produced. It is unclear that evaluating existing available data will be sufficient. Also, it is not clear how the nine hydraulic fracturing service companies that were asked to provide data were selected. Are they representative? Will their information provide a complete picture of the chemicals used in this activity? The others tools are not described in great detail.

**Charge Question 4a: Proposed Research Activities – Water Acquisition**
*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Water Acquisition stage of the water lifecycle. Please provide any suggestions for additional research activities.*

"EPA estimates that approximately 35,000 wells are fractured each year across the United States." It is not clear how this estimate was made as no citation is given. Further, it is unclear why this value would not be known exactly. Permits are issued for drilling and fracturing wells so a number should be verifiable. Since the amount of water used depends on the length of the lateral, it would be important to know how many frac stages were used in each well drilled.

The study areas should include the Marcellus in southwestern Pennsylvania as this area is not part of a basin commission and therefore water withdrawals are not regulated as extensively as in the Susquehanna River Basin in Pennsylvania.

The description of existing data analysis is simplistic and presumes that sufficient data are available to catalog existing water resources for a region. Unless a very small area is selected, and additional gauge stations are installed, there is unlikely to be sufficient quantity data. Similarly, few areas contain sufficient real time water quality data for the type of water and salt balance suggested. The suggestion that the assessment will take place at multiple spatial and temporal scales is likewise ambitious.

**Charge Question 4b: Proposed Research Activities – Chemical Mixing**
*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Chemical Mixing stage of the water lifecycle. Please provide any suggestions for additional research activities.*

The issue of spills, releases or leaks on the surface is critical. Many industries (including oil and gas) have significant potential for spilling materials at the site of use. This is not unique to oil and gas, but this is a concern for drinking water sources, both surface and groundwater. The study plan indicates this will be considered in the case studies, but a thorough research on the frequency of these events is needed in order to allow risk assessment to consider the likely effects in the entire basin as shale gas plays develop fully. A geocoding of these events would also be useful.

Section 6.2.4 (p.25) indicates that the extent to which best practices are utilized in the industry is unclear. In order to evaluate the potential for drinking water impacts from spills or accidents involving chemical mixing, it is important to understand common industry practices as well as the capability of the industry to meet best practices. Section 6.2.5.2 indicates EPA will collect information on the effectiveness of current management practices. It will also be important to compare the current practices with the best practices and to evaluate the distribution of material handling practices across the industry. This will enable predictive modeling of potential drinking water contamination at the watershed level.

The mixing section does not adequately consider the reuse of flowback water, which is now done extensively in the Marcellus. This reuse complicates the composition of the frac water for a given well, and this must be considered. Since the constituents of the flowback are VERY different from the constituents in the original frac water, spills of the reused water should be considered here in the section on chemical mixing as well as in the section on produced/flowback water analysis.

The study plan mentions the use of diesel fuel, quoting from a letter from Representatives Waxman, Markey and DeGette. This has been a long standing issue in the field of hydraulic fracturing, and the public has continued to express significant concern regarding this. This study should consider the use of diesel with particular emphasis on determining the extent of use and the time frame of use of this material in this industry.

Broadly, to consider the toxicity, fate and transport of materials from hydraulic fracturing, it is necessary to have well-specific details on the chemicals used. It is unacceptable for industry trade secrets to impede the evaluation of the protection of drinking water.

Surface spills related to these chemicals are a potential pathway to drinking water. Since extensive prior research has looked at surface impoundment failures and water/chemical handling at industrial sites, it should be possible to evaluate the potential for these types of accidents through a scenario-based study. Similarly, there are best practices in the industry related to handling these materials. An evaluation of the extent of industrial compliance with these practices and the rate of accidental releases and impacts on surface water under standard practice and best practice is needed. This is mentioned at the bottom of pg 26, but few details are given for the method for evaluation of effectiveness of current management practices related to prevention or cleanup of spills.

**Charge Question 4c: Proposed Research Activities – Well Injection**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Well Injection stage of the water lifecycle. Please provide any suggestions for additional research activities.*

The issue of re-fracturing, particularly as wells age, is important. Section 6.3.2 indicates this will not be part of the study due to a lack of a case-study partner. This is not an adequate reason to restrict the study. A first order assessment of the importance of re-fracturing in several shale basins should be made to evaluate how relevant study of this activity would be.

Abandoned wells and their potential intersection with other formations are an important concern in regions like Pennsylvania and West Virginia, where nearer surface gas wells have been drilled for more than 100 years. This is not our first gas boom in SW PA, and we previously had few regulations related to well field spacing, well casings and well closure. Many of these sites are not on maps, and we learn of insufficient well closure or subsequent failure only after gas migration causes tragedy. Not cited in the report but worth reviewing is the gas migration report produced by NETL in 2007. http://www.netl.doe.gov/newsroom/versailles/ Evaluating the potential for migration of gas or water through these anthropogenic pathways should be included in the scenario development. It will also be important to understand the best management practices used by the industry to evaluate the potential for abandoned wells to intersect with planned well. Similar attention needs to be paid to abandoned coal mining activities, which are also not always fully mapped. Mine voids can contain water that is hydraulically connected to surface or groundwater formations and/or gas, including methane, that can endanger drilling and provide pathways to human contact.

The approach of selecting representative sites to evaluate failures is fine if the objective is to understand the frequency of different types of failures, but to understand failure itself and what conditions or activities contribute to its frequency, it would be better to review ALL failures rather than a selective sample of failure and non failure sites. Thus, retrospective case studies on well failure should be added in addition to retrospective case studies selected due to suspected water contamination. Understanding the conditions of well failure is critical, but may be beyond the scope of this study on hydraulic fracturing.

A first stage analysis of the relative importance of well failure vs hydraulic fracturing failure vs fluid spills (frac fluids and wastewaters) on the potential impact on drinking water resources would allow focus of the follow up study on the most important aspects of the overall process. For example, on page 30, the issue of fractures that extend beyond the target formation and reach aquifers is mentioned along with the issue of wellbore failure. It is not clear from this discussion how likely either of these events are, but a first analysis would likely result in very different likelihoods and very different "best practices" to reduce the risk from these activities. This analysis would provide important information to policy makers and the public about potential hazards as well as focus the follow on research on the issues of greatest likelihood to affect drinking water systems.

It is not clear to me what the *actual potential* is for fluid leakoff to cause drinking water contamination. This is mentioned in section 6.3.3 with several citations; however, these are general overview reports rather than scientific studies from the research community (industry, academia or regulatory agencies). One would expect that this is an area well studied by the industry. The EPA should seek significantly more information on the likelihood of this activity in tight shale formations vs other formations that are hydraulically fractured. This will also address some issues of the mass balance of water that would be necessary in order to evaluate the potential source term for fate and transport of chemicals in the hydraulic fracturing fluid. If fluid leakoff is low and flowback is low, the water balance is in question. Over the life of the well, how much returns to the surface eventually.

It is unclear how EPA will determine the representative samples of well files that will be requested. This should be clarified. Since the well file information is requested in database format from the industry, it is unclear why EPA would not simply request ALL the data for a year so that representativeness of future data collection requests could be evaluated. A single year comprehensive collection of data is not atypical for EPA (e.g., the information collection rule requests to drinking water providers are like this). That type of comprehensive time-limited data set often provides extensive information for follow up studies. Data of this type attract additional data analysis by groups outside of EPA; this will provide significant future leverage value.

**Charge Question 4d: Proposed Research Activities – Flowback and Produced Water**
*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Flowback and Produced Water stage of the water lifecycle. Please provide any suggestions for additional research activities.*

A lifecycle approach is an important component of this study, and this lifecycle must be correctly characterized. This requires a distinction between flowback and produced water, and an incorporation of the issue of recycle in the water management.

Flowback and produced water are distinct. While they share some potential drinking water issues, the significantly longer time period of production for "produced water" as well as the fact that it collects at the site when it is unintended rather than during active operations indicates this should be considered separately. Coal bed methane flowback is mentioned here as well, but the conditions for this activity are very different (the formation must be dewatered to enable gas flow in coal bed methane systems). A clear distinction should be made here to avoid confusing the reader. Since coal bed methane produced water has been previously studied by EPA, I recommend this present study focus on tight shale gas fracturing activities. Realizing that fracturing occurs in many other types of gas formation, the focus of the current study appears to be on deep, tight shale gas formations.

Recycle of flowback is extensively practiced in the development of the Marcellus shale. It is less clear how much produced water is recycled. Recycling increases the potential for accidental release as wastewater is held longer, often in open pits/impoundments, and potentially moved more times through multiple methods (pipelines as well as trucks).

Several sources of existing data on produced water are to be reviewed. There are additional sources from all plants that are receiving flowback for treatment or dilution. When deep well injection is used for disposal, detailed analysis may not be undertaken for the produced water; however, in areas where these wastewaters are treated (either for reuse or for surface water disposal of treated effluent), extensive evaluation of the wastewater is undertaken. These sources should be used to augment the initial characterization of produced waters. Also, wastewater treatment plants receive information on the well location for the shipments they receive. This would enable a geographical analysis of the produced water, which would enable deeper understanding of variability in flowback and produced water expected from different parts of the formations. This information would enable better predictions of the long term water quantity and quality expected for new wells in existing formations, and would have significant value as input to the scenario analysis and modeling.

There are ongoing studies of surface waters, with case/control structure, that contain the data EPA suggests collecting from surface waters. The NETL ongoing study of isotopes is mentioned, but there are many other scientific studies currently ongoing by academic institutions and NGOs. Since these studies are ongoing and likely to continue, EPA should leverage this work and include these data (with proper evaluation of QA/QC) in subsequent analyses.

Just as with source water, flowback and produced water must be considered within a spatial-temporal variability in the disposal options as well as the variability in the existing water quantity and quality that must be considered to understand the potential effects of wastewater disposal. These kinds of issues are discussed briefly in section 6.1.2; however, they should be elucidated in Table 2.

The issue of composition and variability of flowback and produced water should be considered on a geographic basis since the nature of the waters is expected to vary with the nature of the formation. Preliminary data are available to address this issue within the Marcellus where wastewater is tracked from well production to wastewater disposal. These data could be used to map the variability of produced water across the shale play.

Storage and transport of flowback and produced water should be included in this section. There is significant discussion of the regulatory issues surrounding this at the top of page 37, but there is not that much discussion of the science and engineering of design and evaluation of these storage and transportation issues.

**Charge Question 4e: Proposed Research Activities – Wastewater Treatment and Waste Disposal**

*Proposed research activities are provided for each stage of the water lifecycle and summarized in Figure 9. Will the proposed research activities adequately answer the secondary questions listed in Table 2 for the Wastewater Treatment and Waste Disposal stage of the water lifecycle. Please provide any suggestions for additional research activities.*

The draft states that "many commercial wastewater treatment facilities are designed to treat the known constituents in flowback and produced water." There is no reference provided, and it is not clear what constituents are the focus here. To my knowledge there are few commercial wastewater plants capable of removal of high levels of monovalent salts (sodium chloride or sodium bromide). This would require desalination-level treatment that is not typical for commercial wastewater pre-treatment.

The focus on bromide and chloride removal in treatment of hydraulic fracturing wastes is important. It is critical that treatment options be evaluated in terms of their removal of these monovalent anions, and particularly that the removal of bromide, which is problematic at much lower concentrations than chloride, be evaluated. The evaluation of treatment methods and their potential effect within a watershed is only slightly described. Additional data are available from plants currently receiving flowback and produced water and these should be included with other flowback data discussed in section 6.4.2. This section does not include retrospective case studies; however, brine "treatment" from oil and gas wells has been ongoing in sections of Pennsylvania for decades. Retrospective studies of the affect of long term disposal of treatment residuals on downstream drinking water systems should be included. Particularly, long term studies of the presence of bromide and its role in DBP formation should be included in regions that have been receiving effluent from treated O&G brine for many years.

Section 6.5.2 page 41 states that the project will "evaluate management practices for chloride and bromide in hydraulic fracturing wastewaters, along with evaluating potential impacts to drinking water utilities and their consumers." It is totally unclear how this project will evaluate potential impacts to DW utilities and their consumers. This is an existing active concern within SW PA, and it represents a potential significant cost to the DW utilities, their customers and society more broadly. Even when DBP totals do not increase, the fraction of brominated DBPs can rise significantly when source water bromide rises. This can change the risk profile of the DBPs even when finished water meets criteria.

How can we consider this impact? Will an evaluation for bromide be undertaken in a river basin to ascertain the level of bromide expected by legal disposal of oil and gas wastewater as well as other bromide inputs (natural and anthropogenic)? Will this target a level of bromide that is considered acceptable for source waters where drinking water plants use free chlorine for disinfection? Will this level consider plants that have to pre-chlorinate for iron or manganese control? These plants would have different "tolerances" for bromide in source water. Will the cost of DBP "treatment" through changing to chloramines or through distribution system storage venting be considered? Drinking water consumers will bear the cost of these changes.

Similarly, with chloride effects on corrosion, it will be up to the DW providers to 'fix' this and these costs will be borne by those who drink the water not by those who added the constituents to the source water. This is a significant environmental and economic justice issue.

It is not clear that the laboratory studies here will have significant value. Since SW PA is already experiencing higher bromide levels than in previous years, the drinking water plants themselves are ideal evaluation points for the role of this constituent in formation of DBPs. Some plants are also seeing higher chloride levels that might lead to corrosion and lead and copper issues. Drinking water providers often have the capability to expand their analytical work to the full suite of DBPs and to identify metals and could prove excellent partners to EPA in this evaluation. Similarly, POTWs and industrial water treatment systems are monitoring their treatment processes, and these partners could be leveraged to provide important water quality information.

**Charge Question 5: Research Outcomes**

*If EPA conducts the proposed research, will we be able to:*

a. *Identify the key impacts, if any, of hydraulic fracturing on drinking water resources; and*
b. *Provide relevant information on the toxicity and possible exposure pathways of chemicals associated with hydraulic fracturing.*

Due to the lack of specifics in the research plan, it is difficult to assess the likelihood of success in addressing these general desired outcomes, and it is particularly difficult to answer the specific research outcomes listed in multiple sections in the document. Further, since much of the plan is extremely ambitious considering the timeline and budget, it is difficult to assess if the specific outcomes will be met under the actual study conditions, which will necessarily be more limited than described.

I would strongly recommend EPA adjust the specific outcomes (deleting, adding, and revising) to be reflective of the changes to the research plan that have been suggested by the SAB. Those specific outcomes can then be re-reviewed.

Unrelated to the outcomes listed, it is worth mentioning that if the data are collected, managed and published, then an outcome that will be achieved is that data will be available for extensive follow up research. EPA information collection rule (ICR) data have often been the foundation of extensive follow up study that provides important insights into environmental issues – those directly related to the data collected as well as issues not considered when the data were collected. Extensive data sets that are available and well cataloged attract research, thus providing additional value to the project beyond the original scope.

**Comments from Dr. Radisav Vidic**

**Charge Question 4(d): Proposed Research Activities – Flowback and Produced Water**

The proposed hydraulic fracturing lifecycle framework outlined in Figure 7 and associated research question listed in Table 2 include all major potential impacts that hydraulic fracturing may have on drinking water resources. The proposed research activities are designed to answer the secondary questions included in Table 2 and are reviewed below with respect to the relevance and adequacy of the expected outcomes:

1. Composition and variability of flowback and produced water: Analysis of existing data and prospective case studies

   Analysis of the data collected by hydraulic fracturing service companies, PA DEP and NY DEC, as well as numerous research institutions will be of great value to identify all potential contaminants that should be used to expand the current Appendix D. It would be prudent to provide information on specific contaminants for each shale play that would be extremely beneficial to both regulatory efforts and efforts to develop treatment technologies that can be tailored for each region. In cases where actual concentrations of contaminants are needed to assess potential environmental impacts, including toxic effects, it would be necessary to validate QA/QC aspects of the studies that generated these data. It is expected that the prospective cases studies would follow the requisite QA/QC protocols.

2. Flowback and produced water release – Analysis of existing data, retrospective case studies, and scenario evaluations

   It is clear that past EPA experience in studying chemical spills and wastewater leakage will ensure that the analysis of the potential releases of flowbackand produced water from storage tanks, surface impoundments, blowouts and transfer pipes. In addition, proposed transport models would likely provide realistic information about the long-term movement of injected chemicals, formation fluids and transformation products up an improperly cemented section of the borehole.

3. Flowback and produced water management: Prospective case studies

   It is not clear how the data in the prospective case studies will be collected. The EPA expects that the information about the on-site handling of flowback and produced water can be collected from the hydraulic fracturing service companies. However, it is not likely that those companies will be able to provide information about the potential leakage of storage tanks or surface impoundments. Furthermore, the exact quality of water in storage tanks and surface impoundments may be significantly different from the quality of the flowback or produced water if this water is recycled for the subsequent hydraulic fracturing operations, as is increasingly the case in Marcellus Shale gas development operations. These changes in water quality should be taken into account when evaluating different scenarios of flowback and produced water impacts on drinking water resources.