United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Wyoming State Office
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MAR 17 2016

Kevin Frederick
Administrator, Water Quality Division
Wyoming Department of Environmental Quality
200 W. 17th St. 4th Floor
Cheyenne, WY 82002

Dear Mr. Frederick:

Thank you for the opportunity to review the Pavillion Domestic Water Well and Palatability Study, Final Draft Report released on December 18, 2015. We provide the following comments for your consideration. Please let us know if we can provide any clarification or additional information.

1) Similar to the Wyoming Oil and Gas Conservation Commission report on Well Integrity, lack of a potentiometric map complicates the analysis of the water quality results presented. All conclusions should be premised upon the lack of a potentiometric map and associated groundwater gradient information.
2) We recommend that the nearby and long term use of petroleum fuel storage tanks (above or underground) be more fully investigated as a potential source of the water quality degradation concerns.
3) A decision matrix would be a useful addition to the report to illustrate how the conclusions were arrived at. While there is a great deal of quality information presented, the lines of evidence are not clearly distinguished and it is difficult to understand why a particular conclusion was drawn.
4) The analysis would benefit from characterization of the reservoir production fluids for comparison. As is, conclusions that the water quality problems are not related to oil and gas production activities are not supported by the water well samples collected to date.

Again, thank you for the opportunity to review the Pavillion Domestic Water Well and Palatability Study, Final Draft Report. We appreciate the extensive efforts undertaken to prepare the final draft report, and generally agree with the stated conclusions. We hope our comments are helpful as the Wyoming Department of Environmental Quality moves forward with its investigation. The BLM would appreciate the opportunity to comment as new data and analysis become available.

If you have questions or wish to discuss these comments, please feel to contact me by phone (303-

775-6049) or e-mail (mvalle@blm.gov). You may also contact Karl Osvald, BLM Representative to the Pavillion Work Group, by phone (307-261-7729) or e-mail (kosvald@blm.gov).

Sincerely,

for Michael Valle
Acting Deputy State Director
Division of Minerals & Lands
Wyoming State Office

Charles and Marilyn Ham

It appears that industry made errors with drilling shallow and deep wells at varying depths in a geology that was too permeable to keep the migration of chemicals from going into the Pavillion drinking water and the State permitted these wells. Also leaking pits affected their potable water. The State needs to do something about this and step forward to repair or reimburse those affected landowners or to get industry to anty up. Both have a responsibility after taking the profits.

Charles Kuckel

Please investigate!

Cheyenne Area Landowner's Coalition

It's time Wyoming gets off dead center and recognizes that past oil and gas drilling operations are primarily responsible for pollution of the water supply in and around Pavillion. Inadequate casing of oil and gas wells and unlined production pits that held oil and gas waste have caused this problem and it is the State's responsibility to rectify it on a permanant basis. Three studies is enough. It's time to act. Remediate the pollution and pay for a long-term water supply for Pavillion area landowners.

Christy Gerrits

Data has been collected ad nauseam and all three studies indicate and point to contamination caused by a large industrial oil and gas field permitted by the State of Wyoming. Ground water does not get contaminated without some sort of source. The studies indicate that possible causes of this contamination are:
1. inadequate casing of oil and gas wells that led to contamination;

2. unlined production pits that held oil and gas waste that contaminated soil and groundwater and;

3. extensive migration and release of gas and fluids from oil and gas drilling and production that polluted the freshwater aquifer.

The residents of Pavillion have been dealing with this problem for way too long. It is time for the State of Wyoming to require industry to remediate the pollution and pay for the development a longterm water supply which will the residents to continue to live there.

Chuck Hall

DEQ Leadership This problem has gone on far to long. It is time to step up and ensure these people have their water needs met.
Thank You, Chuck Hall

CURED

On behalf of CURED, I am commenting on DEQ's reports that identify groundwater pollution in Pavillion, Wyoming. Pavillion residents use the Wind River Aquifer as a source of drinking water. This is the producing formation that was fracked. Many gas fields lie thousands of feet below formations that provide drinking water, and are better protected by impermeable layers that protect groundwater. This is not the case in Pavillion.
Studies show that inadequate casing may have led to contamination. Production pits were not lined. In reading other comments, it is my understanding that there are local well owners that report a change in taste, but there was a period of time when this was not the case prior to oil and gas development. Though this is qualitative in nature, it bears further investigation.

In an article published in December of 2012*, senior EPA hydrologist Mike Wireman referred to advances in science that now question the practice of "exemptions" that allow waste injection. EnCana was allowed to inject waste into aquifers at 38 sites. In that article, Wireman states that waste will flow outside that zone of influence over time, and there is no doubt that it will. Over decades, that water could discharge into a stream. It could seep into a well."

CURED requests that the State of Wyoming require operators to fund a solution for good water supply for residents of Pavillion. Thank you for the opportunity to comment.

Dottie Bentley, Chairman

*https://www.propublica.org/article/poisoning-the-well-how-the-feds-let-industry-pollute-the-nations-undergroun

E. Heyward

DEQ reports identify serious contamination problems caused by oil and gas drilling. Wyoming must require industry to remediate the pollution and pay for a longterm water supply for Pavillion area landowners.

March 16, 2016

Wyoming DEQ
Via fax: 307-777-7682 (1 page)

RE: Pavillion Water Pollution

To the Wyoming Department of Environmental Quality:

There are not many letters I write on environmental or governmental issues, but the issue of contaminated water in the Pavillion area has touched me passionately. I cannot imagine what it would be like to be drinking tap water and not knowing that it is highly contaminated, then upon finding that it IS contaminated, having to deal with the situation for years until something is done by those that are responsible for this unthinkable problem.

First of all, a dear friend of mine had a home in Pavillion during the time of the gas and oil exploration and drank the tap water there. She has since battled cancer and died.

I am writing not only for her and her family, but for all the other people in the area around where the State of Wyoming permitted this large industrial and gas field and allowed the contamination to happen.

This has been going on for years, and these people have had to put up with a lot, including securing clean water, legal battles, property depreciation, health issues or fear of future health issues, plus many other things.

Results from several studies have pointed out these contamination issues were caused by the oil and gas companies, and they should be held liable for their improper or illegal actions. Also, the extensive migration and release of gas and fluids from oil and gas drilling and production has polluted the freshwater aquifer. This is a great shame.

It is high time for the State of Wyoming to address this problem and require the gas/oil industry to remediate this pollution and pay for a long term water supply for the Pavillion area landowners.

Respectfully,

Emily Shelby

Emily Shelby
9255 N Avalanche Canyon Drive
Jackson, WY 83001
307-733-3334

RECEIVED
MAR 17 2016
DEQ WATER QUALITY

Encana Oil & Gas (USA) Inc.

Comments by Encana Oil & Gas (USA) Inc. to 12-14-15 Draft WDEQ Report--Comments; Attachments A, B, C, and E; as well as Part 1 of Attachment D; Part 2: Part 2 of Attachment D; and Part 3: Part 3 of Attachment D.

SUBMITTAL DATE: March 18, 2016

COMMENTS OF ENCANA OIL & GAS (USA) INC.

ON THE WDEQ PAVILLION, WYOMING AREA

DOMESTIC WATER WELLS

DRAFT FINAL REPORT AND PALATABILITY STUDY

(DECEMBER 14, 2015)

Comments of Encana Oil & Gas (USA) Inc. on the Draft Final WDEQ Report: Pavillion, Wyoming Area Domestic Water Wells and Palatability Study (Dec. 14, 2015)

I. Overview

Encana Oil & Gas (USA) Inc. ("Encana") appreciates the opportunity to comment on the referenced report prepared by Acton • Mickelson • Environmental, Inc. and the Wyoming Department of Environmental Quality (the "draft WDEQ Report" or "Report"). The draft WDEQ Report reflects a significant, rigorous effort to amass, integrate, and evaluate an array of available information across multiple scientific disciplines on the history and science of water-quality conditions and impacts in Pavillion Field. Encana believes that the draft WDEQ Report provides the requisite detailed evidence and analysis to support the vast majority of the conclusions presented in Section 6.1 of the Report. In particular, Encana fully supports WDEQ's recognition that groundwater resources in Pavillion Field are generally of poor quality due to naturally occurring constituents, including sodium, sulfate and total dissolved solids (TDS), exacerbated by decades of flood irrigation practices and other agricultural impacts. There also are geochemically-induced impacts associated with some amount of natural gas charging of shallow sands, but methane concentrations at shallow depths are generally inconsequential. The draft WDEQ Report also documents that the water quality in the 13 water wells evaluated[1] is consistent with Wind River Basin water quality results more generally.[2] In

[1] LD02 was never properly completed or permitted and should not be denominated or evaluated as a domestic water source.

[2] The draft WDEQ Report also properly characterizes the disparate nature of the water-bearing zones in Pavillion Field, and recognizes that the Wind River Formation in this area is not a singular underground source of drinking water. Draft WDEQ Report, p. 25.

addition, the draft WDEQ Report concludes that there is no indication of any oil and gas industry fingerprint, and certainly no hydraulic fracturing fingerprint, associated with the limited detections of organic constituents in the water wells evaluated.

However, for the reasons noted herein, and in prior comments on WOGCC's wellbore integrity and pit reports,[3] Encana must disagree with all five "Considerations for Additional Work" set out in Section 6.2 of the draft WDEQ Report. Encana does not believe the need for, or the utility of, these additional investigative activities is supported by either the Report's conclusions, or the voluminous data and detailed evaluations presented in the body of the Report and the supporting appendices. Section 6.2 of the draft WDEQ Report suggests more evaluation of wellbores and pits, even though multiple rounds of sampling have failed to document any oil and gas-related fingerprint in Pavillion Field water wells. Section 6.2 also ignores the overwhelming evidence, confirmed just pages before in Section 6.1, of the presence and natural prevalence of the same types of constituents that are known to impact groundwater palatability under EPA's secondary water quality standards. While the draft WDEQ Report acknowledges the long history of flood irrigation practices in Pavillion Field, it does not address the water quality degradation inevitably associated with these and other agricultural practices. Nor, given these problems, is there due discussion on the importance of proper construction techniques and ongoing well maintenance practices required for water wells in this environment. The Interview Questionnaires in Appendix F of the draft WDEQ Report document that little is known about the construction of the water supply wells evaluated and the apparent lack of any regular maintenance of these wells.

[3] Encana incorporates by reference as relevant its September 4, 2014 comments on the WOGCC Wellbore Integrity Report and its January 16, 2015 comments on the WOGCC Pavillion Field Pit Review (the "Pit Report").

Encana requests that the State of Wyoming reevaluate its "Considerations for Additional Work" against the substance of the draft WDEQ Report and the conclusions in the two WOGCC studies to develop one integrated set of recommendations that is driven by science and quality data, not by politics. The data and science document the quality of the groundwater resource in Pavillion Field as generally poor and degraded further by systemic flood irrigation and other agricultural practices. The focus of any further work on Pavillion Field palatability concerns should be on efficient, potable water delivery to the few remaining residents without access to potable water.

II. Specific Comments

A. No Additional Investigation is Necessary with Regard to the Legacy Surface Pits.

1. The Current VRP Process Should Continue Through Completion.

As WDEQ notes on page 110 of the Report, eight legacy surface pit locations identified as presenting potential risks to groundwater in Pavillion Field have been or are being addressed through the WDEQ Voluntary Remediation Program ("VRP"), W.S. §35-11-1601, *et seq*. Encana agrees with WDEQ's recommendation to complete the remaining work on these pits through the VRP.

As WDEQ notes on page 32 of the Report, four of the eight pit locations enrolled in the VRP have received Letters of Completion from WDEQ. Data for one additional pit location, TP 22-12, documenting four quarters of groundwater quality compliance, and a summary report requesting no further action for this location was submitted to WDEQ in January 2016. *See* Attachment A (Summary Table of Pit Evaluation and Remediation Activities).

In March 2012, Encana undertook an interim remediation project at the TP 24-3 location to remove contaminated soil and replace it with clean fill. Encana also has implemented a pilot test of an injected oxygen release compound at the TP 24-3 location. Groundwater monitoring is ongoing at this site to document the benefits of these activities. Draft Remedial Agreements are under review by the surface owners at the TP 14-11 and TP 42X-11 pit locations to complete necessary soil excavation and enhance soil and/or groundwater bioremediation, as needed. Ongoing, quarterly groundwater monitoring is also occurring at these two former pit locations.

More generally, as summarized in Attachment A and in Encana's Pit Report comments, legacy pit locations in Pavillion Field have been surveyed and evaluated now multiple times, by Encana and by the Working Group, to identify the locations requiring further investigation and possibly cleanup. In addition, as production wells are decommissioned and well locations are reclaimed, any associated historic pit locations will be evaluated again through the applicable WOGCC or Bureau of Land Management reclamation processes. *See* Wyo. Oil & Gas Conservation Comm'n Rules, Ch. 4 (2015); Bureau of Land Mgmt., 43 C.F.R.

§ 3162.3-1(f) (2016); Bureau of Land Mgmt., Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development, the Gold Book Ch. (4th ed. 2007).

In summary, no additional investigation is necessary, because existing programs and initiatives are sufficient to address any environmental impacts associated with legacy pit locations.

2. Surface Pits are Not Sources of Widespread Impacts to Groundwater.

The oil-based mud ("OBM") pits in Pavillion Field were used decades ago and never by Encana.[4] The WDEQ water quality data from the water wells sampled do not evidence any pit-related impacts to the water supply wells. The key groundwater constituents of concern from the OBM pits are diesel-range organics ("DRO") and benzene. The WDEQ data, however, document benzene, ethyl benzene, toluene and xylenes ("BTEX") concentrations below detection levels in all of the water supply wells. See Table 16A of the Report. DRO and gasoline-range organics ("GRO") concentrations also were below detection levels in PGDW23 (the water supply well located downgradient of the 33X-10 OBM pit) and were less than the Wyoming VRP cleanup levels (1.0 mg/L and 6.6 mg/L, respectively) in all of the other water supply wells. *See* draft WDEQ Report, Table 15. Furthermore, even the low concentrations of DRO and/or GRO detected in water supply wells were flagged by the laboratory in 10 out of 17

[4] As the Pit Report acknowledges, all of the Pavillion Field legacy pits were constructed or used by Encana's predecessors, not Encana. Encana has always used a closed loop drilling system in Pavillion Field, that does not require the use of pits.

samples as "exhibiting a chromatographic pattern which did not resemble diesel or gasoline standards." See Report, p. 63.[5]

The data from VRP pit locations are also instructive on the long-term impacts associated with OBM pits in Pavillion Field. In fact, the VRP data document the limited footprint of the OBM pits on groundwater quality. For example, as illustrated below, the groundwater impacts associated with the three pit locations still in the VRP reach no more than 150 feet downgradient of the former pit locations.

Pit Name	**Constituents**	**Approximate Impact Area**
Tribal Pavillion 42X - 11	Benzene and DRO	100 feet by 40 feet
Tribal Pavillion 24 – 3	Benzene and DRO	150 feet by 80 feet
Tribal Pavillion 14 - 11	Benzene and DRO	150 feet by 90 feet

As detailed in Encana's comments on the Pit Report, this is due to several hydrogeological and geochemical factors. *See* Comments of Encana on the WOGCC Report: Pavillion Field Pit Review (Nov. 24, 2014), dated January 16, 2015 ("Encana Pit Report Comments"), pp. 8-10. The limited extent of groundwater impact from the pits is primarily due to the ubiquitous, naturally occurring sulfates in groundwater that support degradation of petroleum hydrocarbons through the biologically mediated process of sulfate reduction. This conclusion is evidenced by the oxidation-reduction potential ("ORP") values determined for

[5] WDEQ's analytical data and associated documentation reveal QA/QC issues with the GRO and DRO results. The persistent detections in the laboratory and equipment blank samples indicate GRO and DRO contamination from field sampling and/or laboratory analysis. The draft WDEQ Report does not adequately address these shortcomings, and it should be revised to clearly document any QA/QC issues.

samples taken from shallow groundwater monitoring wells in the vicinity of these pits; measurements that are consistent with the range of ORP values (e.g., approximately -100 to -300 mV) associated with sulfate-reduction reactions. *See* Langmuir, D. Aqueous Environmental Chemistry Prentice Hall, Inc. (1997). As a result of these reactions, as well as other hydrogeological considerations detailed in the Encana Pit Report comments, the surface pits are not sources of widespread impacts to groundwater.

In summary, investigations of the VRP pits confirm limited groundwater impacts associated with legacy OBM pit locations in Pavillion Field. The former pit locations are not sources of widespread impacts to groundwater and there is no evidence of related impacts on near-by domestic wells.

3. Further Investigation of Other OBM Pit Sites is Unnecessary.

At page 110 of its Report, WDEQ endorses WOGCC's recommendation in the Pit Report for "further investigation of numerous closed pits." WOGCC's recommendation for further investigation, however, is not supported by existing data as previously detailed by Encana in its comments on the Pit Report. *See* Encana Pit Report Comments, pp. 9-11. As discussed above, data on OBM pits remediated under the VRP demonstrates that these pits have had a very limited impact on groundwater quality. VRP and other data also document that these pits have not impacted domestic wells evaluated by WDEQ.

Moreover, groundwater flow data should be considered in evaluating whether further investigation is necessary, and the draft WDEQ Report does not consider groundwater flow direction data in reaching its conclusions. As detailed in Encana's comments on the Pit Report, once groundwater flow direction is accounted for, there are no downgradient water supply wells proximate to OBM pits that would likely be impacted by the pits. *See* Encana Pit Report Comments, pp. 9-11.

In summary, given the screening processes utilized, the data gathered to date, and the limited impact on groundwater quality from surface pit locations already identified for remediation, there is no need for further evaluation of other OBM pit locations.

4. No Further Investigation of LSND Pits is Warranted.

The WOGCC's Pit Report concludes that no further evaluation of low solids non-dispersed ("LSND") drill cuttings pits is warranted. *See* Pit Report, p. 34. This recommendation is based, in part, on analytical data provided by Encana for drill cuttings from 40 gas production wells in the Pavillion Field that were collected from depths similar to the depths of the gas wells associated with the LSND drill cuttings pits at issue. *Id.* These 40 well sites were drilled using LSND water-based drilling mud systems, making the sample results particularly relevant to an assessment of the drill cutting constituents.

All 40 cuttings samples were analyzed for total petroleum hydrocarbons ("TPH") and chlorides. The highest detection of TPH was 645 mg/kg. Chlorides were analyzed at three

locations and were reported at 63.6 mg/kg, 115 mg/kg, and 215 mg/kg, respectively. *See* Attachment B (Table Summarizing LSND Drill Cuttings Analytical Data). Based on these low levels of TPH and chloride in the samples, WOGCC found no further investigation of LSND cuttings pits was necessary. *See* Pit Report, pp. 34. WDEQ ignores WOGCC's recommendation with regard to these LSND pits, and provides no basis in its Report to conclude, contrary to WOGCC, that further investigation of LSND pit locations is warranted.

In summary, no further investigation of LSND pits is warranted in light of the extensive data collected on drill cuttings from pits associated with LSND water-based mud drilling operations, which demonstrate limited impact from TPH and chlorides. This conclusion is further supported by the findings of WOGCC in its Pit Report.

5. No Further Investigation of KCl Pits is Warranted.

As detailed in Encana's comments on the Pit Report, there is no indication that surface pits associated with potassium chloride polymer ("KCl-polymer"), water-based drilling mud systems, are a likely source of objectionable changes in the palatability of water supply wells. *See* Encana Pit Report Comments, pp. 13. The pits were lined and were not used to store drilling fluids. Moreover, water quality data from the water supply wells do not indicate impacts from these former pit locations. The key constituents in KCl cuttings pits relative to any water quality impacts would be chloride and potassium associated with the KCl-polymer mud. As indicated in Table 12A of the Report, the concentrations of chloride (ranging from 17 to 68 mg/L) and potassium (ranging from 0.11 to 12 mg/L) in the domestic wells within 1,420

feet of the KCl-polymer mud pit locations are low, within the ranges of background conditions, and would not impact palatability. .

In fact, WDEQ's own evaluation supports this conclusion. At page 82 of the Report, WDEQ notes, as reflected in Figures 20 and 21 of the Report, that there is no pattern of higher concentrations of chloride and potassium in domestic wells close to the KCl-polymer pit locations to lower concentrations away from these locations, as one would expect if the KCl-polymer mud pits were a source of inorganic constituents in groundwater.

In summary, no further investigation of the KCl-polymer mud pits is warranted, because water quality data from water supply wells show no correlation to pits associated with KCl-polymer drilling mud systems. Concentrations of potassium and chlorides in the domestic wells are also low and unlikely to impact water palatability.

B. Any Vertical Gas Migration Associated with Production Well Construction is Not Impacting Domestic Water Sources.

Appendix G to the draft WDEQ Report, prepared by Dr. Maurice B. Dusseault, is entitled, "Pavillion, Wyoming Shallow Gas: Sources, Well Integrity, Options." Dr. Dusseault's analysis suggests that gas seepage along gas production wellbores could be migrating to and impacting groundwater resources utilized by Pavillion Field residents. It is true, as noted in the draft WDEQ Report and prior studies, that gas is found naturally in near-surface strata in Pavillion Field because of the lack of a rock gas cap. However, as detailed in Attachment C (MHA Comments) to these comments, Dr. Dusseault's analysis is premised on a

misunderstanding of hydrostatic pressures in Pavillion Field and the apparent, erroneous presumption that overpressure conditions are present in Pavillion Field sufficient to rupture the area around the surface casing shoe in a given gas well, thus allowing for the vertical and/or lateral migration of methane gas into water sources. Pressure and pressure gradients in the Wind River Formation simply do not result in overpressure conditions, and there is no valid mechanism to move any gas migrating vertically along a wellbore laterally towards a groundwater source. Also, to the extent Dr. Dusseault's discussion in Appendix G presupposes abundant methane gas in Pavillion Field at shallow depths serving as a feed stock for the substrate that generates iron-reducing bacteria, he is incorrect. For this geologic setting, the methane concentrations in the water wells sampled by WDEQ are extremely low. The highest methane concentration reported, at PGDW30, was 1,300 ppb (0.00013%). The average methane concentration across the 13 water wells sampled was 119 ppb (0.0000119%).

The comments in Attachment C (MHA Comments) also address the suggestion raised by the draft WDEQ Report that liquids can migrate up the gas wellbores, and then move laterally into water-bearing zones. Production wells in Pavillion Field are typically associated with dry gas production and have limited to no liquids production. Additionally, the produced liquids are not buoyant and the low formation pressures in Pavillion Field are insufficient to cause denser liquids to migrate vertically upward. Produced liquids that are sometimes associated with bradenhead gas are driven by conditions in the bradenhead and not liquid migration at depth.

Finally, the comments in Attachment C (MHA Comments) address the significant limitations of the wellfield diagnostics that Dr. Dusseault suggests might be helpful to evaluate gas leakage along gas wellbores in Pavillion Field.

In summary, any gas migration is not impacting domestic water sources, as reflected by the methane concentrations measured in domestic wells within the study area. The pressures in this system are also insufficient pressures to support movement of gas laterally into water-bearing zones.

C. Further Soil Gas Diagnostics are Unlikely to be Helpful.

With no proven method to distinguish between thermogenic gas naturally migrating in the rock strata over geologic time versus migrating along a wellbore, further soil gas analysis will only confirm what is already known, or will not otherwise advance the inquiry into well water palatability concerns in Pavillion Field.

1. Surficial Soil Gas Distribution

Section 6.2 of the draft WDEQ Report suggests further "[s]oil gas sampling from spatially distributed locations is preferred to quantitatively assess the upward seepage of gas as a function of distance from gas wells, so that the relative contribution from gas wells versus natural occurrence may be estimated." Draft WDEQ Report, Section 6.2, p. 109. However, a soil gas study as described will not advance the inquiry into Pavillion Field groundwater

palatability, except perhaps to confirm the known fact that gas is and has been naturally migrating from deeper to shallower zones in the Wind River Formation since long before oil and gas exploration and development began. As discussed earlier in these comments, in Section II.B, and in Attachment C (MHA comments), there is no pathway from the wellbores laterally to domestic water sources. Additionally, no control has been established that would support any scientifically valid comparison of near-wellbore soil gas results to more distant outcomes.

Finally, before any further soil gas evaluation is considered, the authors of the draft WDEQ Report should consult with EPA on the soil gas work EPA completed in 2010. For some reason, the Agency declined to publish or publicize this information in its 2011 draft report or related documents. Information on EPA's soil gas sampling activities, obtained by Encana in response to a Freedom of Information Act request to EPA, is included as Attachment D to these comments. Soil gas probes apparently were installed in July 2010 and sampled as part of EPA's Phase III sampling effort. The field notes from the effort suggest the probes were installed at nine locations. It appears that the majority of the soil gas sample results were non-detect. Encana suggests that WDEQ request additional information from EPA on these activities and evaluate EPA's soil gas work in its final report, prior to determining the efficacy of conducting further work.

2. Isotopic Analysis

The investigation of shallow gas sources in the Pavillion Field continues in the present WDEQ study and there is some suggestion in the draft WDEQ Report, and particularly

in Appendix G, that consideration might be given to additional study of isotopic of formation gases,(including the use of stable isotopes), that may be useful in defining methane source and pathways.

Previous investigations have evaluated the analyses of $\delta^{13}C$ and δD in dissolved methane samples from the water supply wells and compared them with $\delta^{13}C$ and δD in methane from produced gas samples (i.e., gas obtained from producing wells). Data for dissolved methane in water samples are available from the June and August 2014 DEQ sampling event, as well as the EPA Phase II, Phase III, and Phase IV sampling events. Data for produced gas samples from both the Wind River Formation and the deeper Fort Union Formation are available from EPA Phase II work and from Johnson and Rice, 1993. These data are compiled in Appendix P of the WDEQ Report.

Based on the analyses of carbon-13 and deuterium isotope abundance, methane in the samples from the water supply wells is thermogenic in origin, showing signs of alteration by biodegradation. (*See* draft WDEQ Report, Figure 15.) The isotope ratios for the produced gas samples are very similar in signature and gas from the Wind River is indistinguishable from gas from the Fort Union. All the samples from the water supply wells largely group within the region of thermogenic gas, although the Report notes that stable isotope samples from certain water supply wells (PGDW30 and PGDW23) are depleted in ethane and propane versus methane, indicating significant alteration by migration, and by biodegradation in the case of the later well. EPA also concluded much the same as to the thermogenic nature of shallow gases in Pavillion Field.

Additional study focused on elucidating the sources of shallow gases would be expensive, time consuming and, as the draft WDEQ Report itself acknowledges, "very difficult to quantify" with any reasonable degree of certainty. Draft WDEQ Report, Section 6.1, p. 108. If the point of such a study was to differentiate gas that had migrated naturally to the surface versus gas that had migrated up a wellbore, the source of the gas in both cases would be the same thermogenic gas, as all of the prior studies have demonstrated. The available data also do not suggest any sort of systematic isotopic fractionation of the gases as they migrate. Absent isotopic fractionation, there is no reliable method to define a thermogenic signature for gas that is "naturally" migrating, as opposed to gas that might be migrating along a wellbore. The conclusions in the body of the Report at Section 6.1, p. 109, acknowledge this fact. ("The relative contribution of potential gas seepage along gas wells versus natural upward migration of gas is undefined and would be difficult to quantify.") *See also* draft WDEQ Report, Appendix G, p. ii. ("The reliable quantification of gas sources, seepage rates and pathways is challenging, with no guarantee that specific issues can be resolved with a high degree of certainty.")

Given the presence of a single uniform gas source that has been migrating since long before oil and gas exploration and development began and the apparent lack of any isotopic fractionation during migration to the near surface, the final Report should clearly reject additional isotopic analysis as a means to try to distinguish sources and pathways of methane.

3. Nitrogen Isotopes

As noted in Section 5.7.1.5 of the draft WDEQ Report, stable isotopes of nitrogen and oxygen in nitrate may be used to identify the source of nitrate in groundwater in agricultural areas. Ammonium based fertilizers are produced from atmospheric gas which has the isotopic signature of nitrogen-15 is near 0 permil. Nitrogen from urea involves mineralization from soil water which is depleted in oxygen-18; thus nitrate for most chemical fertilizers has $\delta^{15}N$ and δ18O values near 0 permil. Subsequent denitrification will result in enrichment of nitrogen-15 and oxygen-18. Nitrate from human or animal waste is generally enriched in nitrogen-15 by 5 to 10 permil or greater.

Stable isotope data for nitrogen-15 and oxygen-18 in dissolved nitrate indicate that groundwater from PGDW41A and PGDW45 (which should read 49) is enriched in the heavier isotopes, with $\delta^{15}N$ values of 30 and 40 permil, respectively, δ18O values of approximately 10 and 15 permil, respectively. See Table 27. This indicates, as WDEQ identifies, that the groundwater has undergone denitrification. WDEQ suggests that nitrate reduction may also be occurring at PDGW33 and PGDW45. $\delta^{15}N$ values of 30 to 40 permil suggest a source of human or animal waste that has been subsequently enriched. Here again, strong vertical gradients associated with irrigation practices appear to be driving these agricultural impacts to significant depths below the ground surface.

In summary, with no method to distinguish between thermogenic gas naturally migrating in the rock strata over geologic time, versus thermogenic gas migrating along a

wellbore, conducting further soil gas diagnostics is unlikely to be helpful and will not otherwise advance the inquiry into domestic water palatability in Pavillion Field. Moreover, the nitrogen isotope data and the nitrate data in groundwater document impacts from surface agricultural uses at depths up to 675 feet.

D. Flood Irrigation and Other Agricultural Practices Have Negatively Impacted Domestic Water Sources in Pavillion Field, Including at Depth.

The draft WDEQ Report acknowledges irrigation-related impacts on shallow water wells, which the Report fails to consistently define (*e.g.*, p. 12—less than 50 feet; p. 20—1 to 30 feet bgs). The Report cites a 1959 USGS Water-Supply Paper that "found that wells less than 200 feet deep generally yielded highly mineralized surface water, the result of leaching by infiltrating irrigation water," draft WDEQ Report, p. 22, and "deeper wells generally contain lower TDS, but a higher percentage of sodium." *See generally,* USGS Ground-Water Resources of Riverton Irrigation Project Area; Wyoming Geological Survey Water-Supply Paper 1375 (1959) ("USGS Water-Supply Paper"). However, the draft WDEQ Report fails to evaluate this and the other information documenting a significant impact on water quality from many decades of flood irrigation practices, not just in "shallow" water wells, but also in water wells completed much deeper, apparently as deep as 675 feet.

1. Irrigation Practices Dramatically Altered the Groundwater System

Surface irrigation began in the Pavillion area as early as 1906. Flood irrigation began there in the early 1920s. *See* Draft WDEQ Report, p. 17. Prior to that time, infiltration of

precipitation and natural surface water likely would have been the principal source of groundwater recharge. This primary source of groundwater recharge changed with the start of flood irrigation (http://midvaleirrigation.net/Projectfeatures.com).

The USGS Water-Supply Paper cited by WDEQ states, based on 1948–1950 data, that "recharge to the ground-water reservoirs in the Riverton area occurs mainly by influent seepage from irrigation canals, laterals and reservoirs and by infiltration of water applied to cultivated lands" and further clarifies that "precipitation is not an important direct source of ground-water recharge." USGS Water-Supply Paper, p. 47. The USGS also points to hydraulic losses in the system and states that the "Bureau of Reclamation report that only about 50 percent of the water diverted for the Riverton project actually reaches cultivated land." USGS Water-Supply Paper, p. 50. This means that, in addition to irrigation water recharge, one-half of the irrigation flows are almost entirely lost to recharge among the 100 miles of main canals, 300 miles of laterals, and 335 miles of drains that make up the Midvale Irrigation District systems. *See generally,* http://midvaleirrigation.net/Projectfeatures.com at p. 4. The USGS Water Supply Paper further questions whether shallow groundwater would exist without irrigation and concludes that "available evidence indicates that, before irrigation, ground water in the surficial materials either was non-existent or generally far below the surface and that infiltration from canals and applied irrigation water has formed a permanent ground-water body or has enlarged one already present." USGS Water-Supply Paper, p. 93.

In light of these events, the water table in the area has likely risen over time, with strong downward vertical gradients created by recharge from a combination of irrigation

water and return flows. No pre-irrigation water levels are presented by the USGS Water-Supply Paper, so comparative depths to water cannot be quantified. However, it appears that the WDEQ statement that "historically, the depth to water in shallow wells in the Pavillion area has ranged from 1 to 30 feet bgs" is referring to water levels taken following the practice of flood irrigation, and not prior. Draft WDEQ Report, p. 20.

2. Influence of Poor Quality Irrigation Water was Documented by the USGS in 1959.

In addition to documenting the dominance of irrigation on groundwater recharge and water levels, the USGS Water-Supply Paper provides water quality data for irrigation water and irrigation return flows, which would have contributed to the degradation of groundwater quality over time. A summary of data obtained from locations closest to Pavillion Field is provided in Table I below.

Table I

Analyte	Units	EPA MCL	Irrigation Water and Return Flow [1]								
			Wind River above Wind River Diversion Dam	Wyoming Canal at Power Drop	Pilot Butte Reservoir at Outlet	Fivemile Creek below Upper Gaging Station	Ocean Lake	Upper Ocean Drain	Lower Ocean Drain	Lower Fivemile Creek at Bridge	Spring along Eagle Drain near Fivemile Creek
			Oct-1948	Sep-1949	Sep-1949	Oct-1948	Sep-1947	Sep-1947 - Sep-1949	Oct-1948	Oct-1948 - Sep-1949	Sep-1949 - Aug-1950
Nitrate as N	mg/L	10	1.1	0.7	1.3	0.4	0.2	0.2 - 1.6	1.4	10 - 13	13 - 18
Calcium	mg/L	--	44	30	34	2.5	143	101 - 140	118	139 - 222	142 - 172
Magnesium	mg/L	--	13	7.6	7.9	1.3	49	41 - 48	42	30 - 53	32 - 44
Sodium	mg/L	--	19	9.7	14	150	532	518 - 519	513	344 - 592	603
Potassium	mg/L	--	1.6	3.2	4	0.8	0	3.2 - 4.8	4.8	2.4 - 7.2	4.8
Bicarbonate	mg/L	--	167	100	114	193	152	88 - 148	108	176 - 237	256 - 320
Chloride	mg/L	250	8	3.6	4	11	100	83 - 100	86	44 - 78	64 - 66
Sulfate	mg/L	250	62	38	52	157	1390	1310 - 1360	1310	992 - 1640	1440 - 1560
pH	SU	6.5-8.5	7.7	7.6	7.1	8.5	8.2	7.1 - 8.2	7.8	7.5 - 7.7	7.7 - 7.8
TDS	mg/L	500	262	158	188	451	2290	2120 - 2240	2150	1660 - 2730	2480 - 2600

Notes:

1 Ground-Water Resources of Riverton Irrigaton Project Area, Wyoming, by D.A. Morris, O.M. Hackett, K.E. Vanlier and E.A. Moulder, USGS Water-Supply Paper 1375, 1959, Table 9

Highlight indicates that constituent concentration exceeded the USEPA Maximum Contaminant Level (MCL)

Two distinct water types are apparent from review of the historic results: 1) a low TDS, low sulfate group, reflected in the left side of Table I, which represents irrigation waters and 2) a high TDS, sulfate, sodium, and nitrate group, to the right side of Table I, which represents irrigation return flow. The first group is an end member of relatively dilute irrigation water applications and the second group represents another end member generated as dilute irrigation water that was applied or infiltrated out of canals and reservoirs, was concentrated by evapotranspiration, moved downward under a strong downward hydraulic gradient, leached soluble salts and dissolved other minerals along groundwater flow paths and ultimately either discharged as return flow or became part of the groundwater system.

3. Irrigation Significantly Impacts Water Quality in Water Supply Wells at All Depths.

EPA prepared a presentation for a November 30, 2011 Workgroup Meeting entitled "Investigation of Ground-Water Contamination near Pavillion, Wyoming." The presentation included a Durov diagram, which is included as Attachment E (EPA presentation cover sheet and Durov diagram). The diagram shows EPA Phase I through IV data for major ions, pH and TDS for domestic wells, as well as "Wyoming Canal Irrigation Water." The presentation further discusses the diagram and states:

> Shallow ground waters (< 31 m bgs) collected from drinking water wells and stock wells are near neutral (pH 7.7 ± 0.4, n = 19) and display calcium-bicarbonate composition. Total dissolved solids concentrations are <6000 mg/L in all ground water samples. With depth, ground water becomes increasingly alkaline (pH 9.0 ± 1.0, n = 55), . . ., is dominated by sodium and sulfate as the major cation/anion pair. This gradient in pH and

> water chemistry likely arises from the wide-scale surface application of irrigation water from the Wind River to support crop growth since irrigation water appears to represent an endmember composition. The chemical alteration from bicarbonate-type recharge water to sulfate-type ground water involves multiple water-rock interactions, including salt dissolution, carbonate mineralization, and exchange of divalent cations for sodium (Morris et al. 1959).

EPA acknowledges the relatively dilute, calcium-bicarbonate end member that represents irrigation water (which is assumed to be "Wyoming Canal at Power Drop" in Table I) and concludes that the general trend from calcium-bicarbonate to sodium-sulfate water with depth in the water supply wells is likely attributed to irrigation water. The Durov plot did not include the irrigation return-flow end-member (high TDS, sulfate, sodium and nitrate group in Table I).

Table II clearly demonstrates the similarity between domestic water supply well chemistry and irrigation return flow water chemistry.

Table II

Analyte	Units	EPA MCL	Irrigation Water and Return Flow [1]									Groundwater
			Wind River above Wind River Diversion Dam	Wyoming Canal at Power Drop	Pilot Butte Reservoir at Outlet	Fivemile Creek below Upper Gaging Station	Ocean Lake	Upper Ocean Drain	Lower Ocean Drain	Lower Fivemile Creek at Bridge	Spring along Eagle Drain near Fivemile Creek	Domestic Wells in WDEQ Study (average concentration)
			Oct-1948	Sep-1949	Sep-1949	Oct-1948	Sep-1947	Sep-1947 - Sep-1949	Oct-1948	Oct-1948 - Sep-1949	Sep-1949 - Aug-1950	Jun-2014 and Aug-2014
Nitrate as N	mg/L	10	1.1	0.7	1.3	0.4	0.2	0.2 - 1.6	1.4	10 - 13	13 - 18	2.3
Calcium	mg/L	--	44	30	34	2.5	143	101 - 140	118	139 - 222	142 - 172	182
Magnesium	mg/L	--	13	7.6	7.9	1.3	49	41 - 48	42	30 - 53	32 - 44	30
Sodium	mg/L	--	19	9.7	14	150	532	518 - 519	513	344 - 592	603	598
Potassium	mg/L	--	1.6	3.2	4	0.8	0	3.2 - 4.8	4.8	2.4 - 7.2	4.8	3.0
Bicarbonate	mg/L	--	167	100	114	193	152	88 - 148	108	176 - 237	256 - 320	196
Chloride	mg/L	250	8	3.6	4	11	100	83 - 100	86	44 - 78	64 - 66	89
Sulfate	mg/L	250	62	38	52	157	1390	1310 - 1360	1310	992 - 1640	1440 - 1560	1509
pH	SU	6.5-8.5	7.7	7.6	7.1	8.5	8.2	7.1 - 8.2	7.8	7.5 - 7.7	7.7 - 7.8	8.2
TDS	mg/L	500	262	158	188	451	2290	2120 - 2240	2150	1660 - 2730	2480 - 2600	2460

Notes:

1 Ground-Water Resources of Riverton Irrigaton Project Area, Wyoming, by D.A. Morris, O.M. Hackett, K.E. Vanlier and E.A. Moulder, USGS Water-Supply Paper 1375, 1959, Table 9.

Highlight indicates that constituent concentration exceeded the USEPA Maximum Contaminant Level (MCL)

Table II demonstrates, that the agricultural water quality from the 1950s and water quality in the 13 wells investigated by WDEQ are essentially the same. This chemical degradation of groundwater quality has occurred over the last 100 years as irrigation waters have continued to infiltrate and geochemically evolve with a deepening, sodium-sulfate recharge into the underlying Wind River Formation.

4. Irrigation Water has Negatively Impacted Well Water as Deep as 675 Feet.

The discussion above provides context and support for the EPA's interpretation that the range of water types displayed by the domestic water supply wells included in the EPA Phase I through IV investigations can be explained by the repeated, systemic application of irrigation water. Supporting evidence for deeper groundwater impacts associated with irrigation and other agricultural practices includes:

- The likelihood that the pre-irrigation groundwater system was characterized by recharge solely of precipitation and surface water, which would have translated into much greater depth to water than the current system as postulated by the USGS (1959);
- The start of flood irrigation in the 1920s would have raised water levels and replenished aquifers, possibly to the extent the area represented a large groundwater mound;

- The long history of widespread irrigation in the area could only further degrade groundwater to even greater depths than described by the USGS based on 1948 – 1950 data; and
- Strong hydraulic controls exerted by irrigation and return flow waters and the development of a long-term supply of poor quality irrigation, high TDS and sulfate water created along groundwater flow paths.
- The presence of agricultural chemicals, as well as nitrates and stable isotopes of nitrate, consistent with the presence of animal waste based nitrogen in domestic wells at depth.

The analytical data from the draft WDEQ Report confirm the likely depths of these impacts. Table II, above, documents the average quality for the key palatability constituents across all 13 domestic wells, and in the deepest domestic well in comparison to irrigation return flow quality. Again, the similarity in quality, including at depth, is compelling. In addition, as noted in Section II.E.3 of these comments, Lindane, a pesticide used on barley and other crops, was detected in multiple wells at depths ranging from 30 to 675 feet. Additionally, as discussed in Section II.C.3 of these comments, nitrogen isotope data also point to impacts from human or animal waste in certain deeper wells.

In summary, historic USGS reports and the more recent domestic well water-quality data demonstrate that agricultural practices at the land surface have, over time, recharged and negatively impacted groundwater sources in Pavillion Field at significant depth.

E. Poor Domestic Well Construction and Maintenance Are Contributing Factors to Water Supply Palatability.

The draft WDEQ Report effectively ignores the potential importance of domestic well construction and maintenance issues as contributors to Pavillion Field palatability complaints. The Report's recommendation in this regard also misses the mark. Studying the origin of specific bacteria in the domestic wells, as suggested in Section 6.2 in the draft WDEQ Report, might be of academic interest relative to geomicrobiology and basin geochemistry, but will not aid the evaluation of what causes water palatability issues in Pavillion Field or how these issues might best be addressed in specific domestic wells. What is clear is that each of the 13 domestic wells evaluated would likely benefit considerably from routine maintenance to limit the bacteria and biofouling associated with the poor ambient groundwater quality and hydrogeologic conditions.

1. Well Construction Issues

As addressed elsewhere in connection with EPA's earlier work in Pavillion Field,[6] well construction and poor downhole conditions often contribute to well water palatability issues. These effects have been widely understood for decades, and are the basis for well construction standards and rules, such as those set by the Wyoming State Engineer's Office ("SEO"). *See* http://seo.wyo.gov/ground-water/water-well-construction. The SEO's 1974 Water

[6] *See generally* Smith-Comeskey (Ground Water Science), Report on US EPA's Investigatory Approach to Palatability Issues in Water wells Near Pavillion, Wyoming (2013) ("Smith-Comeskey Report"), which is cited as Document #6 in Appendix H to the draft WDEQ Report.

Well Minimum Construction Standards went through a major revision in 2010 that brought them up to modern construction standards. Consequently, all of the 13 wells addressed in the draft WDEQ Report were built under older, less rigorous standards and process. While the available information on the construction of these 13 wells is quite limited, the authors of the draft WDEQ Report did make an effort to compile well owner survey information (Appendix F) and well records when available. The Report also includes still-photos from recent downhole well videos (reports in Appendix E) for eight of the 13 wells evaluated.

The well owner surveys confirm that the well owners generally know little about the construction and condition of their water wells, even now—years after palatability complaints were first voiced. PGDW23 is the only well documented with a driller's log, providing as-built documentation of the well construction. Information on the remainder of the wells consists of some combination of owner recollection, unsubstantiated EPA records, SEO records and some well video. The available well video selections (Appendix E) themselves are incomplete as pumps were not pulled for the investigation, so the videos terminate at the tops of pumps, centralizers, or other obstructions. For eight of the wells, the means of completion (open hole or screened), and the producing interval or intervals are unknown. Two wells are reported as open hole completions. Three are reported as having some sort of slotted or perforated completion. Knowledge of completion history, including any multiple completions, is important to any rigorous evaluation of water well integrity and impacted water sources. Lacking in all but one case is any discussion of the method of drilling (cable tool or forward rotary). PGDW32 apparently was originally drilled by cable tool, but the hole collapsed before casing installation. A forward rotary hole was drilled adjacent to the collapsed hole. (A well that is constructed by

cable tool methods is often more vulnerable to contaminant migration along the casing and annular space than a forward rotary well.) Proper casing installation and grouting, which are critical to the sanitary integrity of a well, also are not documented.

Well head completion is another critical variable in maintaining the sanitary integrity of a water well. In this regard, a properly attached well cap is essential. One Pavillion Field water well, PGDW44, is reported not to have a well cap (draft WDEQ Report Table 2, and interviews, still photo in Appendix E). This leaves the well vulnerable to small vermin and other contaminants. One well reportedly has a PVC slip-on cap. The remaining wells have some type of bolt-on cap. The owner interviews indicated that only one well may be vented (through a broken fitting). Without venting, there is a vacuum pulled on the casing during pumping drawdown, which can pull contaminants and irrigation water through any casing breach, through the seal for the pitless adapter (which is just drilled through the casing), and potentially along the casing in open hole completions (if the water level declines below the casing). In examining the video still photos in Appendix E, there are glimpses of the cap set up for some wells. Wells PGDW41A and 41B appear to have vented bolt-on caps. Well PGDW49 has an insert four-bolt well seal with what looks like silicon caulk on the casing, but the four bolt holes, which are not screened, act as both vents and access for small vermin and other contaminants.

Some information on domestic well casing condition can be gleaned from the well videos, although even that information is limited. Because well pumps and other appurtenances were not pulled or removed, conditions at depth, which are critically important to

a water well evaluation, cannot be determined. In general, the steel casings (PGDW 44 and 49) exhibited what appeared to be well-established scale, encrustation and biofouling. PVC casing (also indicating rotary well drilling) generally was cleaner, although there was some apparent biofouling present. Casing (PVC) damage was observed in both PGDW41A (visible in stills) and 41B (reported), with fingerlike protrusions visible in 41A likely indicating mineral deposition associated with leakage at a casing joint.

2. Domestic Well Maintenance

Two things about water well maintenance are widely understood and documented: 1) wells do deteriorate over time, with accumulations of biofilm and debris that impact water quality; and 2) domestic well owners (in particular) seldom perform water well maintenance to limit that deterioration.

The importance of water well maintenance is widely recognized. There are numerous additional state and federal level documents related to these topics. The National Ground Water Association (www.ngwa.org and www.wellowner.org), Water Systems Council (https://www.watersystemscouncil.org/about-wsc/wellcare-program/), and others (several referenced in the Smith-Comeskey Report) have for many years recommended well maintenance practices and provided guidance to well owners on how to proceed. WDEQ encourages well maintenance and wellhead protection (which are the responsibility of the well owner) and provides references to information sources (http://deq.wyoming.gov/wqd/groundwater/resources/drinking-water-wells/). The SEO also

requires: "…the well owner(s) must maintain a well in a condition so that it does not contribute to contamination (pollution) of the groundwater supply." *See* http://seo.wyo.gov/ground-water/water-well-construction.

Despite this knowledge and the available resources, the well owner interviews conducted for the draft WDEQ Report, Appendix F, document that, except for PGDW05, little or no maintenance has been conducted on the sampled wells, even though the need for well maintenance is especially important in a difficult water quality setting such as the Wind River Basin.

A lack of systematic well maintenance is likely exacerbating palatability concerns. The draft WDEQ Report should address this point as well and recommend that individual well owners pursue an appropriate maintenance program, consistent with that well's purpose and use.

3. Capture Zones

The capture zones associated with the domestic wells in Pavillion Field, and potential hazards within likely capture zones, also should be more carefully considered in the Report. This is part of the wellhead protection responsibility of well owners, and the basis for defining sanitary isolation distances in state environmental regulations. For a contaminant to be pulled into a well, it has to be situated within the capture zone of the well.

Sterrett (2012) calculated approximate capture zones for the water wells at a 100 ft. radius. Certain potential sources of contamination on the order of a 100 ft. radius are identified in the well owner surveys (Appendix F). Most properties have septic systems, fuel storage, livestock and manure, and light pesticide or herbicide use in the vicinity. Again, these sorts of impacts need to be considered in evaluating palatability concerns, especially where water quality data document these types of impacts to be present.

In summary, it is well documented that the construction techniques for developing a water supply well and its long-term maintenance are key factors affecting water palatability. In attempting to assess causal factors for groundwater palatability concerns, all elements of potential influence must be considered and appropriate corrective measures evaluated.

III. Conclusion

Additional data collection will not advance the inquiry into causation of or response to palatability concerns. These comments have already addressed the draft WDEQ Report conclusions and recommendations relative to the need for further pit investigatory work and the need for, or utility of, any further investigation to evaluate potential gas seepage along gas well boreholes. *See* Sections II.A and II.B, respectively. Additionally, Section II.E explains why further sampling and analysis to identify the origin of specific bacteria are unnecessary.

Previous reports, and most immediately the two WOGCC reports, have recommended what is termed "a comprehensive hydrogeological" study in Pavillion Field. Encana's comments on the WOGCC reports detail why such a study is neither necessary nor helpful. In summary: a large amount of data already exists documenting the heterogeneity of Wind River Formation geology; that heterogeneity does not lend itself to a "comprehensive" analysis; and all the evidence points to causes other than oil and gas activities for poor quality well water in Pavillion Field. Additionally, the draft WDEQ Report itself provides a comprehensive review across the extensive hydrogeological information already available for this area. In particular, the text of the Report, plus the discussion of references in Appendix H and Appendix I, highlight and integrate the abundance of information already available, including multiple USGS and other governmental reports.

The cause of the palatability issues in Pavillion Field is documented in multiple data sets and reports. After what is now seven rounds of sampling, the EPA and WDEQ results, as well as sampling results from several of the water wells that pre-date the EPA and WDEQ investigations, consistently identify elevated concentrations of sulfate and TDS in well water significantly in excess of EPA's secondary Maximum Contaminant Levels ("MCL"), which set palatability standards for these constituents, both of which contribute to bad-tasting water. Additionally, although there is no EPA MCL for sodium, this constituent can also impact palatability and is elevated in many domestic water wells in Pavillion Field. There is no oil and gas fingerprint in any of these many data sets. The noted constituents are the key causes of the Pavillion Field palatability issues, along with historic and ongoing flood irrigation and other agricultural practices. Poor well construction and maintenance practices are also a problem.

The State of Wyoming has mechanisms in place to ensure that potable water supplies are available to Pavillion Field residents. Any additional resources should be focused as the State and its constituents deem appropriate on ensuring reliable potable water resources for Pavillion Field residents into the future.

TABLE OF CONTENTS--ATTACHMENTS

Attachment A .....Summary Table of Pit Evaluation and Remediation Activities

Attachment B .....Table Summarizing LSND Drill Cutting Analytical Data

Attachment C .....MHA Comments

Attachment D .....EPA Soil Gas Investigation--Field Notes, etc.

Attachment E .....EPA Cover Sheet and Durov Diagram

ATTACHMENT A

ATTACHMENT A

Summary of Historic Pit Evaluation and Remediation Activities, Pavillion Field, Wyoming

Location	Encana Previously Investigated	Landowner Identified	Comments	No Further Action	Follow up activities
Tribal Pavillion 14-2	x		Investigated prior to 2008, met OCSRRS remediation criteria. Site is in VRP. Additional soil and groundwater data collected in October 2014. Soil and groundwater data is compliant.	x	Notice of Completion letter issued in April 2015.
Tribal Pavillion 23-2	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted to WOGCC on 1/7/08.
Tribal Paviilion 41X-2	x		Investigated prior to 2008, met OSCSRRS remediation criteria.	x	Sundry report was submitted to WOGCC on 1/4/08.
Tribal Pavillion 12-3	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report was submitted to WOGCC on 1/4/08.
Tribal Pavillion 24-3	x		Site is in VRP. Excavation activities and oxygen releasing compounds were added to the site in 2012. Groundwater monitoring ongoing.		Groundwater impacts are attenuating. A Remedial Alternatives Evaluation (RAE) may be considered.
Tribal Pavillion 31X-3	x		Investigated and remediated prior to 2008, remediation criteria re-evaluated in 2011. Follow-up site investigation conducted in 2011. Additional excavation was conducted in November 2013 and remediation activities were completed.	x	Sundry report submitted to WOGCC on 1/30/14. WOGCC approved on 2/6/14.
Tribal Pavillion 21-5	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted to WOGCC on 1/7/08.
Tribal Pavillion 14-6	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted to WOGCC on 1/7/08.
Blankenship Fee 4-8	x		Site is in VRP. Site characterization work was conducted in November 2012. On-going groundwater monitoring has shown groundwater compliance since 2012. A supplemental site characterization was conducted in October 2014.	x	Notice of Completion letter issued in April 2015.
Tribal Pavillion 22-10	x		Investigated prior to 2008, met OCSRRS remediation criteria (TPH reported at 201 mg/Kg).	x	Sundry report submitted to WOGCC on 1/4/08.
Tribal Pavillion 41X-10	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry not submitted. Report was copied to Landowner, WDEQ and WOGCC.
Tribal Pavillion 44-10	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted to WOGCC on 1/7/08.
Tribal Pavillion 14-11	x		Site is in VRP. A second remedial agreement was submitted for Public Notice and Comment to WDEQ in January 2016 and awaiting approval.		Implementation of remedial alternative (limited excavation and groundwater monitoring).
Pavillion Fee 21-11	x		Investigated prior to 2008, met OCSRRS remediation criteria. Site is in VRP. Additional soil and groundwater data collected in October 2014. Soil and groundwater data is compliant.	x	Notice of Completion letter issued in April 2015.
Tribal Pavillion 42X-11 (aka WH Paul Patent)	x		Site is in VRP. Ongoing quarterly groundwater monitoring. Groundwater impacts are attenuating.		Awaiting final Remedial Agreement for signatures from the WDEQ.

ATTACHMENT A

Summary of Historic Pit Evaluation and Remediation Activities, Pavillion Field, Wyoming

Location	Encana Previously Investigated	Landowner Identified	Comments	No Further Action	Follow up activities
Tribal Pavillion 42X-12	x		Investigated prior to 2008, met OCSRRS remediation criteria. The Pavillion Working Group recommended additional assessment work which was completed in August 2011.	x	Sundry report was submitted to WOGCC on 7/23/2012. WOGCC approved on 7/23/12.
Tribal Pavillion 13-13	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted on 1/7/08.
Tribal Pavillion 31-15	x		Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted on 1/4/08.
Tribal Pavillion 14-1	x	x	Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry submitted on 1/4/08.
Tribal Pavillion 41-9	x	x	Site was excavated in 2007, but excavation was limited by site infrastructure.	x	Sundry report submitted on 1/4/08. Monitor adjacent ditch for evidence of visible sheen during irrigation season. No evidence of a visible sheen.
Tribal Pavillion 33x-10	x	x	Investigated in 2008, met OCSRRS remediation criteria.	x	Sundry not submitted. Report was copied to Landowner, WDEQ and WOGCC.
Tribal Pavillion 14-12 (aka Ora Wells)	x	x	WOGCC indicated closure criteria had not been met following remediation activities conducted in 2008. Site was reinstated in the VRP and additional excavation activities were conducted in December 2013. Groundwater monitoring confirmed compliance.	x	The WDEQ issued a Notice of Completion letter in April 2015.
Tribal Pavillion 22-12	x	x	Site is in VRP. Investigated prior to 2008, documentation of remediation confirmation sampling could not be located. Site was further investigated in 2011.	Pending	Four quarters of groundwater compliance was achieved in 2015. Request for Notice of Completion submitted in January 2016.
Tribal Pavillion 11-14	x	x	Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted on 1/4/08.
Tribal Pavillion 24X-14	x	x	Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted on 1/7/08.
Tribal Pavillion 31X-14	x	x	Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted on 1/7/08.
Tribal Pavillion 21-15	x	x	Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted on 1/4/08.
Doles Unit 44-15	x	x	Investigated prior to 2008, met OCSRRS remediation criteria.	x	Sundry report submitted on 1/7/08.
Tribal 1		x	No evidence of former well pad or PA marker. Encana was never the operator of this well.	X	
WE Lloyd 1		x	Site was investigated in 2011 and no pit could be identified. Encana was never the operator of this well.	X	Sundry report was submitted to WOGCC on 7/23/12. Sundry was approved on 7/23/12.
Pavillion Fee 13-03W		x	Site drilled closed loop and cuttings disposed of off-site, therefore no pit at this site.	x	

ATTACHMENT A

Summary of Historic Pit Evaluation and Remediation Activities, Pavillion Field, Wyoming

Location	Encana Previously Investigated	Landowner Identified	Comments	No Further Action	Follow up activities
John Coolidge 1-4		x	Data from cuttings at wells at comparable depths show no contamination, no indication of issues with cuttings or reserve pit, no former production pit at this location, no water well within 1,500 ft.	x	
Tribal Pavillion 21-9		x	Site was investigated in 2011 and additional work will be done. Additional excavation activities were conducted in November 2013. Remediation activities complete.	x	Sundry report submitted to WOGCC on 1/10/14. WOGCC approved on 2/6/14.
Pavillion Fee 31-9		x	Site was investigated in 2011 and no contamination was identified.	x	Sundry report submitted to WOGCC on 6/28/12. WOGCC approved on 6/29/2012.
Tribal Pavillion 11-10		x	Although 1960's era concrete pad is at location, no documentation that location was ever drilled.	x	
Tribal Pavillion 23-10B		x	Data from cuttings at wells at comparable depths show no contamination. No production pit. No sign of vegetation distress.	x	
Tribal Pavillion 23-10C		x	Data from cuttings at wells at comparable depths show no contamination. No production pit. No sign of vegetation distress.	x	
Tribal Pavillion 31-10		x	Site drilled closed loop and cuttings disposed of off-site, therefore no pit at this site.	x	
Tribal Pavillion 33-10		x	No cuttings or production pit. Site is on solid rock.	x	
Tribal Pavillion 33-10B		x	Data from cuttings at wells at comparable depths show no contamination. No production pit. No sign of vegetation distress	x	
Tribal Pavillion 33-10W		x	No cuttings or production pit. Site is on solid rock.	x	
Tribal Pavillion 41-10B		x	Identified feature is not a pit, but rather appears to be a large semi-circular stormwater retention structure installed by the previous landowner.	x	
Tribal Pavillion 43-10		x	Cuttings pit initially stable, survey plats indicate landowner road may have been moved between drilling and present day exposing part of cuttings pit.	x	

ATTACHMENT A

Summary of Historic Pit Evaluation and Remediation Activities, Pavillion Field, Wyoming

Location	Encana Previously Investigated	Landowner Identified	Comments	No Further Action	Follow up activities
Tribal Pavillion 43-10B		x	Data from cuttings at wells at comparable depths show no contamination, no production pit, cuttings pit is on ridge well above irrigated land and wells, cuttings pit bottom is solid rock.	x	
Pavillion Fee 33-11		x	Cuttings not buried at this location but at offsite location north of rock outcropping near Tribal Pavillion 42X-11 monitoring well 5. No hydrocarbons have been detected in monitoring well 5.	x	There has been no indication of hydrocarbon impacts/contamination in monitoring well 5.
Tribal Pavillion 12-13		x	Site was investigated in 2011. No evidence of a pit was found.	x	Sundry report was submitted to WOGCC on 7/23/12. WOGCC approved on 7/23/12.
Tribal Pavillion 41-15		x	Landowner was merely curious about disposition of cuttings and drilling fluids as location was drilled prior to their ownership. Location was closed-loop drilled, therefore no production pit or reserve pit at this location.	x	
Tribal Pavillion 15-21X		x	Cuttings solidified. No production pit present.	x	
Tribal 1-22		x	No evidence of former well pad or PA marker. Encana was never the operator of this well.	x	

ATTACHMENT B

ATTACHMENT B

Drill Cuttings Analytical

Pavillion Gas Field, Wyoming

Location	Drilling Mud Material	Sample Collected Date	Analyte	Result	Unit	Test Method	Regulatory Limit or Action Level	Agency
13-02B	LSND	11-Mar-05	DRO	27.2	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	55.1	mg/kg	SW 846 8015M	1000 ppm	WOGCC
24-02	LSND	31-Oct-04	TEH-SGT	93.9	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	10.3		SW-846 9045C	NA	
33-02B	LSND	4-Mar-05	DRO	244	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	391	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	8.03	s.u.	SW-846 9045C	NA	
33-02C	LSND	4-Mar-05	DRO	97	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	151	mg/kg	SW 846 8015M	1000 ppm	WOGCC
34-28 (formerly 24-02B)	LSND	21-Mar-05	DRO-SGT	201	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	10.9	s.u.	SW-846 9045C	NA	
11-03	LSND	30-Nov-01	hydrocarbons, recoverable	400	mg/kg	EPA 418.1	1000 ppm	WOGCC
			pH	8.78		SW-846 9045C	NA	
14-03B	LSND	31-Mar-05	TEH-SGT	25	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	6.5		SW-846 9045C	NA	
23-03	LSND	16-Nov-01	tot ext HC	<10	mg/kg	SW-846 3540C	1000 ppm	WOGCC
			TVH-GRO	12	mg/kg	SW-846 5030B	1000 ppm	WOGCC
			TCLP Arsenic	<0.006	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			TCLP Barium	1.536	mg/l	SW-846 1311/6020	100 mg/l	USEPA
			TCLP Cadmium	<0.007	mg/l	SW-846 1311/6020	1 mg/l	USEPA
			TCLP Chromium	0.06	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			TCLP Lead	1.75	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			TCLP Mercury	<0.006	mg/l	SW-846 1311/6020	0.2 mg/l	USEPA
			TCLP Selenium	<0.02	mg/l	SW-846 1311/6020	1 mg/l	USEPA
			TCLP Silver	<0.01	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			Chloride	115	mg/kg	4110B	NA	
			pH	11.2		SW-846 9045C	NA	
			Calcium	97			NA	
			Potassium	61			NA	
			Magnesium	0			NA	
			Sodium	1140			NA	
			SAR	31.8		USDA 60 27a	Depends on disposition	
24-03B	LSND	14-Jan-02	hydrocarbons, recoverable	229	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	12.2		SW-846 9045C	NA	
33-03	LSND	2-Jul-02	TPH	<4.0	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	8.4		SW-846 9045C	NA	
44-03	LSND	2-Jul-02	TPH	<4.0	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	7.98		SW-846 9045C	NA	
34-03B	LSND/PHPA	31-Oct-04	TEH-SGT	87.8	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	8.96		SW-846 9045C	NA	
42-04B	LSND	21-Mar-05	DRO-SGT	306	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	7.32	s.u.	SW-846 9045C	NA	
43-04	LSND	4-Mar-05	DRO	145	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	171	mg/kg	SW 846 8015M	1000 ppm	WOGCC
44-04	LSND	11-Feb-05	DRO	100	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	137	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	8.22	s.u.	SW-846 9045C	NA	
32-9W	LSND	11-Mar-02	SGT-HEM (TPH)		mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	11.4		SW-846 9045C	NA	
42-9W	LSND	11-Mar-02	SGT-HEM (TPH)	90	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	11.5		SW-846 9045C	NA	
13-10	LSND	6-Dec-04	DRO-SGT	189	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	9.66		SW-846 9045C	NA	
21-10	LSND	19-Jul-01	TCLP Arsenic	0.0134	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			TCLP Barium	3.42	mg/l	SW-846 1311/6020	100 mg/l	USEPA
			TCLP Cadmium		mg/l	SW-846 1311/6020	1 mg/l	USEPA
			TCLP Chromium	0.015	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			TCLP Lead	0.0364	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			TCLP Mercury	<0.0006	mg/l	SW-846 1311/6020	0.2 mg/l	USEPA
			TCLP Selenium	<0.002	mg/l	SW-846 1311/6020	1 mg/l	USEPA

ATTACHMENT B

Drill Cuttings Analytical

Pavillion Gas Field, Wyoming

Location	Drilling Mud Material	Sample Collected Date	Analyte	Result	Unit	Test Method	Regulatory Limit or Action Level	Agency
			TCLP Silver	<0.007	mg/l	SW-846 1311/6020	5 mg/l	USEPA
			Chloride	63.6			NA	
			pH	11.3		SW-846 9045C	NA	
21-10B	LSND	28-Dec-04	TEH-SGT	118	mg/kg	SW 846 8015M	1000 ppm	WOGCC
31-10B	LSND	28-Dec-04	TEH-SGT	314	mg/kg	SW 846 8015M	1000 ppm	WOGCC
32-10C	LSND/PHPA/NEWGEL	4-Feb-05	DRO	642	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	645	mg/kg	SW 846 8015M	1000 ppm	WOGCC
11-11	LSND	6-Dec-00	tot ext HC	80	mg/kg		1000 ppm	WOGCC
			TVH-GRO	19	mg/kg		1000 ppm	WOGCC
			RCRA Metals Arsenic	2.65	mg/kg		5 mg/l	USEPA
			RCRA Metals Barium	2470	mg/kg		100 mg/l	USEPA
			RCRA Metals Cadmium	0.5	mg/kg		1 mg/l	USEPA
			RCRA Metals Chromium	23.6	mg/kg		5 mg/l	USEPA
			RCRA Metals Lead	41.3	mg/kg		5 mg/l	USEPA
			RCRA Metals Mercury	<0.2	mg/kg		0.2 mg/l	USEPA
			RCRA Metals Selenium	0.39	mg/kg		1 mg/l	USEPA
			RCRA Metals Silver	0.4	mg/kg		5 mg/l	USEPA
			Chloride	215	mg/kg		NA	
			Calcium	17.2	mg/l		NA	
			Potassium	22.9	mg/l		NA	
			Magnesium	0.66	mg/l		NA	
			Sodium	645	mg/l		NA	
			SAR	41.5			Depends on disposition	
11-11B	LSND	24-Jan-02	hydrocarbons, recoverable	184	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	11.4		SW-846 9045C	NA	
12-11B	LSND	28-Dec-04	TEH-SGT	137	mg/kg	SW 846 8015M	1000 ppm	WOGCC
13-11B	LSND	15-Feb-02	hydrocarbons, recoverable	77	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	9.14		SW-846 9045C	NA	
21-11B	LSND	31-Mar-05	TEH-SGT	133	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	7.11		SW-846 9045C	NA	
22-11	LSND	30-Nov-01	hydrocarbons, recoverable	300	mg/kg		1000 ppm	WOGCC
			pH	9.8		SW-846 9045C	NA	
22-11B	LSND	4-Feb-05	DRO	295	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	339	mg/kg	SW 846 8015M	1000 ppm	WOGCC

ATTACHMENT B

Drill Cuttings Analytical

Pavillion Gas Field, Wyoming

Location	Drilling Mud Material	Sample Collected Date	Analyte	Result	Unit	Test Method	Regulatory Limit or Action Level	Agency
22-11C	LSND	11-Feb-05	DRO	91.8	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	144	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	8.13	s.u.	SW-846 9045C	NA	
24-11	LSND/PHPA	28-Dec-04	TEH-SGT	431	mg/kg	SW 846 8015M	1000 ppm	WOGCC
31-11	LSND	6-Feb-02	hydrocarbons, recoverable	120	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	8.6		SW-846 9045C	NA	
32-11	LSND	6-Feb-02	hydrocarbons, recoverable	400	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	12.4		SW-846 9045C	NA	
33-11B	LSND	3-Jan-05	DRO	61	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	73.8	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	7.9	s.u.	SW-846 9045C	NA	
41-11B	LSND	31-Mar-05	TEH-SGT	65	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	6.59		SW-846 9045C	NA	
43-11	LSND	7-Dec-01	hydrocarbons, recoverable	120	mg/kg	EPA 418.1	1000 ppm	WOGCC
			pH	10.9		SW-846 9045C	NA	
43-11B	LSND	26-Jan-05	DRO	105	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	159	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			pH	9.15	s.u.	SW-846 9045C	NA	
44-11	LSND	11-Feb-02	hydrocarbons, recoverable	250	mg/kg	EPA 1664	1000 ppm	WOGCC
			pH	10.4		SW-846 9045C	NA	
12-12	LSND	11-Mar-05	DRO	97.6	mg/kg	SW 846 8015M	1000 ppm	WOGCC
			TEH-SGT	164	mg/kg	SW 846 8015M	1000 ppm	WOGCC
13-12W	LSND	14-Dec-01	hydrocarbons, recoverable	240	mg/kg	EPA 418.1	1000 ppm	WOGCC
			pH	10.1		SW-846 9045C	NA	
12-7	LSND	12-Jul-01	hydrocarbons, recoverable	110	mg/kg		1000 ppm	WOGCC
			RCRA Metals Arsenic	2.62	mg/kg		5 mg/l	USEPA
			RCRA Metals Barium	1120	mg/kg		100 mg/l	USEPA
			RCRA Metals Cadmium	0.15	mg/kg		1 mg/l	USEPA
			RCRA Metals Chromium	24.9	mg/kg		5 mg/l	USEPA
			RCRA Metals Lead	21.3	mg/kg		5 mg/l	USEPA
			RCRA Metals Mercury	<0.0025	mg/kg		0.2 mg/l	USEPA
			RCRA Metals Selenium	0.39	mg/kg		1 mg/l	USEPA

ATTACHMENT B

Drill Cuttings Analytical

Pavillion Gas Field, Wyoming

Location	Drilling Mud Material	Sample Collected Date	Analyte	Result	Unit	Test Method	Regulatory Limit or Action Level	Agency
			RCRA Metals Silver	0.4	mg/kg		5 mg/l	USEPA
			Calcium	17500	mg/l		NA	
			Potassium	2480	mg/l		NA	
			Magnesium	6620	mg/l		NA	
			Sodium	1340	mg/l		NA	
			SAR	2.19			Depends on disposition	
Tribal Pavillion 32-3	LSND	6/3/2005	pH	7.65	s.u.	SW-846 9045C	NA	
			TEH-SGT	476	mg/kg	SW 846 8015M	1000 ppm	WOGCC
Tribal Pavillion 44-3C	LSND	6/3/2005	pH	7.46	s.u.	SW-846 9045C	NA	
			TEH-SGT	532	mg/kg	SW 846 8015M	1000 ppm	WOGCC
Tribal Pavillion 22-3	LSND	6/3/2005	pH	7.25	s.u.	SW-846 9045C		
			TEH-SGT	358	mg/kg	SW 846 8015M	1000 ppm	WOGCC

* It is generally accepted practice that a total metals analysis result can be divided by 20 to compare to the TCLP limit
** This result exceeds the result ÷ 20 for comparison to the TCLP regulatory limit. However, barium is generally either in barium sulfate form or barium chloride form in soil. Barium sulfate is not very soluble in water, barium chloride is much more soluble in water, thereby producing a high TCLP reading Since the chloride content of this sample is low, barium is likely in the insoluble (low leach potential) form and therefore should not exceed TCLP

ATTACHMENT C

ATTACHMENT C

Comments to the Draft WDEQ Report and Appendix G

Prepared for

Encana Oil & Gas (USA) Inc.

March 2016

MHA PETROLEUM CONSULTANTS LLC
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ATTACHMENT C

MHA Petroleum Consultants LLC (MHA) was asked to review the "Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study", prepared by the Wyoming Department of Environmental Quality (WDEQ) in December 2015, as well as Appendix G of the WDEQ document, which is entitled "MBDCI Evaluation of the WOGCC's Well Integrity Review Report". MHA's focus was primarily on the Appendix G document, as the bulk of that evaluation centered around the topics of the source of bradenhead gas in the Pavillion Area and the possible migration paths of that gas. MHA's comments are set forth below.

1. Vertical Gas Migration Along Energy Wellbores Is Not Impacting Groundwater Quality.

1.1 On Page 1 of Appendix G, Dusseault states the following:

> *Thus, the presence of Bradenhead gas in some energy wells is also almost certain confirmation that there is gas present in some groundwater zones and perhaps also as free gas in at least some of the shallow permeable (coarse-grained) groundwater zones used for WSW [i.e., water supply well] development.*

MHA agrees that gas exists naturally within the shallow strata at Pavillion, and this could be a source of bradenhead gas. However, in most cases, bradenhead gas is quite simply a near wellbore phenomenon where gas enters the annulus around an energy well. Dusseault posits that the source of this gas may be from shallow horizons, below the casing shoe, or from intermediate depth intervals that are gassy but non-commercial. This gas then migrates vertically upward into the bradenhead annulus between the surface casing and the production casing. However, the bradenhead annulus is a closed, low pressure environment. Any gas would not migrate laterally away from the wellbore or into groundwater zones. The path of least resistance is for the gas to migrate into the bradenhead annular space, and there is insufficient pressure to force the gas into the shallow groundwater strata.

Dusseault later, at p. 43, seems to reverse course and concede that the presence of bradenhead gas tells one nothing at all about what is contained or occurring in other strata:

> *The presence of Bradenhead gas is clearly not proof of the existence or absence of gas elsewhere.*

1.2 On Page 2 of Appendix G, Dusseault makes the following statement suggesting that the presence of positive pressure in the bradenhead annulus confirms contamination of groundwater sources by energy wells:

> *The presence of sustainable pressure in the Bradenhead annulus (i.e. pressure that can be re-established after some time) has been identified*

> *decades ago as a potential source of natural gas contamination of aquifers near energy wells.*[1]

This statement is also incorrect. Sustainable pressure in the bradenhead annulus of an energy well does not mean that aquifers near that energy well are or will be contaminated. The critical factor is not whether there is sustainable pressure in the bradenhead annulus, rather it is the magnitude of that pressure in relation to the hydrostatic pressure within strata in the vicinity of the surface casing shoe in that energy well.

The reference cited by Dusseault discusses situations where pressure at the surface casing shoe, or in shallow strata in that same general vicinity, are overpressured due to communication with a deeper gas source. An example in the reference uses an assumed depth of surface casing of 500 feet, where pore pressure would be expected to be approximately 215 psi, based on the hydrostatic gradient. This depth is consistent with the typical depth of the surface casing shoe in Pavillion Field. However, in the cited reference, the example provided has the strata in the vicinity of the surface casing shoe exposed to gas pressure in the annulus of 400 psi. This represents an overpressure condition of 185 psi. And, in this particular example, the reference demonstrates how that overpressure condition could result in gas breaching the containment of the annular space around the energy wellbore and migrating into a shallow aquifer zone.

Pressures measured in the bradenhead annulus at Pavillion Field are not 400 psi, but are instead in the range of 120 – 185 psi (refer to Dusseault, Appendix G, Table 1). These pressures are less than the hydrostatic pressure that would be anticipated in the strata in the vicinity of the surface casing shoe or deeper intermediate strata. Thus, the pressure in the bradenhead annulus would be less than the pressure in the relevant strata, so there is no overpressure condition. Without overpressure, there is no way for the gas to breach its containment within the annulus around the wellbore.

1.3 The Wyoming Oil and Gas Conservation Commission (WOGCC) issued a report in August 5, 2014 titled, "Pavillion Field Well Integrity Review". In that report, the WOGCC concluded that "…the bradenhead (annulus) gas likely did not result from behind-the-pipe migration of gas from the producing intervals, but rather from shallow gas-bearing Wind River Sands penetrated by drilling after surface casing was set."

On Page 7 of Appendix G, Dusseault states that he "agrees fully with this assertion". Further, Dusseault then discusses at several points within Appendix G, three possible pathways for this gas. It could migrate vertically along the wellbore and enter the bradenhead annulus (A), it could exit the near wellbore area around the surface casing shoe and migrate to the surface outside the surface casing (B), or it could exit the near wellbore area around the surface casing shoe and then enter a shallow groundwater aquifer (C). These three possibilities are also shown in Figure 1 below taken from Appendix G.

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[1]Harrison, S.S., "Contamination of aquifers by overpressuring the annulus of oil and gas wells", Groundwater, v. 23, no. 3, pp. 317-324, 1985.

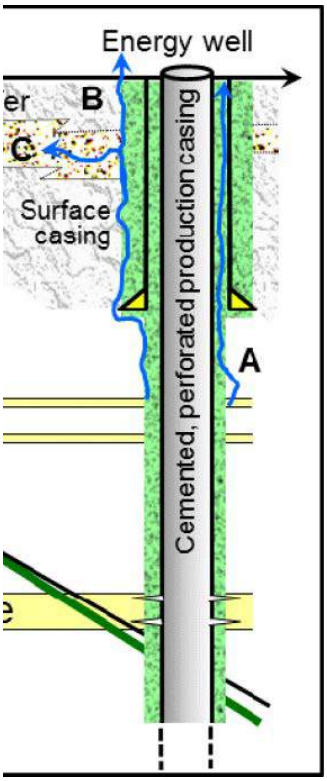

Figure 1: Portion of Figure 14 From Appendix G Showing Possible Gas Migration Paths

Pathway A shown above is the most likely, it is the easiest to explain, and it represents the scenario that is most consistent with the observations of bradenhead gas pressures in Pavillion Field. As the gas migrates vertically via the path of least resistance into the bradenhead annulus, a positive pressure is created in the annulus. At Pavillion Field, these pressures are typically in the range of 120 - 185 psi. If the bradenhead pressure is bled off, it frequently builds back up to the same level as it was before due to recharge from the shallow strata sourcing the gas. This range of bradenhead pressures indicates that these shallow strata are at the same approximate depth as the surface casing shoe.

For the gas to travel along Pathway B, as shown above, the gas would first have to rupture the area around the surface casing shoe, and then have to migrate vertically through a region behind the surface casing that is fully cemented to the surface. In Figure 1, which is a portion of Figure 14 in Appendix G, Dusseault neglected to show that the surface casing is fully cemented to the surface. However, in Figure 2 below, which is Figure 6 from Appendix G, one can see that this is clearly the case. This is a much more implausible scenario than that of Pathway A. This is because the bradenhead annulus would have to be substantially overpressured, relative to the hydrostatic pressure of the surrounding strata, for the gas to breach the area around the surface casing shoe. Such overpressure conditions have not been observed in Pavillion Field. Further, the gas would then have to migrate vertically toward the surface through an area that is fully cemented. This is not a path of least resistance. In addition, if gas then migrated to the surface, gas would be bubbling around the wellhead at the surface, and there

would be large areas of distressed vegetation around the energy wells. There is no recent evidence of these impacts in Pavillion Field.

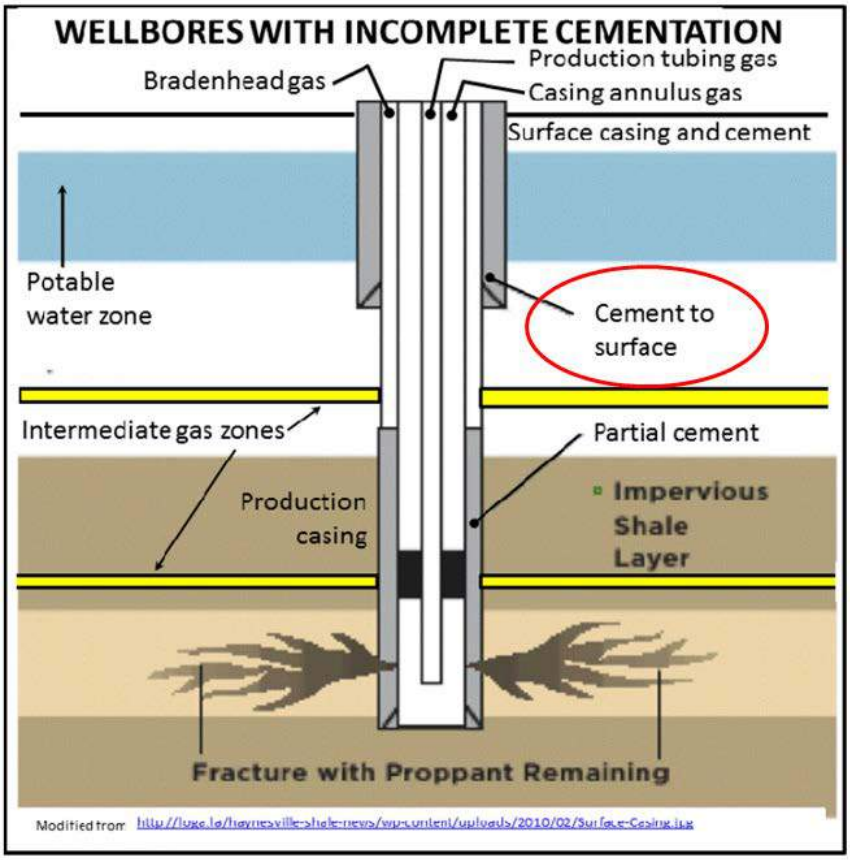

Figure 2: Figure 6 from Appendix G with Cement Behind Surface Casing Highlighted

For the gas to travel along Pathway C, this would also require the gas to rupture the area around the surface casing shoe, and then migrate vertically through a region behind the surface casing that is fully cemented. In addition, the migrating gas would need to enter a shallow groundwater bearing zone as shown in Figure 1. Pathway C is also implausible and it is not supported by the data collected and the observations made at Pavillion Field.

For the scenario shown in Pathway C to exist, what would first have to happen is that the gas would travel Pathway A, migrate into the bradenhead annulus, and then build up sufficient overpressure such that the gas ruptures the area around the surface casing shoe. The pressure would then need to remain elevated so that the gas could migrate vertically behind the surface casing through an area that is fully cemented, and then still have enough pressure to move into the groundwater zone. If such a situation existed, there would be numerous observations where bradenhead pressures were measured well in excess of the hydrostatic pressure at the base of the surface casing due to the overpressure condition required. However, while there are many cases of positive bradenhead pressured reported in Pavillion Field, none of these reflected an overpressure condition. All of the bradenhead pressures measured have been

less than the hydrostatic pressure estimated at the base of the surface casing. Dusseault himself recognizes this with his statement on Page 8 of Appendix G:

> *There is no evidence of an existing active pressure connection to a gas source at greater depth below the groundwater protection zone; otherwise, a higher equilibration pressure would have been expected for the Bradenhead gas, at least in some cases.*

Therefore, the magnitude of the bradenhead pressures measured at Pavillion Field indicate that the gas source for the bradenhead gas is shallow strata at the same approximate depth as the surface casing shoe. Further, based on these measured bradenhead pressures, Pathways B and C, as shown in Figure 1, are implausible.

1.4 Section 2.6 of the draft WDEQ Report supports the conclusion that the gas source for the bradenhead gas at Pavillion Field is shallow strata at the same approximate depth as the surface casing shoe. When discussing well results in Pavillion Field area, the report notes:

> *….most of the gas wells studied had encountered gas-charged sands immediately below surface casing, with many near 500 feet deep.*

1.5 On Page i of Appendix G, Dusseault states the following:

> *However, based on experience elsewhere, it is highly probable that some energy wells are experiencing slow gas seepage from non-producing intermediate depth zones to the groundwater protection zone, evidenced in part as Bradenhead gas.*

Dusseault's conclusion conflicts with results presented in the industry literature. Certainly, gas seepage along energy wellbores is a relatively common occurrence. And, there is no argument that vertical gas migration in the annulus of energy wells can occur. This phenomenon is what causes gas accumulation and positive pressure in the bradenhead annulus. However, there is no evidence that this near wellbore gas enters groundwater zones and contaminates water supply wells. The evidence, in fact, is to the contrary. A recent study[2], which consisted of 11,309 individual water well samples, including baseline samples collected before drilling of energy wells in the near proximity to the water supply wells, found that there was no significant correlation between dissolved methane concentrations in groundwater and proximity to nearby oil and gas wells. This confirms the conclusion stated in Section 1.1; the presence of bradenhead gas is not confirmation that there is gas migrating along wellbores into nearby groundwater zones. As previously discussed in Section 1.2, Bradenhead pressures are relatively low, and there is insufficient pressure to force the gas into the shallow groundwater strata.

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[2] Siegel, D. I., et al, "Methane Concentrations in Water Wells Unrelated to Proximity to Existing Oil and Gas Wells in Northeastern Pennsylvania", Environmental Science and Technology, 2015.

1.6 On Page 2 of Appendix G, Dusseault states the following:

> *It is not possible at the present time to specify the source (or sources) of the thermogenic gas in the Bradenhead annulus, except to say that it has migrated into the shallower strata, either naturally over long times before O&G E&P activity (geological time), or as the results of O&G E&P activity over the last 60 years, but likely some combination of the two.*

Once again, there are no data to support Dusseault's hypothesis that gas migration into shallower strata is possibly the cause of oil and gas activity and the drilling of energy wells. As stated previously, if the gas was sourced from deeper strata at higher pressures, and this gas was liberated via the drilling of oil and gas wells, then one would expect to see higher pressures, indicating an overpressured condition, measured in the bradenhead annulus. However, this has not occurred.

Rather, Dusseault gives us the most likely answer himself in other portions of Appendix G. On Pages 20-21, he states:

> *In most petroleum-prone regions such as eastern Ohio, Pennsylvania, and Texas, naturally occurring shallow gas may be found in a substantial percentage of WSWs, and regional frequencies of 10 percent to over 30 percent have been reported.*

On Page 44 of Appendix G, while discussing the results of a study conducted in New York state, Dusseault notes with respect to the comments presented in the report:

> *These comments are to reinforce the fact that the vast majority of groundwater methane cases are known to be from naturally occurring processes unconnected with energy development.*

Finally, on Page 8 of Appendix G, Dusseault states the following:

> *Furthermore, because most of the Bradenhead pressure tests show a re-equilibration pressure that is similar, it is likely that most of the Bradenhead annular spaces of the wells showing Bradenhead pressurization are hydraulically connected to the same source of pressurization and that gas is at shallow depth, within the groundwater protection zone.*

This is an excellent example of Occam's Razor, which is a line of reasoning that states among competing hypotheses, the one requiring the fewest assumptions should be selected. As shown above in Figure 1, Dusseault's hypothetical Pathway C, which would support groundwater contamination, requires the assumption of an overpressured condition, which measured data do not support, and gas migration around the surface casing shoe, through an area fully cemented to surface, and then into a shallow groundwater zone. On the other hand, the scenario which suggests the gas is naturally occurring in the groundwater zone requires only

that simple assumption itself. Further, this scenario is known to be plausible and one that commonly occurs.

1.7 On Page 16 of Appendix G, Dusseault initiates a discussion of a breached gas storage facility located in Hutchinson, Kansas, and he describes this event as "perhaps the most notorious example of lateral gas migration known in the world at this time". The discussion of the Yaggy gas storage field disaster has no place in Dusseault's Appendix G, as it is not an appropriate analog to circumstances in Pavillion Field.

The Yaggy storage facility was artificially created. The gas storage reservoir was a salt cavern created by solution mining a subsurface salt interval. Then, gas was injected at high pressure into the salt cavern to create the temporary gas storage facility. The high pressure gas leaked from the storage reservoir through a failed well casing. This gas then migrated several miles and caused explosions in the nearby town of Hutchinson, Kansas.

Conversely, Pavillion Field is a naturally occurring hydrocarbon accumulation. More importantly, as discussed in detail above, the bradenhead gas in question at Pavillion Field is at very low pressure and does not reflect any kind of overpressured condition such as that in the Yaggy storage field. And, finally, as Dusseault notes in his Brief Summary section on Page i of Appendix G, "there is no evidence that production casing impairment exists in the existing active production wells in Pavillion Field."

1.8 The draft WDEQ report includes some discussion suggesting that liquids, in addition to gas, are migrating or could migrate upwards in the annular space of some energy wells, as opposed to only vertical gas migration in that space. This is noted in several locations, including in Section 5.1.5 of the WDEQ report where it is stated:

> *It is not known however, if gas (and sometimes liquid) seeping along the gas wells has entered or is entering shallow permeable zones in which the water-supply wells are completed.*

See also WDEQ's Pavillion Groundwater Report Fact Sheet dated December 16, 2015:

> *Bradenhead pressures in several gas wells provide strong indication that gas and possibly liquid migration may be happening, however, there is no evidence this migration has caused water quality issues.*

There is no reason to believe that there is any vertical migration of liquids along the energy wells in Pavillion Field. The vertical migration of gas is easily explained by the effects of buoyancy. Free gas is much lighter than liquid (water, condensate or mud), and that density difference provides a buoyant force which causes the gas to rise vertically in the annular space of the well. Liquids are not buoyant. In fact, because liquids have a much higher density, the opposite is true and gravity forces those fluids to collect in the deepest portion of the wellbore or the annular space.

There have been some reports of liquids being produced, along with gas, from the bradenhead annulus when the bradenhead pressure is bled off. This is a completely different phenomenon, and it is not caused by vertical migration of the liquid. Rather, liquid can be present in the base of the bradenhead annulus. This liquid could be remaining from drilling operations, or it could be present in rock strata that open to the annular space in wells which are incompletely cemented. When the bradenhead pressure is bled off, the gas in the bradenhead annulus rapidly expands and lifts this liquid along with it to be produced.

2. Further Diagnostic Testing of the Gas Wells in Pavillion Field Will Not Be Useful.

2.1 Dusseault (Page ii, Appendix G) mentions running noise logs on energy wells to identify possible sources of gas leaks from the well. Dusseault himself states that "*There is no evidence that production casing impairment exists in the existing active production wells in Pavillion Field.*" Further, none of the available pressure data (bradenhead or casing) supports the theory that any of the wells have any sort of casing leak. Thus, there is no reason to suspect that there are any leaks in these wells. However, even if one were to accept the premise that leaks in the production casing were the cause of gas seepage in Pavillion Field wells, noise logs would not be able to prove or disprove that theory.

Noise logs record sound measured at different positions in a wellbore. Because fluid turbulence generates sound, high noise amplitudes indicate locations of greater turbulence, such as leaks or perforations. Any gas seepage in the annulus of energy wells at Pavillion Field that at very low volumes and flow rates. These low flow rates would also be below the resolution of a noise log. Other diagnostic techniques such as casing bond logs or pressure integrity tests (Page 10, Appendix G) would not provide any new meaningful information.

2.2 Dusseault (Page 29, Appendix G) suggests that mud gas logging information could be used to demonstrate that the natural gas found in the groundwater protection zone is associated with energy well development. That is not necessary. Shallow gas zones were previously identified by early wells drilled in Pavillion Field area from 1965 to 1973. There is no need for further testing or review to identify this gas; its presence is already understood. Further, the more recent energy wells drilled in the field do not have mud logs across these shallow intervals. Mud logs are run by companies to identify commercial hydrocarbon pay zones. It was unnecessary to run these mud logs across the shallow intervals, generally less than 1,000 feet in depth, because there were no commercial hydrocarbons at those depths.

2.3 With the knowledge that shallow gas existed at Pavillion Field naturally before any oil and gas development, it would be an inappropriate use of resources to conduct costly diagnostic tests in an attempt to identify if there is any near wellbore gas migration in the vicinity of energy wells. As Dusseault states on Page ii of Appendix G:

> *The reliable quantification of gas sources, seepage rates, and pathways is challenging, with no guarantee that specific issues can be resolved with a high degree of certainty.*

ATTACHMENT C

There is no certainty that specific sources and pathways of fluid migration can be identified using existing techniques because of the number of energy wells, the complex pathways arising from the geological complexity in the shallow strata, and the uncertain gas provenance (deep, intermediate, mixed).

ATTACHMENT E

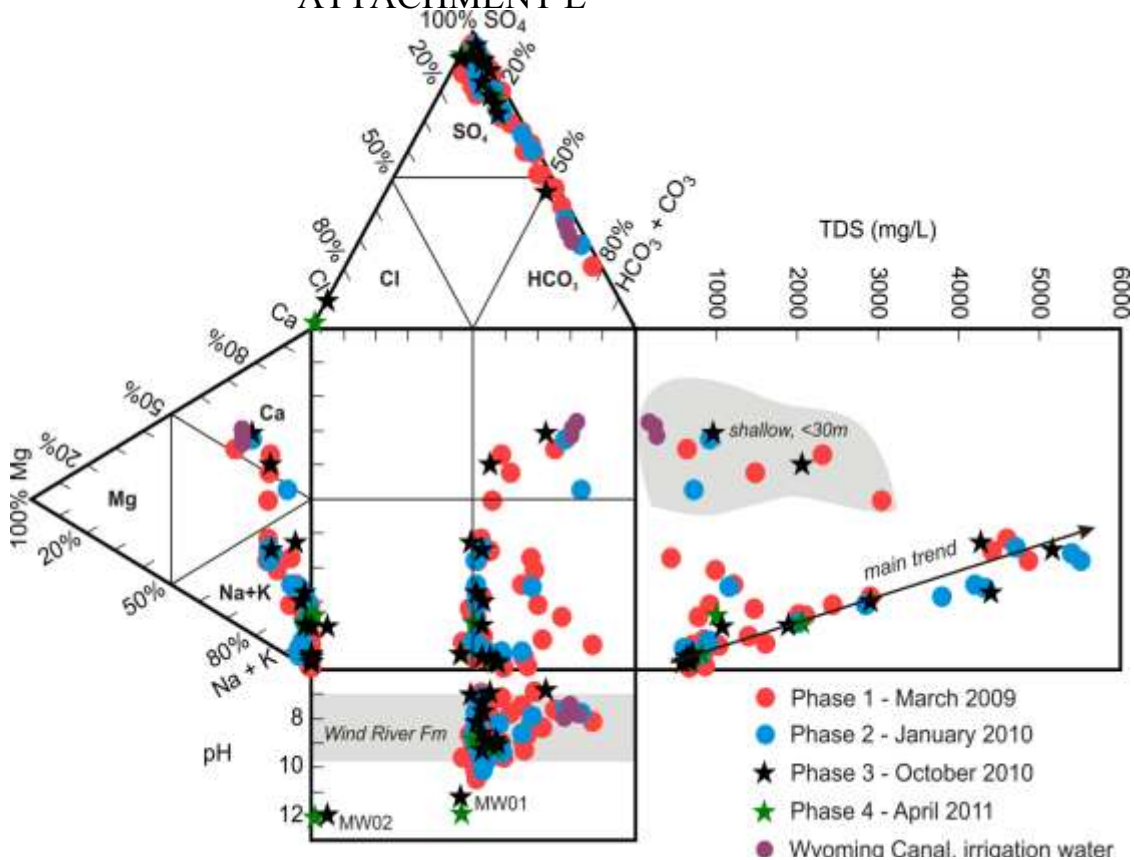
ATTACHMENT E

United States Environmental Protection Agency

Investigation of Ground-Water Contamination near Pavillion, Wyoming Workgroup Meeting November 30, 2011

Office of Research and Development
National Risk Management Research Laboratory,
Ground Water and Ecosystem Restoration Division, Ada, OK

United States Environmental Protection Agency



Shallow ground waters (< 31 m bgs) collected from drinking water wells and stock wells are near-neutral (pH 7.7 ± 0.4, n = 19) and display calcium-bicarbonate composition. Total dissolved solids concentrations are <6000 mg/L in all ground water samples. With depth, ground water becomes increasingly alkaline (pH 9.0 ± 1.0, n = 55), and with only one exception (MW02), is dominated by sodium and sulfate as the major cation/anion pair. This gradient in pH and water chemistry likely arises from the wide-scale surface application of irrigation water from the Wind River to support crop growth since irrigation water appears to represent an endmember composition. The chemical alteration from bicarbonate-type recharge water to sulfate-type ground water involves multiple water-rock interactions, including salt dissolution, carbonate mineralization, and exchange of divalent cations for sodium (Morris et al. 1959).

ATTACHMENT D

Project: **Ground-Water Investigation in Pavillion, Wyoming.**
Location: **Pavillion, Wyoming**
Date of Audit: **September 23, 2010**
Assessors: **Steve Vandegrift, EPA Groundwater and Ecosystems Restoration Division (Ada, OK)**
David Gratson, Neptune and Company (Contractor to EPA, Los Alamos, NM)

This field based Technical System Audit (TSA) will only cover the Gas Sampling associated with the Ground-Water Investigation in Pavillion, Wyoming. The gas sampling conducted for this project entails soil-gas surveys using a Geoprobe Post Run Tube System (PRT), along with field screening for fixed and total hydrocarbons. This PRT field survey was completed during July, 2010. During this time dedicated soil-gas probes were installed and these will be sampled in September, 2010. Fixed gases, light hydrocarbons, and isotopes will be the analytes of interest that will be collected from the dedicated soil-gas probes using Cali-5-bond sampling bags equipped with a Leur-Fit Valve™. These soil-gas samples will be submitted to Isotech Laboratories for analysis. An additional TSA will be conducted at Isotech Laboratories as part of this project. A stability study will be conducted by EPA using the Cali-5-bond sampling bags. The 2 deep wells (Type A) and 4 domestic wells (Type C) will also be sampled for gas analytes. Gas from domestic wells will be sampled using the Cali-5-bond evacuated gas sample bags for fixed gases, light hydrocarbons, stable isotopes of carbon and hydrogen for methane, ethane, and propane, and radiocarbon for methane. Gas from deep monitoring wells will be sampled for fixed gases, light hydrocarbons, stable isotopes of carbon and hydrogen for methane, ethane, and propane, and radiocarbon for methane in disposable Isotubes or Cali-5 bags, depending on pressure.

Fixed gases and light hydrocarbons to be analyzed include Ar, He, H_2, O_2, N_2, CO_2, CH_4, C_2H_6, C_2H_4, C_3H_6, C_3H_8, iC_4H_{10}, nC_4H_{10}, iC_5H_{12}, nC_5H_{12}, and C_6+. (Helium has been eliminated as a target analyte in this investigation.) $\delta^{13}C$ and δD of methane ethane, and propane will be determined as well as radiocarbon for methane.

ITEM	Reference	*YES*	*NO*	*N/A*	*COMMENTS*
A. QUALITY SYSTEM DOCUMENTATION					
1. Is there a copy of the approved QAPP on-site for reference during the sampling?	QAPP G-14478				
2. Is the design and conduct of the project proceeding as is specified in the QAPP?	QAPP G-14478				
3. Are there deviations from the QAPP since the June 8, 2010 Revision 0 version?	QAPP G-14478				
4. How are any deviations from the plan noted that are associated with the soil gas sampling and analysis?	General				
Additional Questions or Comments:					
B. PROJECT ORGANIZATION AND RESPONSIBILITIES					

5. At what stage is the project currently at with respect to soil gas survey and sampling?	General				
6. Who is responsible for: • overseeing the EPA field team soil sampling activities? • maintaining communications with test participants, EPA ORD, EPA Reg VIII? • Is the QA manager independent from the project manager?	QAPP, Section 2.0.				
7. Have all field personnel associated with soil gas sampling read and understood the QAPP?	General and QAPP.				
8. Will Isotech or their subcontractor conduct all fixed laboratory gas analysis? 9. Who will be the point of contact at Isotech that will receive the samples?	QAPP, Section 5.0.				

10. Will Isotech Laboratories conduct the fixed-laboratory analysis of fixed gases, light hydrocarbons, stable isotopes of C and H for methane, ethane, and propane and radiocarbon for methane? 11. Who will be the point of contact at Isotech that will receive the samples?	QAPP, Section 2.0 and 5.0., Table 6, and DiGiulio SOW.				
12. Are there regularly scheduled meetings planned between the project participants?	General.				
Additional Questions or Comments:					
C. SCIENTIFIC APPROACH – CONCEPTUAL MODEL					
13. Was the soil gas survey, using a Geoprobe PRT system and field screening, completed?	QAPP, Sections 3.2 and 3.3.				

14. Were 9 dedicated vapor probes installed during the soil-gas survey?	QAPP, Sections 3.2 and 3.3.				
15. How long have the dedicated soil-gas probes been in the soil?	QAPP, Sections 3.2 and 3.3.				
Did the soil-gas survey indicate increased levels of CO2 bulk soil gas concentration with depth?	QAPP, Sections 3.2b.				
16. Was the sampling conducted at three depths for oxygen, carbon dioxide, methane, hydrogen, hydrogen sulfide, and total hydrocarbons, gas permeability?	QAPP Sections 3.2 – 3.3.				
17. Were elevated levels of methane, ethane, propane, and normal butane detected during the soil-gas survey?	QAPP, Sections 3.2b.				

Additional Questions or Comments:
D. FIELD SAMPLE COLLECTION and MONITORING

Installation of Dedicated Soil-Gas Probes: 18. Were the probes constructed using a 5' section of schedule-40 PVC 1" I.D. slotted screen and riser pipe? 19. Were the probes sealed and locked using expandable well caps with o-rings placed between sections of riser pipe to ensure a gas-tight seal? 20. Were all materials connected without the use of solvent, glues, or volatile compounds? 21. Was a sandpack installed to 0.5' below and above the screened interval and a 0.5' of bentonite chips above? 22. Was a bentonite slurry used to create an impervious watertight bond between the casing and the formation?	QAPP Section 4.2b.				

Soil-Gas Sampling Train: 23. Are samples collected using a stainless-steel chamber and sample train that uses viton and tygon tubing, a drying system (Perm Pure or Durridge Drystik), utilizing Nafion tubing that will be tested for reaction to the analytes of interest? 24. Will flow be measured with a calibrated flowmeter and samples collected in Cali-5-bond gas sample bags equipped with a Leur-Fit Valve™? 25. Is a GEM2000 Plus CES LandTech Gas Analyzer in series with TVA-1000B used for continuous measurement of gases? Gas Permeability: 26. Are pressure reading recorded every second using a calibrated Sper Scientific manometer, with the measurement upstream of the gas/water separator? Is this used along with a Gilmont 150 mm variable area Accual flowmeter (range 0-2100 sccm, accuracy and precision 2% and 1% respectively) and needle valve to evaluate gas permeability?	QAPP, Section 4.2c.				

Leak Testing: 27. Are the above ground components of the sampling train leak tested prior to use by observing vacuum loss, with a vacuum of greater than 90 kPa? 28. Is the vacuum measured using a calibrated Spcr Scientific manometer with pressure readings every second stored in the PC? 29. Were the sample flow rates in the 300-1000 sccm range? 30. Did leakage exceed 0.1 sccm or 10% (Section 3.3)? 31. Was a tracer gas containing 10% He (non-target analyte) injected into the chamber during leak testing while monitoring the flow? 32. What gas was used for leak testing and where any leaks detected?	QAPP, Sections 3.2 and 4.2d.				

Purge Testing: 33. Did real time gas concentrations achieve near constant concentration (±1% O2, CO2, CH4) during purging to ensure collecting equilibrium gas samples? 34. Were these values manually recorded to be entered into a spreadsheet (Figure 10)?	QAPP, Section 4.2e.				

Soil Gas Sampling: 35. Were samples collected from 9 soil gas probes in 0.5L Cali-5 bond bags equipped with a Leur-Fit Valve™ for fixed gases and light hydrocarbons? 36. Were 2 equipment blanks (ultrapure N_2 or air circulated through the sample train) and 2 transportation blanks (ultrapure N_2 or air introduced into a sample bag) collected for fixed gases and light hydrocarbons? 37. Were 2 duplicate samples collected? 38. Were soil gas probes purged and monitored for O_2, CO_2, CH_4, CO, H_2S, H_2, and light hydrocarbons prior to sample collection?	QAPP, Section 5.2b, Table 7 and DiGiulio SOW.				

<u>Domestic Well Gas Sampling:</u> 39. Were samples collected from 4 domestic wells in 0.5L Cali-5 Bond Sample bags equipped with a Leur-Fit Valve™ for fixed gases, light hydrocarbons, stable isotopes of carbon (^{12}C, ^{13}C) and hydrogen (^{1}H, ^{2}H) for methane, ethane, and propane, and radiocarbon (^{14}C) for methane? 40. Were 2 equipment blanks (ultrapure N_2 or air circulated through the sample train) and 2 transportation blanks (ultrapure N_2 or air introduced into a sample bag) collected for fixed gases and light hydrocarbons? 41. Was 1 duplicate sample collected?	QAPP, Section 5.2b, Table 7 and DiGiulio SOW.				

Deep Well Gas Sampling: 42. Were samples collected from 2 deep wells in Isotubes (see #45) for fixed gases, light hydrocarbons, stable isotopes of carbon and hydrogen for methane, ethane, and propane, and radiocarbon for methane (same isotopes as outlined above for domestic wells)? 43. Was 1 duplicate sample collected? 44. Was 1 equipment blank (ultrapure N_2 or air circulated through the sample train) and 1 transportation blank (ultrapure N_2 or air introduced into a sample vessel) for fixed gases and light hydrocarbons collected? 45. What gas pressure was found inside the well casing of each well and as a result how were samples collected (Cali-5 Bond or an Isotech wellhead manifold – Figure 15)?	QAPP, Section 5.2b , Table 7 and DiGiulio SOW.				

Additional Questions or Comments:					
F. FIELD QA/QC					
46. Are check standards fed into the sampling train to ensure the absence of flow and material affects?	QAPP, Section 5.2.				
47. Are the GEM2000 Plus, Bacharach PCA2 (IRGA), and TVA-1000B calibrated using certified standards of the analytes of interest (O2, CO2, CO, CH4, H2S, H2, and light hydrocarbons))? 48. Did the calibration checks meet the accuracy, precision, and blank levels specified in Tables 4 and 5?	QAPP, Section 5.2 and Tables 4 and 5.				
49. Were Equipment Blanks collected using the Cali-5-bond bags and/or Isotubes with one collected per day? 50. Were Travel Blanks collected using the Cali-5-bond bags and/or Isotubes? 51. Were duplicates collected, one for approximately every 10 samples?	QAPP Section 5.2b, Table 7 and DiGiulio SOW				

Additional Questions or Comments:

G. FIELD DOCUMENTATION					
52. Are Cali-5-bond and Isotube samples labeled with a unique identifier, date and time of collection, initials of the sampler using water-insoluble ink?	QAPP, Section 4.2.h.				
53. Are the chain-of-custody records adequate to allow unambiguous tracking? Is the chain-of-custody form shown in Figure 11 used?	General and Figure 11.				

Additional Questions or Comments:

L. SAMPLE LABELING, PACKAGING, AND SHIPPING

54. Are sample placed in UN approved one gallon metal cans for shipment, with up to three bags in each can? 55. Are chain-of-custody forms, that contain all field information, included in the fiberboard boxes? 56. Are DOT labels affixed to the outside of these boxes according to the regulations and level of methane? 57. Will each shipment contain an MSDS if methane exceeds 5% as shown in Figure 12?	QAPP, Section 4.2.i.				
58. Are samples being sent via UPS overnight to Isotech Laboratories? 59. Will personnel be available at those locations if shipments are made on a Friday or Saturday?	QAPP, Section 4.2.i.				

Additional Questions or Comments:

Project _____ Notebook No. _____
Continues from Page _____

7/14

PL1 (Probe-[redacted]-1) START coring at 11:00a

0-4 brown silty sand (No SGP set)
4-6 brown sand
6-8 brown moist fine sand/some clay
8-10 brown moist clay sand
10-11 brown moist fine sand/some clay
11-12 brown clayey sand
12-14 wet brown sand clay (perched zone?)
14-16 moist brown sand clay
16-20 moist brown clay
little resistance 16-20'
water at 16.50'
20-24' ?
24'-25' clayey brown sand (wet)
25-27' medium-grained sand (wet)
27-28' wet brown coarse-grained sand
28-32' dry gray friable sandstone (highly weathered)
(debris of clay at 28')
32-33.5 friable brown sandstone
~~water level @~~
Collapse @ 10'
stop coring at 12.28p
bentonite to surface @ 12.45p

Latitude:
Longitude:

Direct-push to 29.2' w/pull-up to 27.9' → water

Continued on Page

Read and Understood By

Signed _____ Date _____ Signed _____ Date _____

Project _____ Notebook No. _____

Continues from Page _____

7/15

SP-L-2 Near [redacted] 6/0' well

0 - 1 surface fill/sand/cobble
1 - 2 brown clayey sand
2 - 3 brown sand & clay
3 - 4 brown sand & clay
4 - 6 brown sand & clay wet
6 - 8 brown sand & clay wet STOP

Continued on Page

Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. _____

Continues from Page _____

7/15/2010

CPL-3 (near production well 12-12

0-2 sand / clayey sand
2-4 brown sandy clay
4-6 brown sandy clay
6-8 brown clay sand to sandy clay
8-10 no recovery
10-12 brown moist / wet clay (plastic)
12-13 no recovery
13-14 wet brown plastic clay
14-15 wet brown plastic clay
15-16 moist brown medium-grained sand
16-20 moist brown clay
20-21 no recovery
21-23 sandy clay
23-24 wet brown medium-grained sand
24-28 wet brown clayey sand
28-31 wet brown clayey sand
31-32 wet brown medium grained sand

Continued on Page

Read and Understood By

Signed _____ Date _____ Signed _____ Date _____

Project _____ Notebook No. _____

Continues from Page _____

7/16/2010

(Adjacent to 12-12)

CL-4 (Near well 12-12) SGP-L-1

0-1.5' brown medium-graded sand
1.5-2.0 light brown fine-graded sand
2.0-2.5 hard dry glassy brown sandy clay
2.5-4.0 brown plastic moist clay
4.0-5.5 No Recovery
5.5-6.5 brown sandy clay
6.5-8.0 moist brown sandy clay, friable
8.0-9.5 No Recovery
9.5-12 brown wet clay
12-13 No Recovery collapse to 14
13-15 wet brown clay
15-16 brown blue sand (wet)
borehole collapse to 14'

bentonite granules 11 1/2 -14'
sand 10-11 1/2
screen 5-10
sand to 4.5'
bentonite granules to 1.0' @ 10.52

slurry set @

Continued on Page

Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. _____

Continues from Page _____

7/16/2010

CL-5 (between 12-12, 12-24) SGP-L-2

START 1:30p

0-2 Brown med-grained sand (dry)
2-3½ Brown clay (dry)
3½-4 Brown fine sand, dry
4-5 No recovery
5½-6 Brown fine sand
6-7 Sand & clay
7-8 Clay sand (brown)
8-9 Clay sand (brown)
9-10 Brown moist plastic clay
10-11 Brown moist clay
11-11½ Fine brown sand
11½-12 Brown clayey sand Collapse 14'
12-13 No recovery
13-14 Brown sand & clay
14-14.5' wet brown fine sand
14.5-15 moist brown clay
15-16 wet brown fine sand

13.5-14.0 sand SGP-L-2
~~12~~. 8.5-13.5 screen
sand to 8.0' SG
bentonite to 1.0'

Slurry set @ 2:26p 7/16/2010

Continued on Page

Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. _____

Continues from Page _____

7/16/2010

SEP-2-B (Near 12-24

START Coring @ 3:15p, Slurry set at 4:40p

0-1' Brown sand
1-2 brown sand clay
2-3' brown fine sand
3-4' brown fine sand
4-5 brown fine sand
5-6' brown fine sand
6-8' brown fine sand
8-9' No recovery
9-10' fine sand (4" clay)
10-12' brown fine sand
12-12½' brown fine sand
12½-16' brown clay
16-20' brown/gray moist clay

Collapse 7'8"

Screen set @ 12.5' (push)

SAND TO 7'

BENTONITE TO 1'

Continued on Page

Read and Understood By

Signed _____ Date _____ Signed _____ Date _____

Project _____ Notebook No. _____

Continues from Page _____

7/15/2010

SGP-M-1

0 - 1/2' no Recovery
1/2' - 2' Brown dry Fine-grained sand
2 - 4' Brown moist sandy clay
4 - 6' No Recovery
6 - 7' Brown fine wet sand
7' - 8' Brown wet gravel
8' - 9' no Recovery
9 - 9 1/2 Sandy clay / clayey sand
9 - 1/2 - 10' Brown Gravel
10 - 12' Brown moist sand & clay
12 - 16' core-barrel locked-up, Brown pulverized sandstone at end of core

Collapse to 7' 3" = 7.25'
push screen to 10'
sand to 4.5,
bentonite chips to 1.0'

Continued on Page

Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. _____

Continues from Page _____

TAT/COB

SGP-M-2

START CORING 2:00p

0-1' NO Recovery
1-2' brown dry sandy clay
2-4' brown dry ~~clay~~ sandy clay
4-5' NO Recovery
5-6 MOIST Fine sand with clay
6-6½ same
6½-7½ Brown coarse sand with gravel and cobble quartz gravel
7½-8 dense green plastic clay
8-12' dense green plastic clay
12-13' " " "
13-14 brown coarse-grained sand
Collapse to 14'
~~Sand to 11'~~ no
water @ 9' 3"

Bentonite to ~~11~~ 8.5' slurry set at 3:00p
sand to 8'
screen at 8'
sand to 2.5'
bentonite to surface

Continued on Page

Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. 7/17/00
Continues from Page _____ 19

SGP-M-3

START coring 4:00p

0-1' brown dry medium-grained sand
1-2' brown dry coarse grained sand/gravel
2-2½ " " " "
2½-4 brown/green clayey sand
3' → 4' core
4-7 dry green clay
7-8½ dry green clay
8½-10 green/brown fine sandstone/sand medium-grained
10-12½ core stuck in core barrel
water at 11'

Collapse @ 12½

Screen @ 12½
Sand to 6½ 7'
Bentonite to surface @ 4:35
14' casing/riser

Continued on Page

Read and Understood By

Signed _____ Date _____ Signed _____ Date _____

Project _____ Notebook No. _____

Continues from Page _____

7/19/2011

leak Test of 9 4' drill stem 5/8" ID
with adapter

Vacuum	(inches) Test
302.4	301.6
220.7	220.1
118.5	117.9
41.7	41.5

$V = \frac{\pi}{4} d^2 h = \frac{\pi}{4} \left(\frac{5}{8} 2.54\right)^2 (4)(30.48) = 241.2\ cm^3$

water w borehole on Meeto property @ 3'

Continued on Page

Read and Understood By

Signed Date Signed

38

Project _____ Notebook No. 19

Continues from Page _____

7/18/20

Move to [redacted] Property

SGP-R-1

0 - 4' brown silt/clay
4 - 4½ brown silt/clay
4½ - 5½ brown sand clay (2" sand lense)
5½ - 6' moist brown fine sand
6 - 7 - wet sandy clay
7 - 8' - wet sandy clay
8 - 11 - wet sandy clay
11 - 14' - brown wet sandy clay

Collapse to 9', push screen to 10'

Sand 4½'
Bentonite to 6" @ 10:57 wt 1.5'

Continued on Page

Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. 19

Continues from Page _____

7/18/20

SGP-R-2 START coring @ 4:15

0-1 No Recovery
1-2 brown silt
2-2½ brown silt
2½-3 Fine brown sand
3-3½ Fine brown sand
3½-4 brown silt
4-5 No Recovery
5-8 moist sand clay clay
8-9 moist sand clay to clay
9-10 SAT/wet fine brown sand
10-12 wet clay sand

Collapse 8'5"

screen pushed to ~~8~~ 10'
sand to 4½
bentonite to 6' @ 4:45

Continued on Page

Read and Understood By

Signed _____ Date _____ Signed _____ Date _____

Project _____ Notebook No. _____

Continues from Page _____

7/20/cord

W-R-1 New SGP-R-3
~~SGP-R-3~~ START 10:30 hr
Core to 12'
Collapse 7' 9"

0 - 1/2' Brown silt (loose/friable)
~~1/2~~ 1/2 - 4' Brown hard silt
4 - 5 Brown hard silt
5 - 6 Dry brown fine sand
6 - 7 moist fine brown sand
7 - 8 moist brown sand & clay
8 - 9 " " " "
9 - 11' brown wet clay sand
11 - 11 1/2 " " " "
11 1/2 - 12 brown wet fine sand
12 - 15 fine brown sand wet
15 - 16 brown clayey sand (wet)
16 - 19 1/2 brown sand & clay (wet)
19 1/2 - 20 fine brown sand (wet)
20 - 22' brown coarse - gravel sand (wet)
22 - 24 brown medium to fine gravel sand (wet)
24 - 25 No Recovery
25 - 25 1/4 coarse wet brown sand
25 1/4 - 28 brown moist plastic clay (sand (0.25')
28 - 28 1/4 coarse wet brown sand at end of core
28 1/4 - 30 brown clay
30 - 32 brown wet fine - gravel sand
32 - 36 fine wet brown sand
36 - 38' fine wet brown sand
38 - 40 medium - gravel brown sand
40 - 42 clayey sand (moist)
42 - 43 clay
43 - 44 medium - gravel sand (moist)
44 - 49 7 cord - barrel stuck
49 - 48 green shale

Continued on Page

Read and Understood By

Signed _____ Date _____ Signed _____ Date _____

Project _____ Notebook No. _____

Continues from Page _____

7/20/2010

2 1/4" OD pipe push to 44"
allow natural collapse to 9'
bentonite to 6"

Ann Drouse
307-332-8442
John Kanisky
307-332-8419

SGP-R-3

Push to 4' START 2:40
Core to 10'
Collapse to 7'9"
Sand to 4.5'
Bentonite to surface @ 3:00

Continued on Page

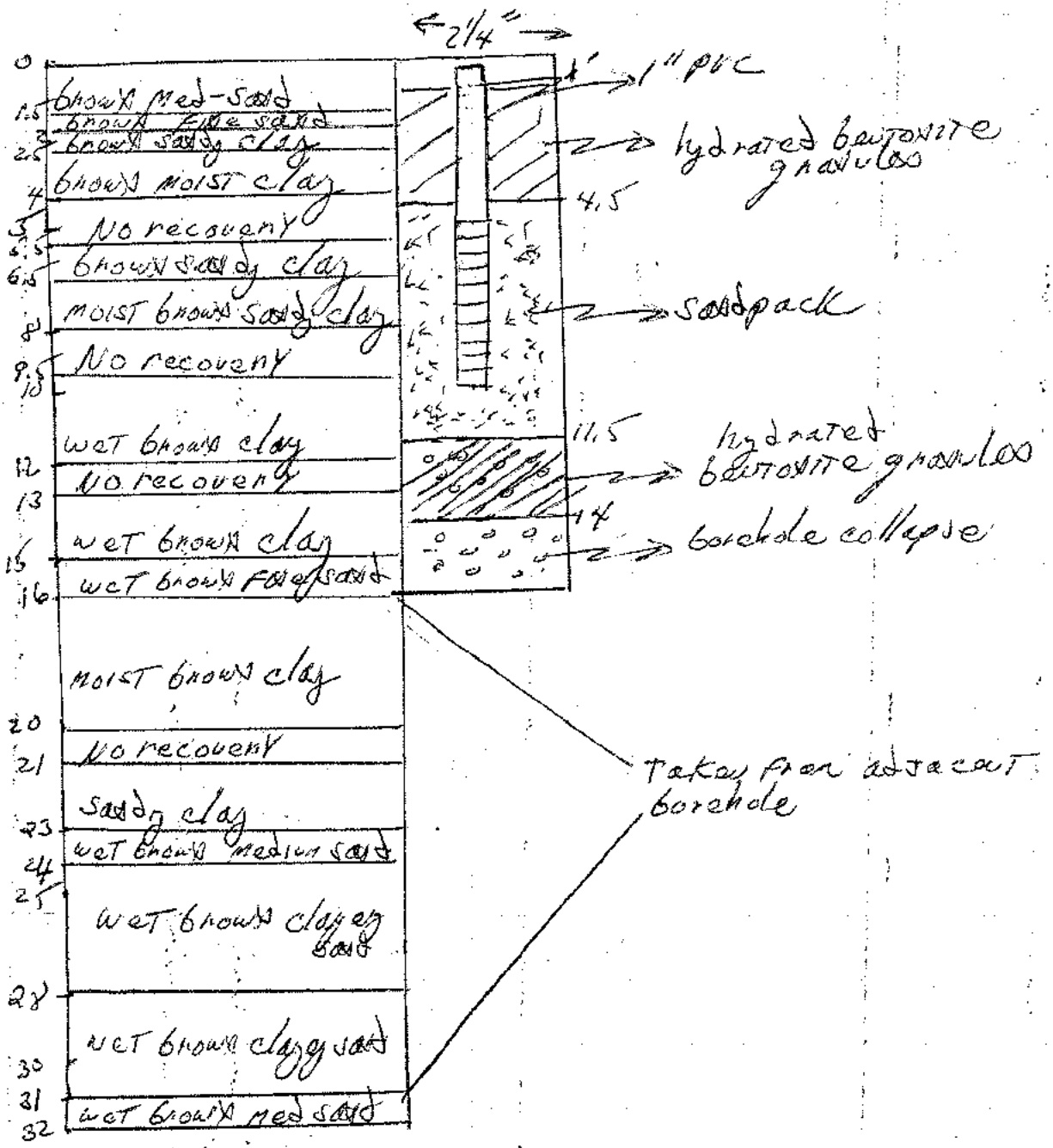
Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. PCD

Continues from Page _____

SGP-L-1 (Adjacent to Production well 12-12)



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Read and Understood By

Signed Date Signed Date

Project _____ Notebook No. _____

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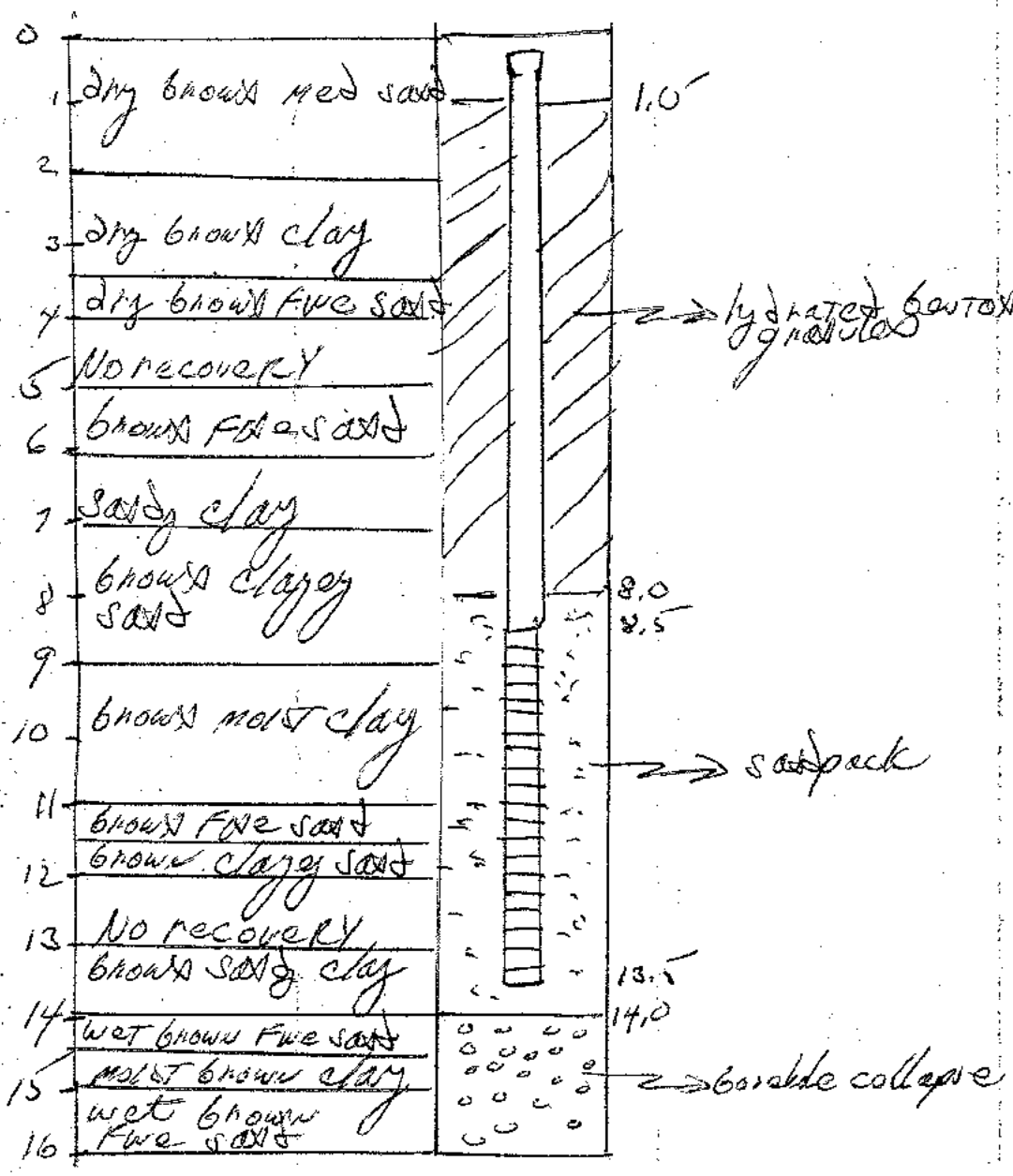
DSD

SEP-L-2 (Between Production well 12-1C and 12-9A)



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Project _____ Notebook No. DCD

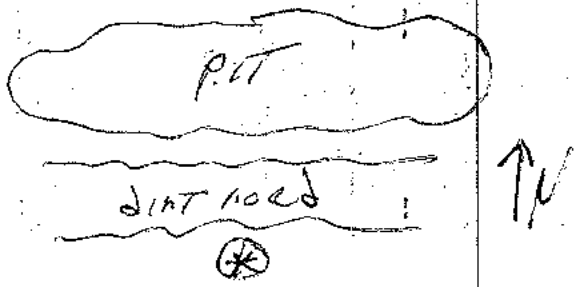
Continues from Page _____

Geoprobe Core Near Pit (South of Pit off dirt road) on [redacted] property

refer to property with well PGDW21

Logged by Jovica Kirilo
U.S EPA/ORD
9/21/2010

OUTCROP



2 dry brown silt

3 moist brown silt

4

5 No recovery

6 moist brown clayey sand to sandy clay

7

8 moist brown clay

9 No recovery

10

11 moist brown sandy clay

12 black-stained medium sand → petroleum/diesel odor
black-stained green soft shale → strong petroleum/diesel odor

13 green soft friable shale → paint thinner type odor

15 black-stained green clayey sand to sandy clay → strong paint-thinner type odor

16

17 green soft friable shale with slight black staining and weak odor

18

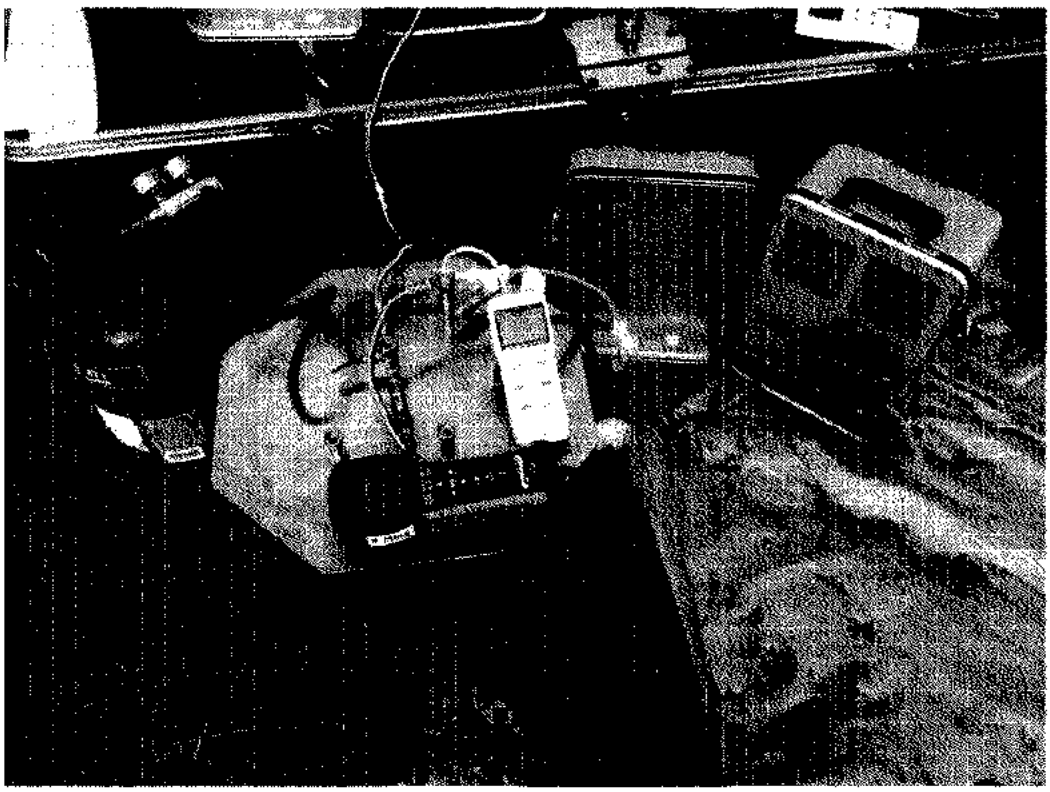
19 refusal. Dry green shale. No odor

20

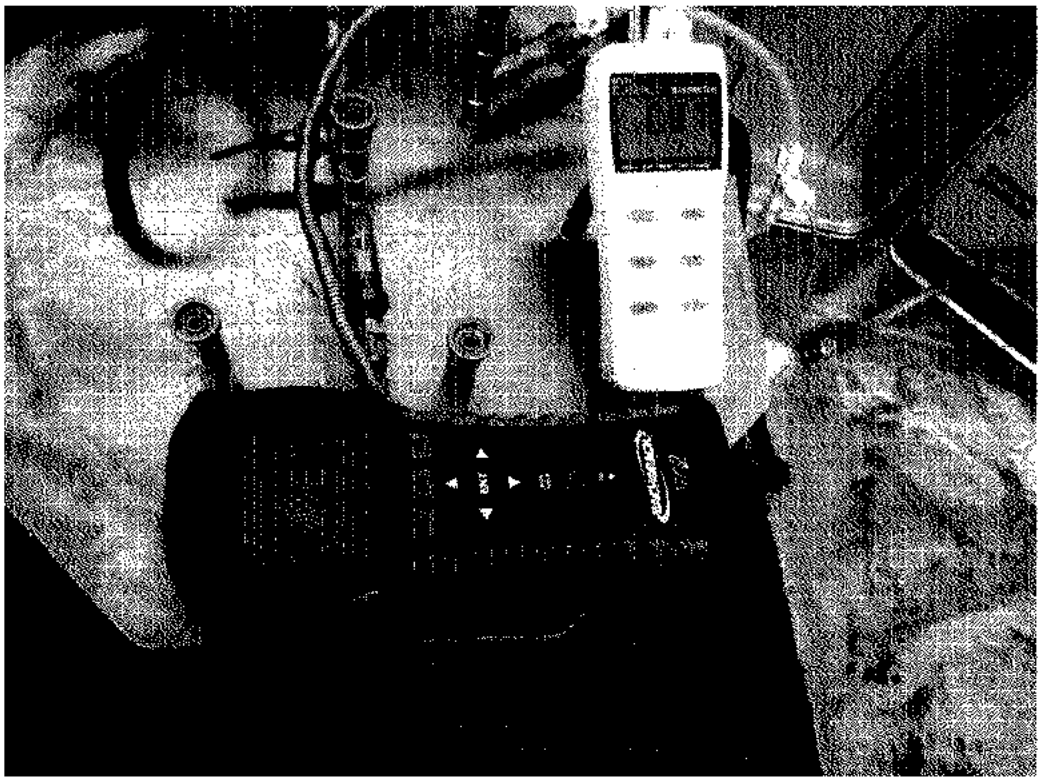
Signed Date Signed Date

Appendix A

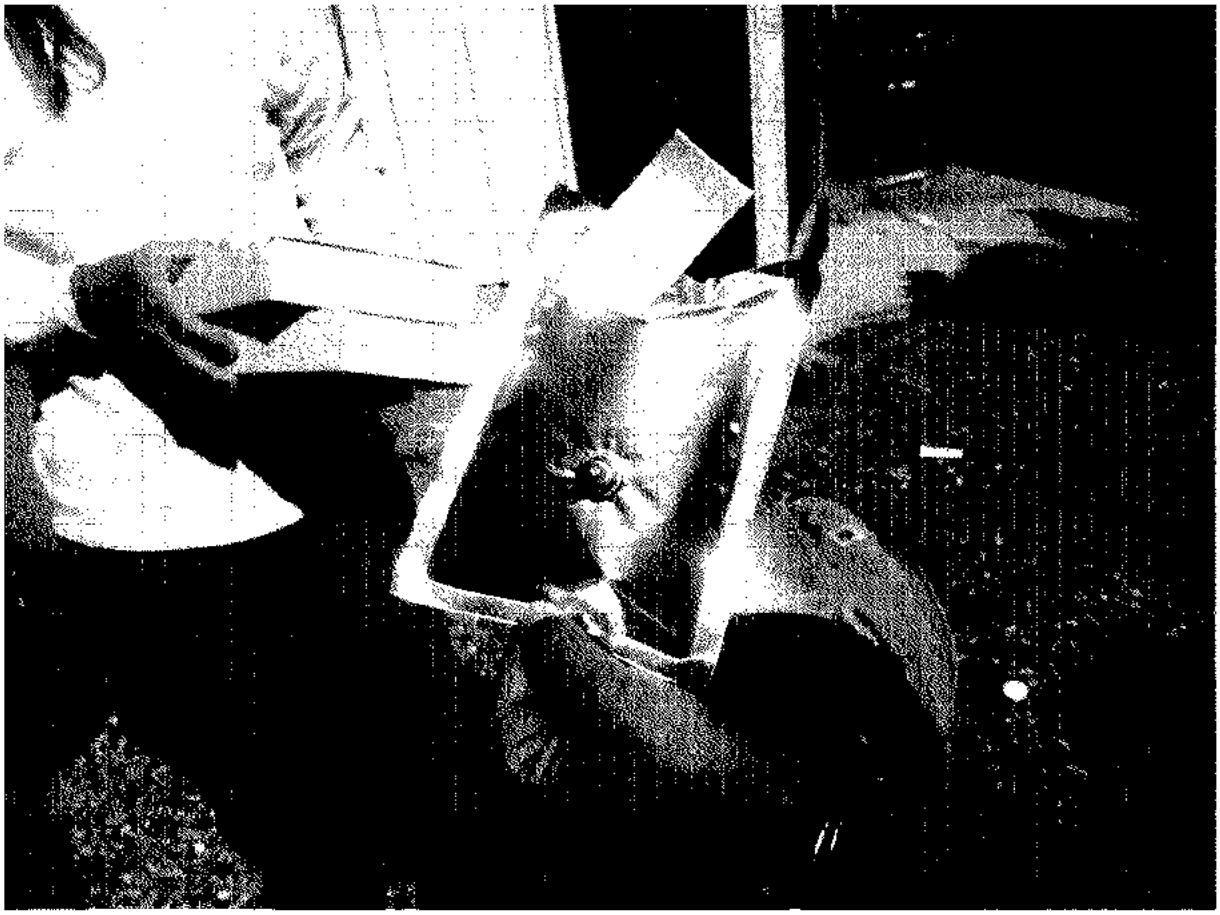
A. Additional Pictures from the Gas Sampling



Equipment used for soil gas probe sampling.

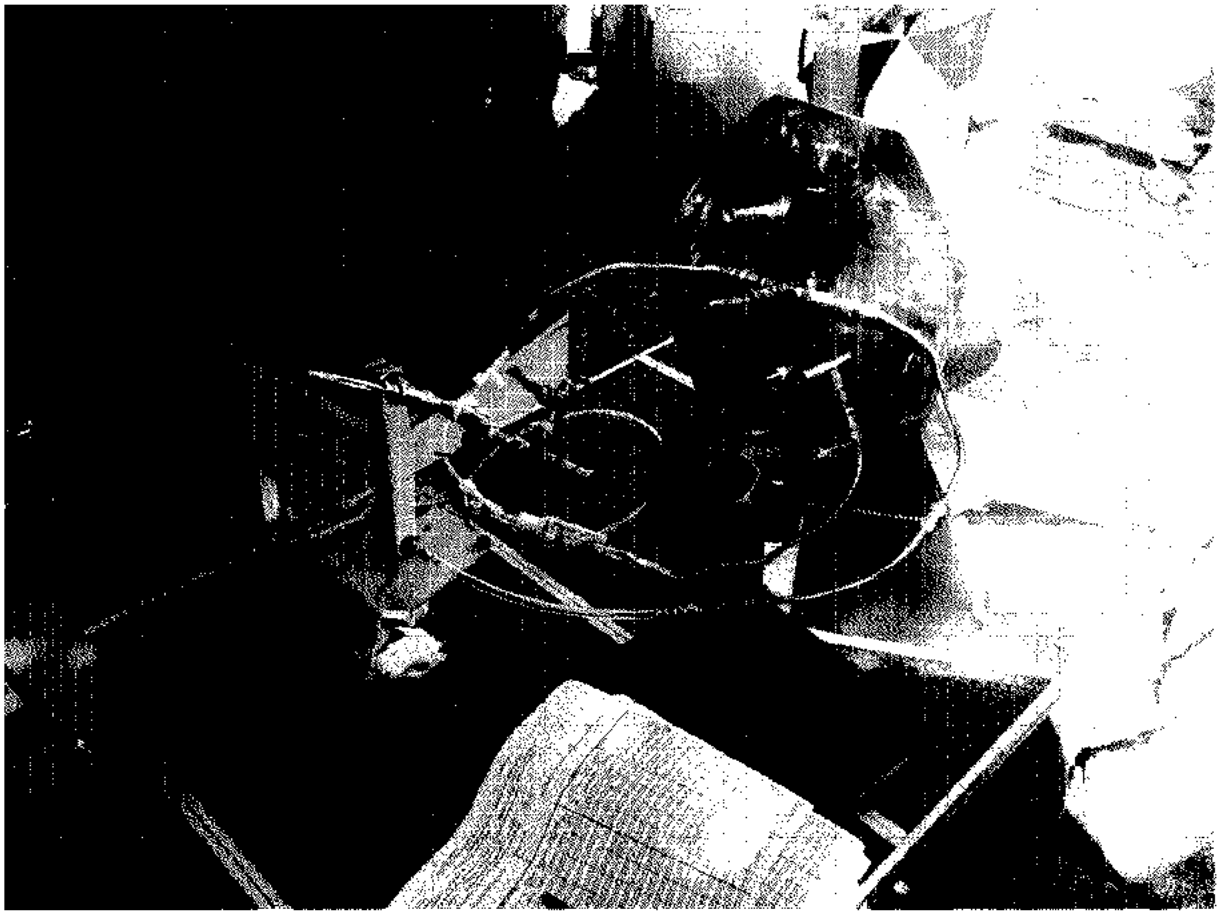


Equipment used for soil gas probe sampling.

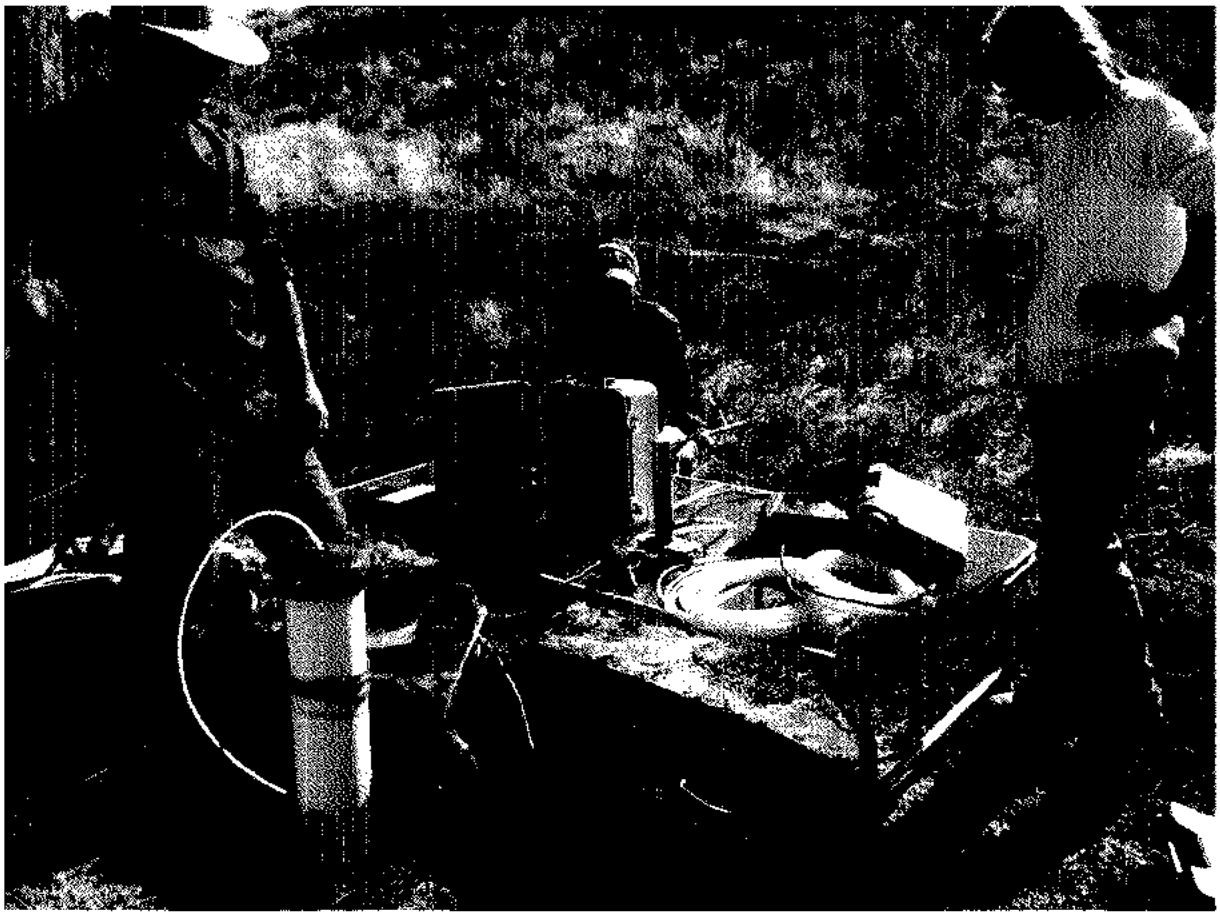


Cali-5-Bond samples

Cali-5-Bond samples in containers ready for shipment to Isotech Laboratories.



Setting up for Sampling Domestic Well – Randall Property

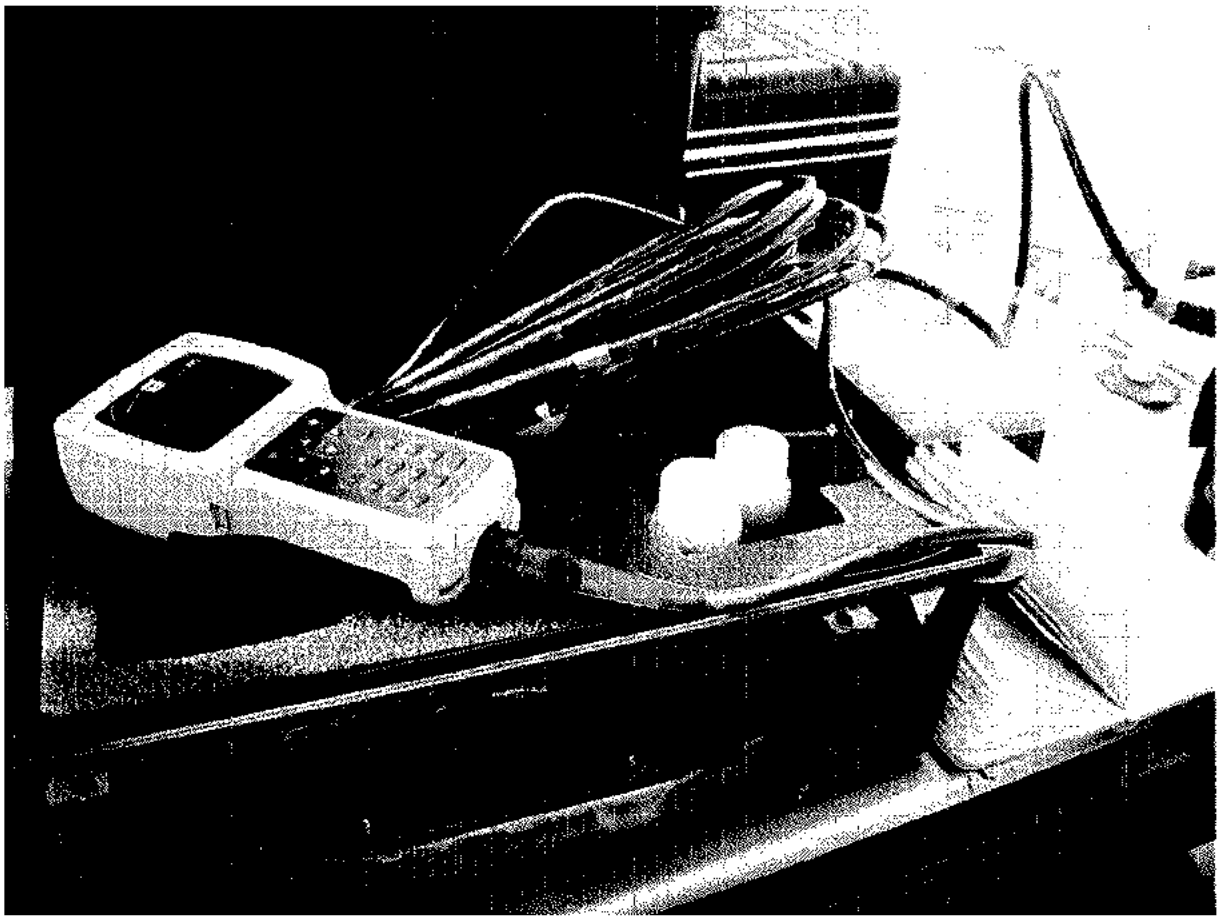


Setting up for Sampling Domestic Well – Fentonl Property

B. Additional Pictures from the Ground Water Sampling

Winch used for sampling Domestic Wells using Bomb Sampler, not used during audit.

Preparing to make field wet chemistry analyses

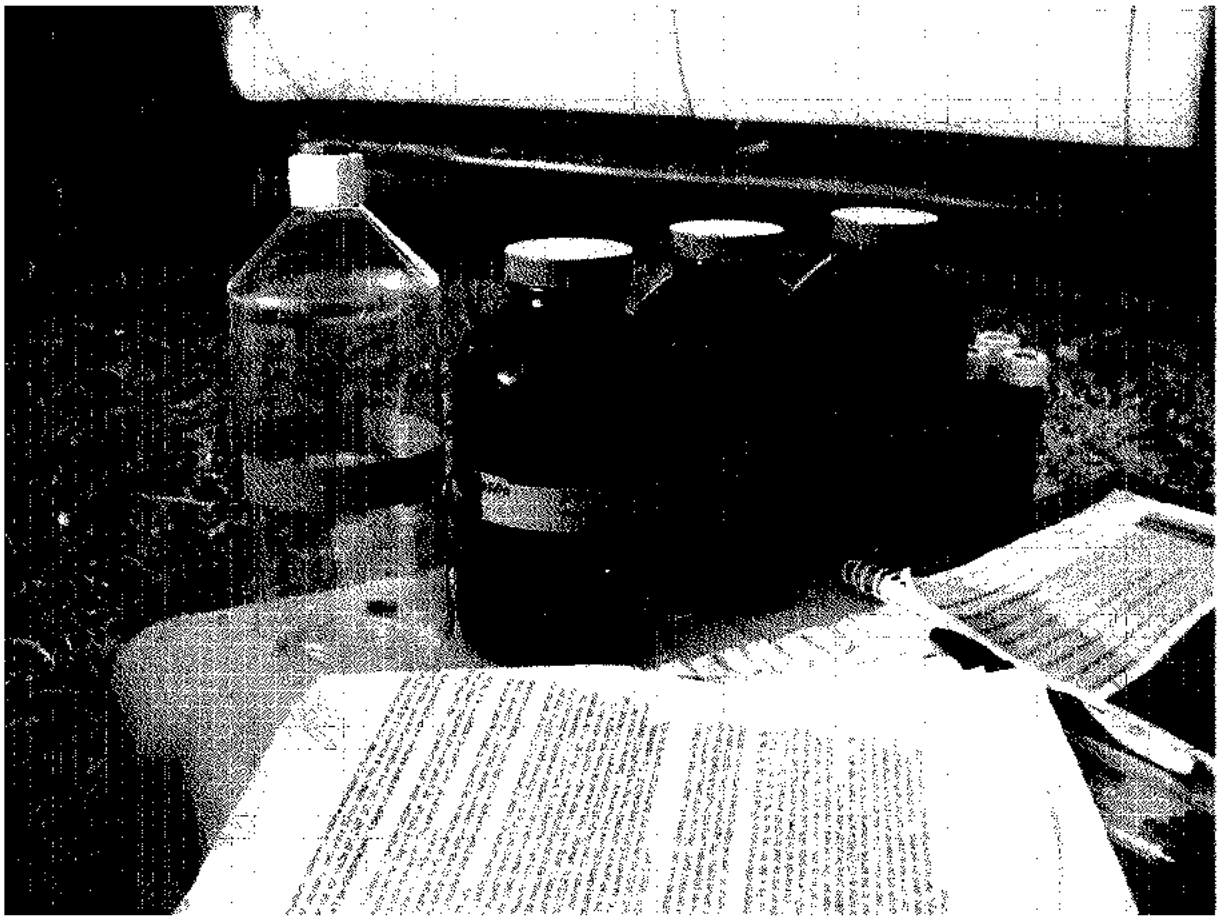


Preparing to make field wet chemistry analyses

Hach field wet chemistry system

ATTACHMENT D

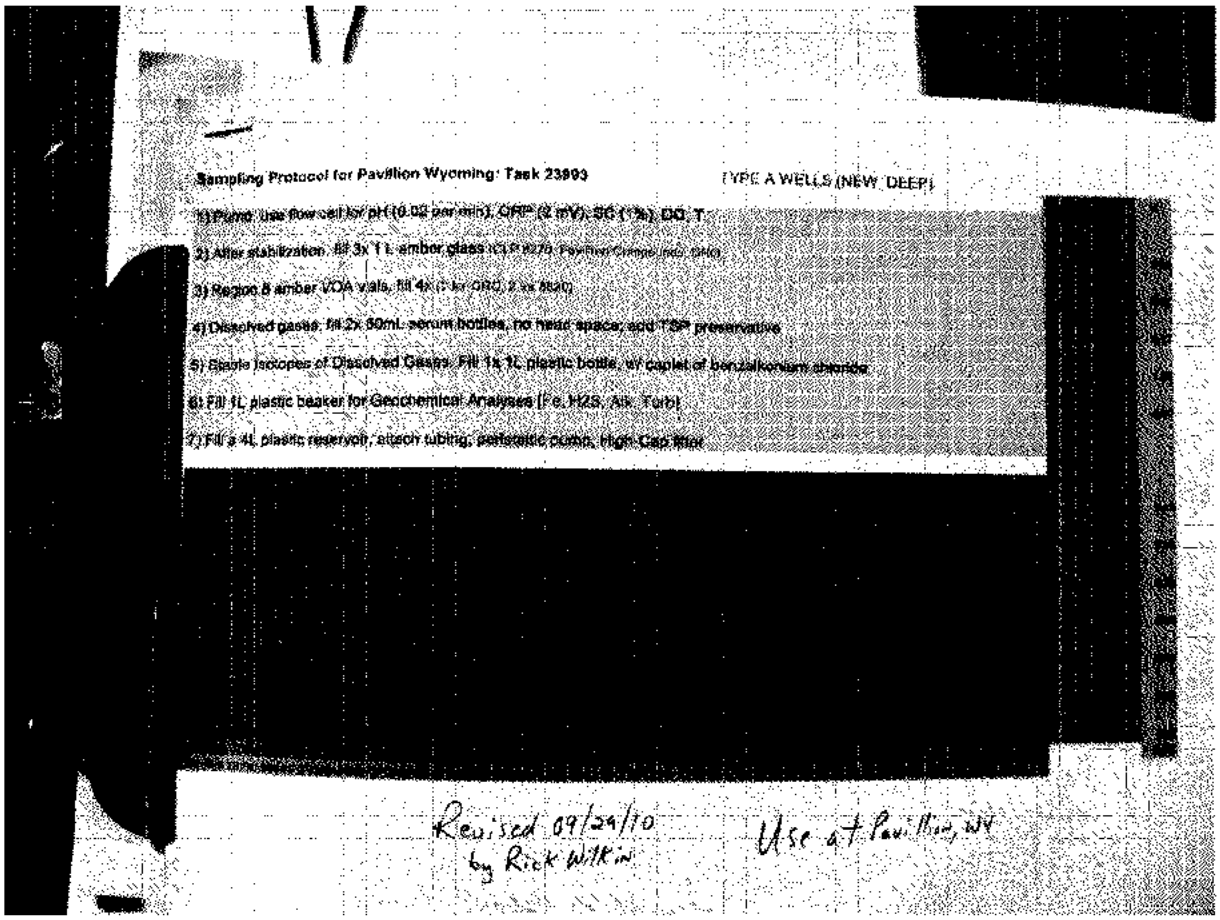
ATTACHMENT D



Sample containers

ATTACHMENT D

Filter used with appropriate samples.



Sampling Protocol for Pavillion Wyoming: Task 23993 (TYPE A WELLS (NEW, DEEP)

1) Purge, use flow cell for pH (0.02 per min), ORP (2 mV), SC (1 %), DO, T

2) After stabilization, fill 3x 1 L amber glass (CLP #276, Pavillion Cleanup Indv. Order)

3) Re-purge 8 amber VOA vials, fill 4x (1 for QRC, 2 vs Blank)

4) Dissolved gases, fill 2x 50mL serum bottles, no head space, add TSP preservative

5) Stable Isotopes of Dissolved Gases, Fill 1x 1L plastic bottle, w/ caplet of benzalkonium chloride

6) Fill 1L plastic beaker for Geochemical Analyses (Fe, H2S, Alk, Turb)

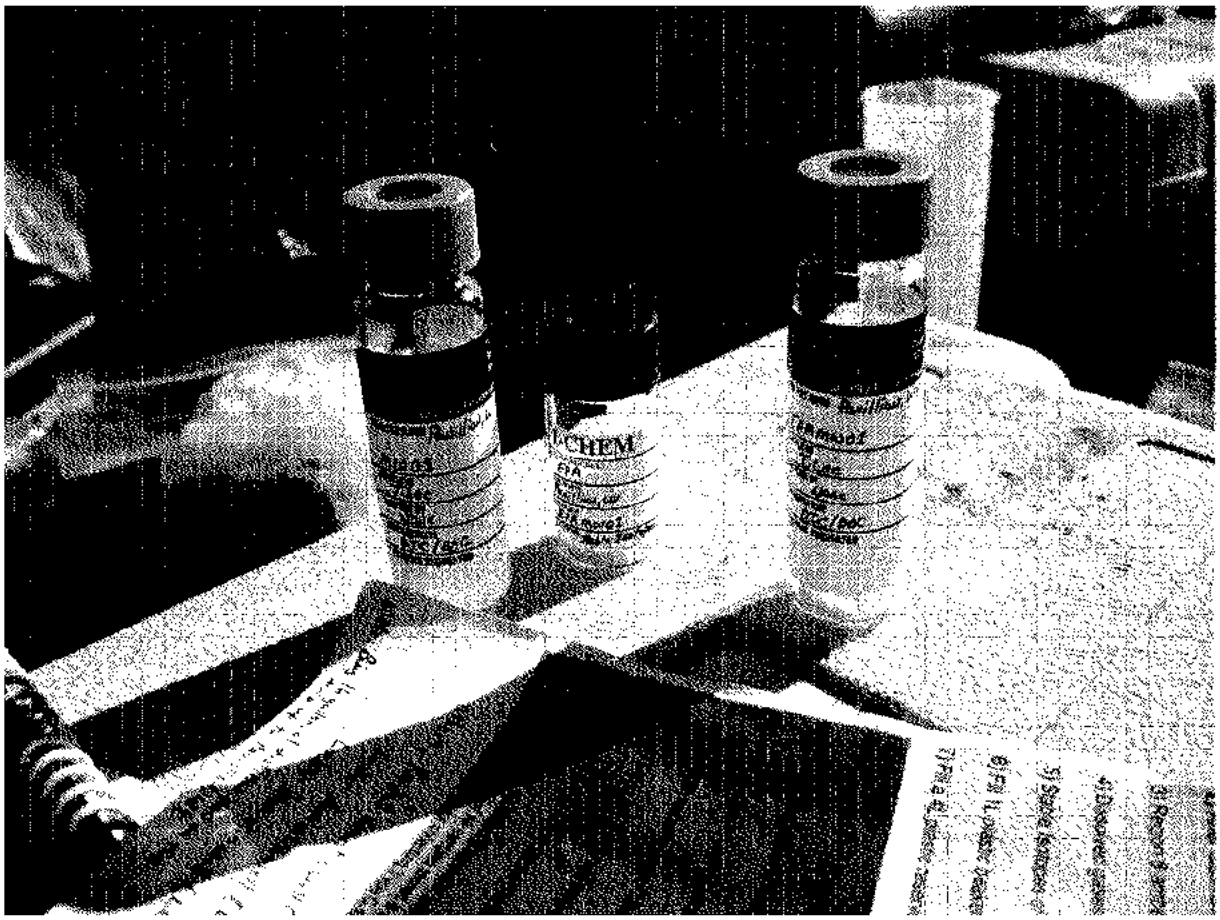
7) Fill a 4L plastic reservoir, attach tubing, peristaltic pump, High Cap filter

Revised 09/29/10 by Rick Wilkin

Use at Pavillion, WY

Field Sheet containing directions for each sample type, volume, whether preservative required.

ATTACHMENT D



Preparing to take Randall Deep Well Samples. Due to submerged pump, none were taken during audit.

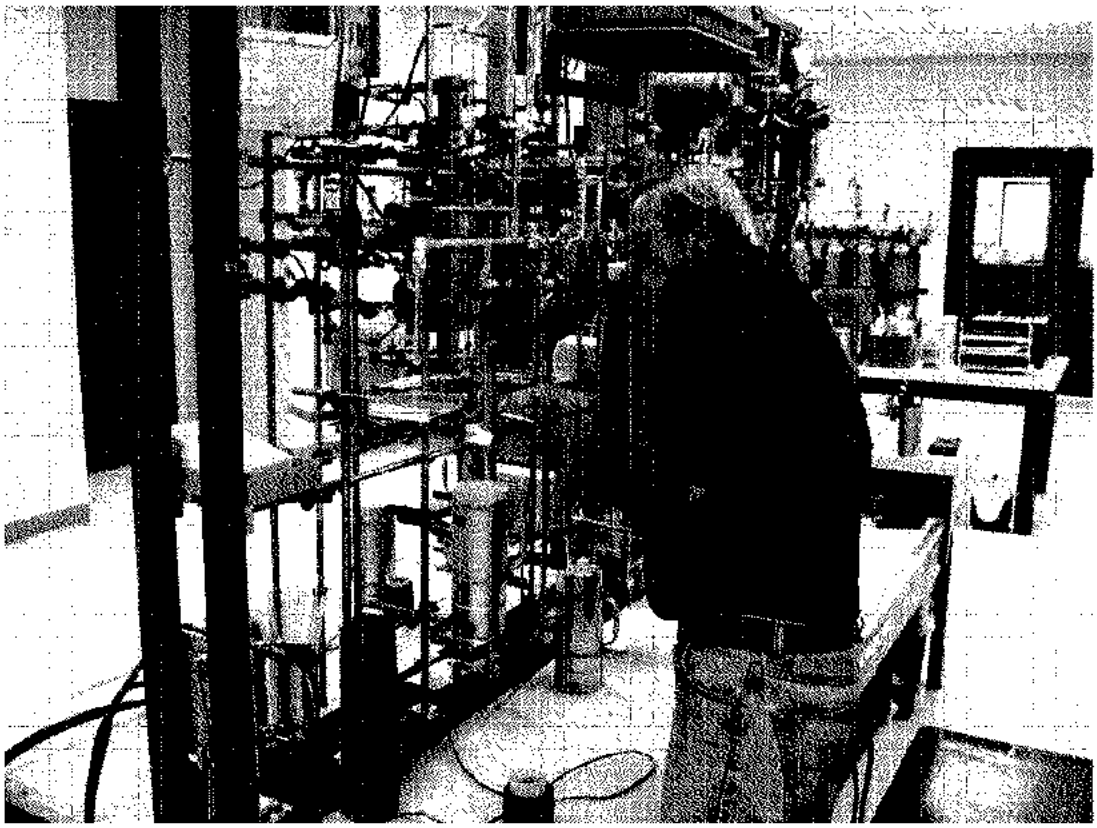
ATTACHMENT D

Domestic Well Tap sampling at Randall property, checking pH after adding acids to appropriate samples

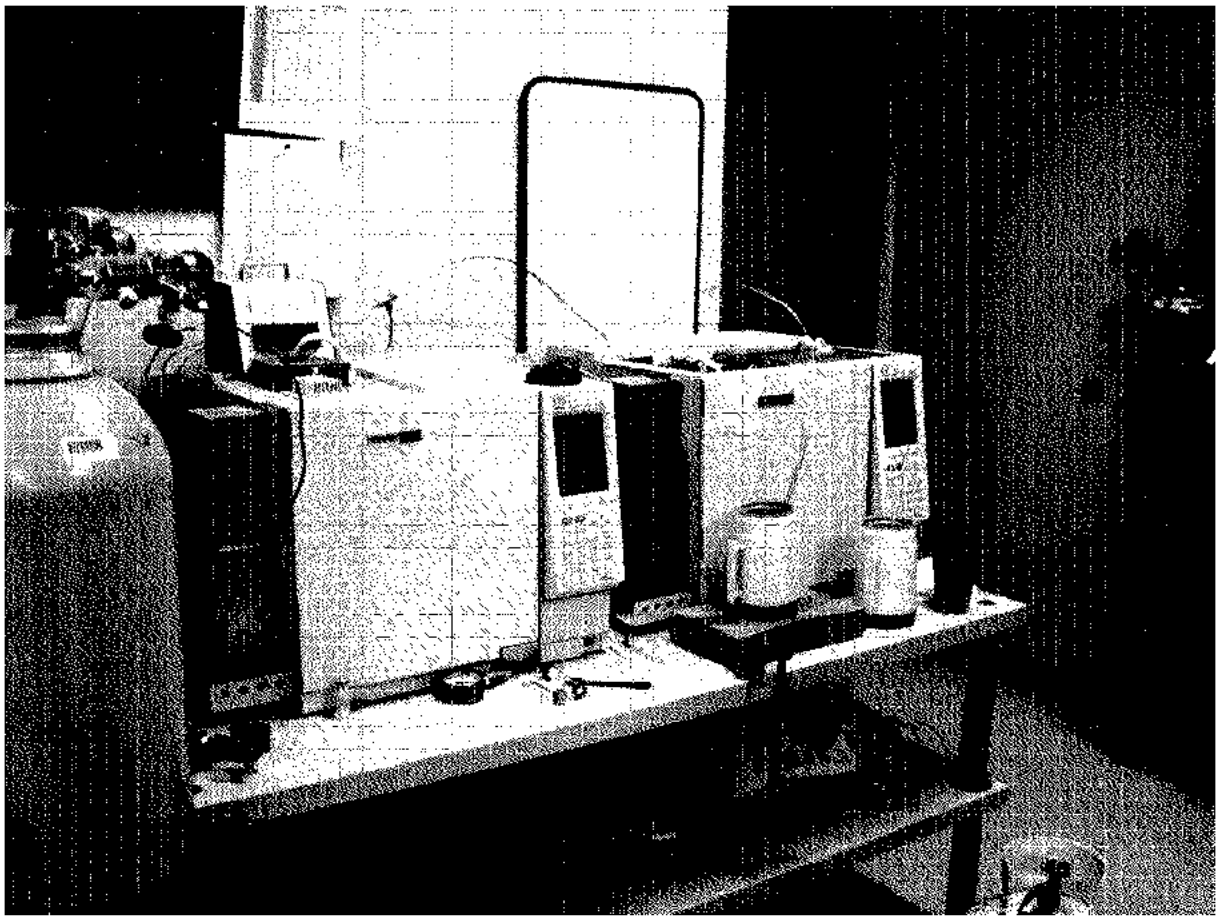
Preparing cooler for Domestic Well Tap Samples, Randall Property.

C. Additional Pictures from Isotech Laboratories

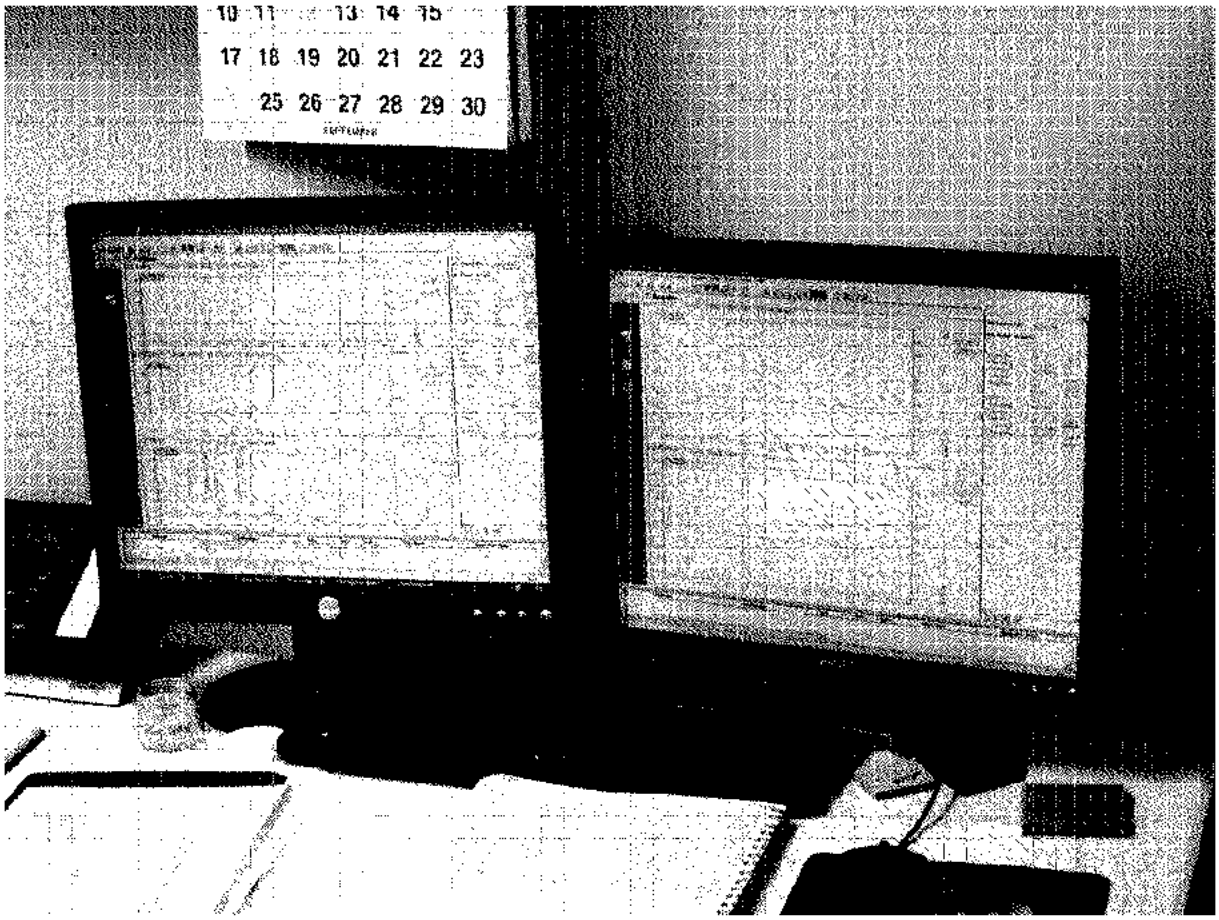
Pavillion gas Samples at Isotech Laboratories in Cali-5-Bond containers.



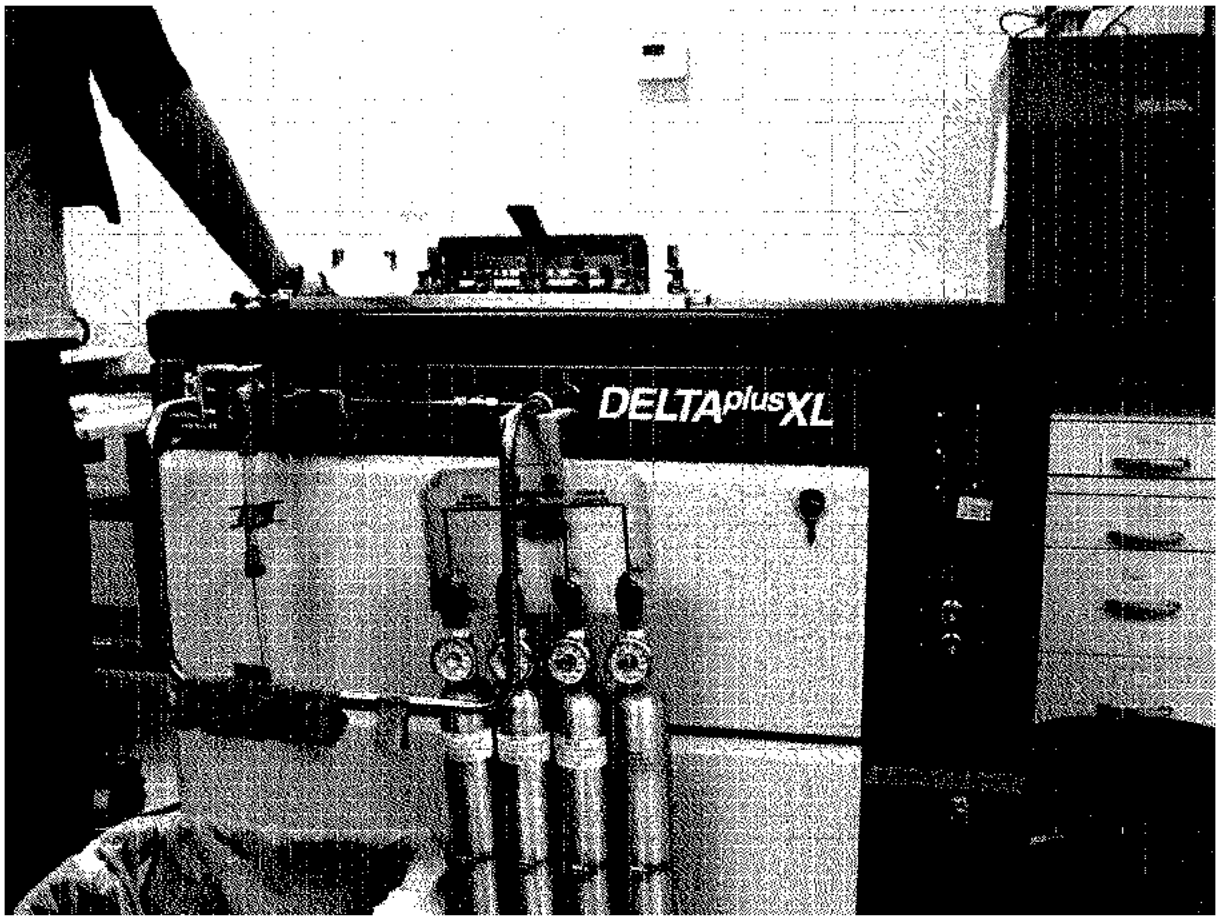
Stable Isotope Analysis – Preparation of Sealed CO2 for IRMS.



Fixed Gases and Hydrocarbons using method based on ASTM-D1945-03



Fixed Gases and Hydrocarbons using method based on ASTM-D1945-03



IRMS – Analysis of stable isotope. Bottles in front are four calibration gases.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195426 Job #: 13817
Sample Name: SGP-R-1 Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/22/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/23/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.905			
Oxygen	18.48			
Nitrogen	76.25			
Carbon Dioxide	4.37			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 1.021

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195427 Job #: 13817
Sample Name: SGP-R-2 Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/22/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/23/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.979			
Oxygen	13.22			
Nitrogen	82.36			
Carbon Dioxide	3.44			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 1.008

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195428 Job #: 13817
Sample Name: SGP-R-2 Field Dup Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/22/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/23/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.982			
Oxygen	13.25			
Nitrogen	82.34			
Carbon Dioxide	3.43			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 1.008

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195429 Job #: 13817
Sample Name: Travel Blank 1 Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/22/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/23/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.0891			
Oxygen	0.030			
Nitrogen	99.86			
Carbon Dioxide	0.016			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 0.968

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195430 Job #: 13817
Sample Name: Equipment Blank 1 Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/22/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/23/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.0920			
Oxygen	0.098			
Nitrogen	99.79			
Carbon Dioxide	0.020			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 0.968

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195477 Job #: 13827

Sample Name: Travel Blank 2 Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/23/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/24/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.0914			
Oxygen	0.054			
Nitrogen	99.85			
Carbon Dioxide	0.009			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 0.968

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195478 Job #: 13827

Sample Name: Equipment Blank 2 Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/23/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/24/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.0887			
Oxygen	0.026			
Nitrogen	99.87			
Carbon Dioxide	0.014			
Methane	0.0029			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 0.968

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195479 Job #: 13827

Sample Name: SGP-R-3 Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/23/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/24/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.915			
Oxygen	18.87			
Nitrogen	77.10			
Carbon Dioxide	3.12			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 1.014

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195480 Job #: 13827
Sample Name: MW-R Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/23/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/24/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	0.0237			
Hydrogen	0.0093			
Argon	0.118			
Oxygen	1.25			
Nitrogen	9.30			
Carbon Dioxide	0.018			
Methane	84.22	-39.44	-209.1	
Ethane	3.43	-26.63	-165.0	
Ethylene	0.0007			
Propane	0.791	-23.76	-143.7	
Iso-butane	0.327			
N-butane	0.191			
Iso-pentane	0.143			
N-pentane	0.0632			
Hexanes +	0.111			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 966
Specific gravity, calculated: 0.639

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195481 Job #: 13827

Sample Name: DW-R Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/23/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/24/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.937			
Oxygen	20.21			
Nitrogen	78.80			
Carbon Dioxide	0.045			
Methane	0.0123			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 0.999

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195480 Job #: 13827
Sample Name/Number: MW-R
Company: Environmental Protection Agency, US
Date Sampled: 9/23/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/24/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	^{14}C conc. pMC	Tritium TU
Carbon Monoxide	nd				
Hydrogen Sulfide	nd				
Helium	0.0237				
Hydrogen	0.0093				
Argon	0.118				
Oxygen	1.25				
Nitrogen	9.30				
Carbon Dioxide	0.018				
Methane	84.22	-39.44	-209.1	< 0.2	
Ethane	3.43	-26.63	-165.0		
Ethylene	0.0007				
Propane	0.791	-23.76	-143.7		
Iso-butane	0.327				
N-butane	0.191				
Iso-pentane	0.143				
N-pentane	0.0632				
Hexanes +	0.111				

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 966
Specific gravity, calculated: 0.639

Remarks:
Report revised on 11/3/10 to include radiocarbon analysis data for methane.

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195493 Job #: 13834
Sample Name/Number: MW-L
Company: Environmental Protection Agency, US
Date Sampled: 9/24/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/27/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	^{14}C conc. pMC	Tritium TU
Carbon Monoxide	nd				
Hydrogen Sulfide	nd				
Helium	nd				
Hydrogen	nd				
Argon	1.03				
Oxygen	11.14				
Nitrogen	86.66				
Carbon Dioxide	0.046				
Methane	1.04	-41.72	-209.2	< 0.2	
Ethane	0.0477				
Ethylene	nd				
Propane	0.0221				
Iso-butane	0.0089				
N-butane	0.0053				
Iso-pentane	0.0020				
N-pentane	0.0008				
Hexanes +	0.0009				

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 13
Specific gravity, calculated: 0.983

Remarks:
Report revised on 11/3/10 to include radiocarbon analysis data for methane.

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195494 Job #: 13834
Sample Name/Number: MW-L Field Dup
Company: Environmental Protection Agency, US
Date Sampled: 9/24/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/27/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	^{14}C conc. pMC	Tritium TU
Carbon Monoxide	nd				
Hydrogen Sulfide	nd				
Helium	nd				
Hydrogen	nd				
Argon	1.03				
Oxygen	11.17				
Nitrogen	86.62				
Carbon Dioxide	0.046				
Methane	1.05	-41.85	-209.4	< 0.2	
Ethane	0.0482				
Ethylene	nd				
Propane	0.0222				
Iso-butane	0.0089				
N-butane	0.0053				
Iso-pentane	0.0020				
N-pentane	0.0008				
Hexanes +	0.0012				

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 13
Specific gravity, calculated: 0.983

Remarks:
Report revised on 11/3/10 to include radiocarbon analysis data for methane.

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195620 Job #: 13848
Sample Name: Equipment Blank 4 Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/25/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.0882			
Oxygen	0.025			
Nitrogen	99.88			
Carbon Dioxide	0.008			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 0.968

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195621 Job #: 13848
Sample Name: Travel Blank 4 Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/25/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.0878			
Oxygen	0.030			
Nitrogen	99.88			
Carbon Dioxide	0.007			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 0.968

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195622 Job #: 13848

Sample Name: SGP-L-2 Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/25/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	1.00			
Oxygen	10.80			
Nitrogen	82.93			
Carbon Dioxide	5.27			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 1.015

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195623 Job #: 13848

Sample Name: SGP-L-1 Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/25/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.928			
Oxygen	12.80			
Nitrogen	76.53			
Carbon Dioxide	9.74			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 1.042

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195624 Job #: 13848
Sample Name: SGP-L-3 Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/25/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.937			
Oxygen	20.48			
Nitrogen	77.53			
Carbon Dioxide	1.05			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 1.005

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195625 Job #: 13848
Sample Name: SGP-L-3 Field Dup Co. Lab#:
Company: Environmental Protection Agency, US
Date Sampled: 9/25/2010
Container: Cali-5-Bond Bag
Field/Site Name: Pavillion, WY
Location:
Formation/Depth:
Sampling Point:
Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.936			
Oxygen	20.48			
Nitrogen	77.52			
Carbon Dioxide	1.06			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 1.005

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195626 Job #: 13848

Sample Name: SGP-M-1 Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/26/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.938			
Oxygen	19.53			
Nitrogen	77.49			
Carbon Dioxide	2.04			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 1.009

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT D

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 195627 Job #: 13848

Sample Name: SGP-M-2 Co. Lab#:

Company: Environmental Protection Agency, US

Date Sampled: 9/26/2010

Container: Cali-5-Bond Bag

Field/Site Name: Pavillion, WY

Location:

Formation/Depth:

Sampling Point:

Date Received: 9/28/2010 Date Reported: 10/20/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	0.949			
Oxygen	16.39			
Nitrogen	78.47			
Carbon Dioxide	4.19			
Methane	nd			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0

Specific gravity, calculated: 1.017

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

Gillian Malone

I feel that after several years of studying this issue, beginning with the EPA findings suggesting that constituents used in fracking were present in drinking water wells, the state should take responsibility for remediating the oil and gas-related contamination for the residents of Pavillion. I also feel that if Encana can help pay for the study then surely Encana can help pay for the remediation with monitoring wells, drinking water delivery for all households, and whatever it takes to clean up the groundwater, soils, and ambient air quality for residents living in and around the gas field. These people have suffered enough. Let's learn from Flint, Michigan and do the right thing for the citizens of Wyoming before we start losing lives from this disaster. Make no mistake, this is an instance of environmental and social justice, and if Wyoming is ready to host the oil and gas industry then Wyoming should also be prepared to hold this industry accountable for its actions and protect the health and welfare of citizens living in this state. Thank you for considering my comments.

BAKER BOTTS L.L.P.

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March 18, 2016

Thomas C. Jackson
TEL: 2026397710
FAX: 2025851009
thomas.jackson@bakerbotts.com

VIA ELECTRONIC SUBMISSION

Wyoming DEQ
Attn: Water Quality Division Pavillion Study
200 West 17th Street
Cheyenne, WY 82002

Re: Pavillion Study

Dear Sir or Madam,

Please find attached the comments of Halliburton Energy Services, Inc. on the *Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study*. Please feel free to contact me if there are any questions .

Respectfully,

Thomas C. Jackson

TJ:sdt
Attachment

Comments of Halliburton Energy Services, Inc.

Regarding Pavillion, Wyoming Area Domestic Water

Wells Draft Final Report and Palatability Study

Halliburton Energy Services, Inc. ("HESI") submits the following comments concerning the "Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study" prepared by Acton Mickelson Environmental, Inc. and the Wyoming Department of Environmental Quality and dated December 14, 2015.

Based on its extensive experience with hydraulic fracturing ("HF") in a wide variety of formations across the country and around the world, HESI agrees with the conclusion of the draft report that there is a negligible likelihood that HF fluids pumped into target formations in the Pavillion area have migrated upwards to the depths utilized by water supply wells. HESI agrees with the analysis of Dr. Maurice Dusseault regarding why such upward migration is so unlikely under the circumstances that surrounded past HF operations in the Pavillion area. HESI believes that the following points are of particular note:

- Based on the well records, the HF treatments in the Pavillion area were relatively low volume, with total fluid volumes being on the order of 1,000 to 10,000 gallons per fractured well interval. Moreover, the predominant fluid type used in the area was CO_2 foam, with 70% or more of the total being made up of CO_2 foam. As a result, the actual liquid volume for these treatments is quite low.

- In comparison, the available pore space in the formation being hydraulically fractured would be much larger in volume. This available pore space would be expected to trap the relatively small volume of HF fluids used.

- During the production period, there would be no movement of any HF fluids within the gas well's radius of influence except movement towards the production well. Once the production period is over any potential for migration of fluid would still be reduced because the pressures within the producing formation would have been reduced by the removal of gas and liquids and any HF fluids would tend to migrate toward the area of lower pressure in the vicinity of the gas well.

There is another key reason why it is extremely unlikely that HF fluids would have migrated upward to reach depths used for domestic water supply. Any such upward migration would require a force to push the fluids upward, i.e., an upward hydraulic gradient. However, available evidence – including studies by USGS and others dating back to the 1950s – indicates that the hydraulic gradient in the Wind River Basin in the Pavillion area is actually downward.[1]

[1] For example, downward flow gradients were noted consistently in a long-term (one and a half year) USGS study undertaken at a monitoring well cluster in the Wind River Formation. *See* McGreevy, L.J., *et al.*, "Ground-water Resources of the Wind River Indian Reservation," USGS Water Supply Paper (1969).

As a result, to the extent the HF fluids are not trapped in the producing formation any vertical migration would be downward, not upward.

Even if there were an upward hydraulic gradient, hundreds – or in some cases thousands – of feet of rock separate the formations that have been hydraulically fractured in the Pavillion area from the depths from which domestic wells draw water. Those intervening expanses of rock include a number of very low permeability layers. As Gradient has previously demonstrated, formations that are dominated by multiple low-permeability layers effectively ensure that any upward fluid or chemical fluxes would be very low and any migration would be very slow, resulting in long migration timescales.[2] However, as noted above, no upward migration would be expected in the Pavillion area due to the downward hydraulic gradient and other factors.

In light of the above, HESI agrees that there is only a negligible possibility that HF fluids have reached the depths used for water supply wells in the Pavillion area. HESI recommends that Wyoming DEQ clarify the conclusions of the report in this regard since the report in places characterizes this potential only as "unlikely," which actually overstates the possibility of such migration.

Finally, HESI agrees with the statement in the draft report that the data from EPA's deep monitoring wells (MW-1 and MW-2) are not representative of actual groundwater conditions in the area. As HESI pointed out in its comments on EPA's "Draft Investigation of Ground Water Contamination in Pavillion, Wyoming," there are a number of significant questions and concerns regarding the methods EPA and its contractor used to construct and sample the monitoring wells.

Among the issues identified are the following:

- EPA did not maintain records of the volume of drilling fluid used nor did it use a tracer in the drilling fluid, either one of which would have allowed steps to be taken to ensure that drilling fluid in the vicinity of the borehole was removed prior to sampling.

- EPA departed from its work plan and standard industry practice by not installing a bentonite seal above the well screens, allowing the water in the well to come into contact with Portland cement.

- EPA did not follow standard practice or the project work plan in developing the wells prior to sampling.

- The sampling methodology used by the Agency—such as the very high purge rates—likewise did not follow industry standards or the project work plan. In addition EPA did not wait for field parameters such as pH and specific conductivity to be stabilized before sampling.

---

[2] Flewelling & Sharma, "Constraints on Upward Migration on Hydraulic Fracturing and Fluid Brine," *Groundwater* (Jul. 29, 2013), available at http://onlinelibrary.wiley.com/doi/10.1111/gwat.12095/abstract.

- Both monitoring wells have a section of open borehole below the well screens in violation of Agency procedures for well installation. Open boreholes can act as reservoirs that collect a variety of materials that can affect water quality.

- MW02 was installed deeper than intended, leaving about half the screen in a shale layer and contributing to the low yield that led USGS to decide not to sample the well.

The deficiencies in the monitoring wells have been recognized by a number of parties, including but not limited to USGS and the Bureau of Land Management. As a result, EPA's sampling results should not be given any weight.

Jana Weber

I'm sure you have gotten many well constructed, specific, and scientific letters about this issue. I am a lifelong citizen of this state and area and I really would like to see Encana and any other corporation who has made millions off our natural resources held accountable to the people for the damage they have done. They have all done damage while making obscene profits. The least they can do is correct these highly noticeable disasters.

Jeff Locker

I do not feel it is possible to provide adequate comments until we have all the information requested in our FOIA of July 23, 2015. We respectfully request these documents be made available to us. Thank you.

Jennifer Miller

It seems to us that this polluted water situation in Pavillion has gone on long enough without a solution. Please help clean up the polluted wells and give these residents a clean source of water whose ever fault it is. The run around these Wyoming residents have endured is not befitting of our great state. Give them relief.
Neil and Jennifer Miller Basin

Joanna Taylor

All three studies indicate and point to contamination caused by a large industrial oil and gas field permitted by the State of Wyoming. These studies identify problems with: Inadequate casing of oil and gas wells that led to contamination; Unlined production pits that held oil and gas waste that contaminated soil and groundwater and; Extensive migration and release of gas and fluids from oil and gas drilling and production that polluted the freshwater aquifer. Wyoming must step up to the plate and require industry to remediate the pollution and pay for a longterm water supply for Pavillion area landowners.

Judith Wilson

How long do the people in Pavillion have to wait to have clean water?

Kristina Korfanta

Please address the contamination problems caused by oil and gas drilling in the Pavillion area as evidenced by your own reports. Please require industry to clean it up AND to pay for a longterm water supply for Pavillion. The health of our citizens is paramount. Thank you.

linda olinger

The EPA conducted four rounds of sampling, first testing the water from more than 40 homes and later drilling two deep wells to test water from layers of earth that chemicals from farming and old oil and gas waste pits were unlikely to reach.
The sampling revealed oil, methane, arsenic, and metals including copper and vanadium – as well as other compounds —in shallow water wells. It also detected a trace of an obscure compound linked to materials used in fracking, called 2-butoxyethanol phosphate (2-BEp).

The deep-well tests showed benzene, at 50 times the level that is considered safe for people, as well as phenols — another dangerous human carcinogen — acetone, toluene, naphthalene and traces of diesel fuel, which seemed to show that man-made pollutants had found their way deep into the cracks of the earth. In all, EPA detected 13 different compounds in the deep aquifer that it said were often used with hydraulic fracturing processes, including 2-Butoxyethanol, a close relation to the 2-BEp found near the surface.[1]

I believe the EPA report shows definite pollution of Pavilion water. These chemicals were NOT present in the aquifer before drilling. And why would Encana paying for most of the Wyoming research be an objective and fair participant!

I am ashamed of the EPA for not standing up to the hypocrites in Congress (like Inofe) and shirking their duty to protect the American taxpayer's health. Maybe, just maybe the Wyoming DEQ's conscience will make sure they do a better job!

(First 3 paragraphs are copied from an 2013 article that appeared in Huffington Green)

2/20/16

To whom it may concern,

Re: City of Pavillion water purity

On December 19th, 2005 Lou's Drilling experienced a major blowout as they were drilling a new water well for Louis Meeks on his farm located about six miles east of Pavillion. At that time Encana Oil and Gas had been drilling and fracking for natural gas in the area.

After the blowout Encana's wells numbers: 11-11, 11-11B, 14-2 and 13-2 experienced a drop in production. When the water well blowout was capped, the Encana wells mentioned above doubled or tripled production. This leads me to believe that those wells were leaking gas into the water table.

Other farms in the area experienced problem with their water quality after Encana began their operations .

It comes as no surprise to me that Pavillion is experiencing problems with their water wells. What does surprise me is that the Wyoming Oil and Gas commission and other government agencies don't want to see this is a problem and seem to be biased in their findings. What needs to be done is a thorough testing of the water by an unbiased entity. The EPA was doing some of the work but suddenly seemed to be discouraged by the state of Wyoming.

The waters of Wyoming need to be protected for the future because someday in the future they will be worth more than any oil or gas. Potable water is a gift that needs to be protected at any cost it is not that common or abundant. It's time for our state's legislator's and governing bodies to step up the plate and protect its citizens not the businesses that come to reap our resources and leave when times get bad.

My family has been living in Wyoming for five generations, we have seen the "boom and bust" cycles common to a state that depends on their natural

resources. We have weathered it all despite many of the questionable decisions some of our legislators have made in the past. When will our state government see that? I hope it is very soon. Please have an independent study of the Pavillion water done. Encana is not going to go broke if they have to remedy the problems.

Wyoming is not going to suffer if they get tough on big corporations and make them institute better practices. We have what they want and they will come to us under our own terms not theirs.

Please protect your citizens, the voters and tax payers of Wyoming, they are your first and only obligation as government entities.

Respectfully,

Louis Dickinson

Lou's Drilling

903 Beth Dr.,

Riverton, WY

2/23/201

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DEQ WATER QUALITY

DEQ
Water Quality
200 W. 17th Street 4th Floor
Cheyenne, WY 82002

To whom it may concern

EnCana cut a lot of corners in the Pavillion gas field when construction the gas well . They did not put surface casing deep enough. Because they were losing circulation and the cement jobs were not done right.

Our contracts said they were to drill with fresh water only on irrigated land but they used heavy mud and lost circulation material from the very start.

When our water went bad EnCana came out and hooked up water to our house . They checked out well 24-2 and found that no cement was around the surface casing but yet they perforated and frocked it anyway. I have completion records that shows that they knew it when they completed it. 24-2 records show that the cement job was no good and that they perforated from 1500 feet to 3000 feet. This kind of practice was just asking for problems because this well is only 500 feet from my water well.

When we tried to drill a new water well we hit gas at 540 feet. This well was cased and cemented and gravel packed. First we got heavy foam used in lost circulation material then gas and then a lot of water with gas. EnCana came in and cemented to kill the well we have records showing that four gas wells increased in production. They were 14-2, 13-2, 11-11B and 11-11. 14-2 tripled in production. These were records from Weston Engineering and pumper told us also. This shows that all of the gas wells are intermingled. So how can you tell if Tribes or fee well are getting the right reading in production. 14-2 and 13-2 are tribal wells, 11-11B and 11-11 are fee wells.

I would like to see the State put monitoring wells from gas wells 14-2 and 24-2 to my house. I was told the 14-2 has a packer stuck in the well and there is a hole in the casing. I would also like to know if the DEQ sampled for chemicals that EnCana used in drilling, lost circulation and frocking materials.

It is pretty bad when you live in the country and you can't have a garden. We have to haul water for our chickens, horses, cows and sheep. The longer you let these wells keep polluting our water source the farther it will spread. The state should be looking out for the people of this state not the oil and gas. I have a lot of records showing all of the short cuts EnCana has done out here. The state should be holding EnCana accountable for all of these short cuts.

We moved to the country to be able to raise a garden, livestock and have clean air. But now we have been told not to grow underground vegetables and we haul water to our animals because we have lost them from drinking our water. We now have brown water stains in our toilet bowls and sinks. We have to rinse all of our dishes with boiled bottled water and dry them off. When you take a shower the smell will clean your sinus we have to have a fan on.

If there is not a problem out here why did the Governor after coming out here and looking around and smelling our water did he allocate 750 thousand dollars of taxes payers money for cisterns. Then EnCana gave the state 1.5 'million dollars and 400 thousand for water for the cisterns. When that money runs out

people will be stuck with a large water bill every month for something they did not do. This is just a cover up for EnCana.

Why let Oil and Gas destroy Wyoming's water. What are we leaving for our children and grandchildren?

Sincerely

Louis A. Meeks Sr.

212 W. Powerline Rd.

Pavillion, WY, 82523

Marvin and Evelyn Griffin

Your reports identify serious contamination problems caused by extensive oil and gas drilling. Wyoming must step up and require industry to remediate the pollution and pay for a longterm water supply for Pavillion area landowners. We are Pavillion area landowners.

Marvin and Evelyn Griffin

Your reports identify serious contamination problems caused by a lot of oil and gas drilling. Please require industry to remediate the pollution and pay for a long term water supply to us, Pavillion area landowners. We still must have water brought in due to the contamination.

Michaela Realsies

Please help the landowners living in and near the Pavillion oil and gas field by filing comments on Wyoming's final water pollution study.
Tell the Wyoming Department of Environmental Quality (DEQ):

Three reports from the state of Wyoming and federal agencies indicate and point to contamination caused by a large industrial oil and gas field permitted by the State of Wyoming. These studies identify problems with:

Inadequate casing of oil and gas wells that led to contamination;

Unlined production pits that held oil and gas waste that contaminated soil and groundwater and;

Extensive migration and release of gas and fluids from oil and gas drilling and production that polluted the freshwater aquifer.

Wyoming DEQ's reports identify serious pollution problems caused by extensive oil and gas drilling. Wyoming must step up and require industry to remediate the pollution and pay for a longterm water supply for Pavillion area landowners.

Nancy McCoy

My name is Nancy McCoy from Clark, Wyoming where we have also had our fair share of water contamination due to the oil and gas industry so I can completely understand and sympathize with what Pavillion is dealing with and how frustrating it is when the state of Wyoming drags this horrible issue out for years and does not use their authority to fix the problem.
All three studies indicate and point to contamination caused by a large industrial oil and gas field permitted by the State of Wyoming. These studies identify problems with:

• Inadequate casing of oil and gas wells that led to contamination;

• Unlined production pits that held oil and gas waste that contaminated soil and groundwater and;

• Extensive migration and release of gas and fluids from oil and gas drilling and production that polluted the freshwater aquifer.

The time has come for Wyoming to address the problem. Wyoming reports identify serious contamination problems caused by extensive oil and gas drilling and Wyoming must step up to the plate and require industry to remediate the pollution and pay for a longterm water supply for Pavillion area landowners.

Thank you in advance for requiring the industry that had done this extensive damage to take responsibility and make it right by the citizens of Pavillion.

Sincerely, Nancy McCoy

Norman Lutter

I am not personally involved in the Pavilion issue, but I am concerned that these people are being pushed off by our elected Rep's and Senators. It appears that the elected officials stray from what is proper and truthful and only wish to fulfill their agenda rather than representing the folks who vote them into office.

In regards to the water quality, the stupidity of the elected officials in this state is beyond comprehension. I have sent emails to many elected officials (state and national) suggesting that without water we are in trouble. Their response is that I do not understand the problem!! All the money from oil and gas will not give us water to drink once it has been contaminated. It appears that the elected folks will just move to another part of the US so they can have clean water to drink and rack in the money from their investments in WY G&O rights. The Wyoming Oil and Gas Commission is Self centered and needs to be replaced with people that have a true understanding of the purpose of life. I can not believe the stupid stuff they allow regarding self insuring reclamation etc. Unfortunately it appears the fox in is the hen house and the hell with the individuals concerns as long as their paycheck is greased by the Oil and Gas industry. God help you folks.

Norman Lutter

It seems that the water contamination in the Pavillion area was caused by oil and gas drilling and the O&G companies should be held responsible to supply these folks with good water. It seems the O&G companies have way too much influence on our states elected officers and agencies. The problem was created by the O&G companies so make them fix the problem.

Peter Beatty

Was a day late and a dollar short. Needs to be done by an outside independent agency!
When Wyoming does anything its always in favor of biziness not the people!

Powder River Basin Resource Council

Please see the uploaded files for comment on the Pavillion report.

Powder River Basin Resource Council * Pavillion Area Concerned Citizens * Western Organization of Resource Councils * Earthworks * Natural Resources Defense Council

March 18, 2016

Mr. Kevin Frederick
Wyoming DEQ
Attn: Water Quality Division, Pavillion Study
200 West 17th Street
Cheyenne, WY 82002

RE: Comments on Pavillion Water Well Report and Palatability Study AME, Inc. December 14, 2015

Dear Mr. Frederick:

The Powder River Basin Resource Council and Pavillion Area Concerned Citizens submit the following and attached comments regarding the above referenced report on behalf of our members who live and work in the Pavillion area. These Wyoming citizens have had their lives turned upside down by the intensive oil and gas development that has taken place near their homes over the years. They have suffered serious impacts to their health, their water, their real property and their way of life. The time has come for Wyoming to address the multitude of problems identified in this and other reports. Our comments are also endorsed by the additional groups signing onto these comments and standing in solidarity with our comments and requests.

The attached technical comments are from Mike Wireman, a hydro-geologist who reviewed the report on behalf of the Powder River Basin Resource Council. We are in agreement with Mr. Wireman's comments regarding the report and we concur with his overall assessment, which states:

> ***"It is important to recognize that the Pavillion Gas Field is a large industrial operation which utilizes a variety of industrial chemicals which can infiltrate into the sub-surface and contaminate shallow groundwater. Production of gas has clearly resulted in enhanced migration of thermogenic gas which has contaminated shallow groundwater in the upper part of the Wind River Formation and contaminated a number of domestic/stock wells. Given the extent of the contamination I suggest that the Pavillion Gas Field be considered a major groundwater contamination site that should be regulated and remediated."***

We support Wireman's review of the Pavillion report and his recommendations. We are especially concerned about the following issues he highlights which are identified in the DEQ's Pavillion report:

- A lack of casing identified in several gas wells and leakage from gas wells indicating pathways for extensive gas migration to the shallow aquifer. Why didn't WOGCC require production casing to be cemented to the surface? Has this failing been fixed?
- The down spacing of gas wells in the Pavillion area from one well every 640 acres to one well every 40 acres which led to and an increase in production and resulted in a huge increase in pathways for migration of gas and other pollutants. Will this practice be altered?
- Why did Wyoming fail to limit extensive oil and gas drilling so close to domestic and stock wells and within a freshwater aquifer? Will this practice be changed?
- The detection of petroleum constituents, organic and volatile organic compounds and dissolved methane in domestic water wells. Will WDEQ do more to determine the source of these pollutants?
- Why were only 14 water supply wells sampled out of nearly 100 water wells in the area? Will WDEQ sample more of them?
- Dissolved methane leading to an increase of iron bacteria and sulfate reducing bacteria that lead to foul water.
- The failure to assess and remediate 55 unlined production pits in the Pavillion Gas Field, many of which are near domestic water wells. These pits remain a potentially significant source of groundwater contamination. Does WDEQ intend to remediate all these pits?

Despite these clear findings the report for DEQ erroneously concludes that existing data are insufficient to demonstrate that the presence of methane or the changes in water quality are associated with gas development. Hydro-geologist Mike Wireman counters that statement and states:

> ***"In my opinion the data, while limited spatially and temporally, clearly indicate hydrocarbon contamination of shallow groundwater, which if considered along with the increased gas well spacing density and the obviously common wellbore integrity pathways, is convincing evidence that the development of gas from the Pavillion field has increased the migration of thermogenic gas upward into shallow water bearing zones of the Wind River Formation and resulted in contamination of numerous water supply wells."***

In addition to Mr. Wireman's attached comments we would like to emphasize his following detailed comments and observations regarding the study:

THE PATH OF THE PREHISTORIC WIND RIVER UNDERLYING THE PAVILLION FIELD AND INTERCONNECTION OF WATER BEARING SANDSTONE DEPOSITS CREATE THE POTENTIAL FOR MIGRATION OF CONTAMINANTS ASSOCIATED WITH HYDRAULIC FRACTURING.

On Page 19 of the report it is correctly stated that "*sandstone and conglomerate bodies vary in size and geometry, and have a range of hydraulic interconnection…Fractures may enhance permeability of sandstones in areas of structural deformation (USGS).*" It is also correctly stated that, "*Differences in water levels as much as 140 feet have been measured in adjacent water-supply wells completed at different depths.*" However, in this paragraph, it is also stated that *"Individual lenticular sand bodies may be considered as separate aquifers on a local scale."* In areas of structural deformation, as is the case for the Pavillion field, fracture systems would be expected to result in hydraulic interconnection, therefore, the term "*separate aquifers"* is not applicable in the Pavillion Field. Equally important, on page 18 it is mentioned, but not discussed, that, "*Paleocurrent studies have mapped the course of the Eocene paleo-wind river flowing to the east-southeast through the Pavillion area."* The presence of paleo-channels in the Pavillion field is relevant to interconnection of water-bearing sand stone deposits and potential offsite migration of contaminants associated with hydraulic fracturing.

The central part of the Wind River Basin where the Pavillion Field lies is characterized by stream-valley fill and broad flood plains. The presence of large quantities of overbank mudstones and near linear channel-sandstone ridges suggest that meandering streams of low sinuosity were dominant during deposition of the Wind River Formation (Seeland 1978). The Eocene (34 – 55 Mya) Wind River flowed directly through an area that is now the Pavillion Field in the vicinity of production well Tribal Unit 14X-11 (Seeland 1978). Inspection of the figures generated by Seeland (1978) indicates that major tributaries of the Eocene Wind River ran directly north and south of Pavillion Field. Maximum intervals of continuous sandstone deposits are greatest near the course of the Eocene Wind River (Seeland 1978).

Gores and Associates (2011) used geophysical logs from production wells and lithologic information from domestic wells to determine whether white coarse sand deposits targeted by local water well drillers were correlated with the flow path(s) of the Eocene Wind River and associated channel or tributaries. Gores and Associates (2011) state that: it appears that there is a reasonable correlation between the coarse white sand lens in private domestic wells and oil and gas wells; the gentle dip to the southeast parallels the mapped paleo-Wind River channel; and static water levels in domestic wells appear fairly uniform with a slight dip to the southeast which generally parallels the dip of the sand bodies in the formation. Based on these observations, Gore and Associates recommended proposed municipal well installation at two locations, both approximately 1000 feet below ground surface (bgs).

THE NEARLY 50 UNLINED PITS IN THE PAVILLION GAS FIELD NEAR DOMESTIC WATER WELLS ARE A SIGNIFICANT SOURCE OF GROUNDWATER CONTAMINATION.

There may be as many as 48 domestic wells within 2,000 feet of unlined pits. Why were only 14 domestic wells near pits sampled? The chemical 2-Butoxyethanol, which was widely used for hydraulic fracturing in the Pavillion field was detected at 3,300 ug/L in a domestic well. The depth of this domestic well is only 30 feet below ground surface and is located within 440 feet of an unlined pit used for disposal of production fluids. Other compounds, including BTEX, associated with production well stimulation (e.g. isopropanol) were detected at lower concentrations in other domestic wells. Sample results at domestic wells indicate the need for further investigation, which must include the installation of monitoring wells. Since flood irrigation is common in the vicinity of unlined pit areas, the lateral extent of groundwater

contamination is potentially greater in the Wind River Formation than in Quaternary deposits due to the potential for uncontaminated water to overlay portions of a contaminant plume.

WYOMING HAS PERMITTED OIL AND GAS DEVELOPMENT IN DRINKING WATER AQUIFERS IN THE PAVILLION FIELD

A number of confusing and erroneous comments and arguments discussed in the report challenge the designation of the Wind River and Fort Union Formations as Underground Sources of Drinking Water (USDWs). The first argument is based on the State of Wyoming's interpretation of delegation of the federal Underground Injection Control (UIC) program to the State of Wyoming on July 15, 1983. It is stated on page 25 of the report that by delegating administration of the UIC program to the State of Wyoming, the EPA "*accepted Wyoming's regulations describing its groundwater classification system."* Also on page 25, it is stated that, *"Wyoming's classification system also includes a class of groundwater (Class 6) that recognizes some groundwater is 'Unusable' or 'Unsuitable' for any purpose due to the presence of contaminants or high (>5,000mg/L) TDS, or because it is located (including depth below the surface) such that any use is technologically or economically impractical."* The federal UIC program requires all groundwater less than 10,000 mg/L TDS to be protected. Wyoming's interpretation of the regulations violate the federal requirement and fail to protect groundwater resources by allowing contamination in aquifers with a level of 5,000 mg/L TDS rather than the more stringent10,000 mg/L TDS.

In addition, the WDEQ Chapter 8 Water Quality Standards for Wyoming Groundwater list no concentration of TDS that is actually specified for "*excessive concentration of total dissolved solids"* for Class 6 groundwater categorized as "*unusable or unsuitable for use."* Yet the report states there is a 5,000 mg/L threshold for Class 6 groundwater. A limit of 5,000 mg/L is specified for livestock use for Class 3 groundwater in Wyoming regulations -- not Class 6 groundwater. Thus, in contrast to a statement in the report, there does not appear to be an explicit TDS threshold for Class 6 groundwater in Wyoming regulations.

The report further confuses the issue by making the argument that deeper groundwater is unusable or unsuitable based on TDS levels of produced water from oil and gas production. On page 26, the report says that "*In 47 produced water samples, taken from permeable zones deeper than the well and spring sample, TDS concentrations ranged from 1060 to 38,800 mg/L; and the 75th percentile concentrations was 4,860 mg/L." (WSGS 2012).*

It is important to note that produced water samples were collected in 2007, subsequent to hydraulic fracturing in these production wells which was not discussed in the Wyoming DEQ report. Produced water samples are not representative of baseline Wind River and Fort Union Formations. These produced water samples have been enriched in potassium and chloride due to extensive use of KCl solutions used during hydraulic fracturing.

In investigating locations for one or two municipal wells to replace domestic wells in the Pavillion Field, Gore and Associates (2011) postulated that lower TDS levels in the Wind River Formation could be associated with lithology – specifically white coarse sand deposits. Domestic well drillers often target these deposits (Gore and Associates 2011). Morris et al. (1959) referred to white coarse-grained sandstone deposits as *"water sands."* White coarse sand deposits are described in the driller's logs and inferred from geophysical logs with porosity approaching 30% (Gore and Associates 2011). According to several reports and data sets, there are no apparent trends in TDS with depth. These include data sets from the WRIR USGS report

(Daddow 1992), Fremont County USGS report (Plafcan et al. 1995), and domestic wells in and around the Pavillion Field. In fact, the Plafcan et al. report in 1995 documented a TDS concentration of 1190 mg/L at 2200 ft bgs in the Wind River Formation.

CONCLUSION

This report, combined with the two previous reports regarding the Pavillion contamination, clearly identifies a serious failure by the State of Wyoming to ensure protection of the drinking water aquifer and water supply wells in the Pavillion area. Instead, the state permitted a massive expansion of gas drilling in the Pavillion area while failing to ensure the gas wells were adequately cased to keep pollutants and methane gas from escaping into the aquifer. Furthermore, the state failed to ensure production pits were lined so that drilling fluids would not contaminate the shallow aquifer. Wyoming's lax permitting and weak regulatory environment caused the contamination of the Wind River aquifer and of Wyoming citizens' water wells in the Pavillion area. The state of Wyoming should accept responsibility and provide a long-term supply of clean water for Pavillion area residents and remediate the contamination without delay.

Respectfully submitted,

Robert LeResche, Chair
Powder River Basin Resource Council
934 North Main
Sheridan, WY 82801

John Fenton
Pavillion Area Concerned Citizens

Nancy Hartenhoff-Crooks, Chair
Western Organization of Resource Councils

Bruce Baizel
Earthworks' Energy Program Director

Amy Mall, Senior Policy Analyst
Natural Resources Defense Council

enc. Wireman Attachment

March 8, 2016

MEMORANDUM

To: Jill Morrison
Powder River Basin Resources Council
Sheridan, WY

From: Mike Wireman
Granite Ridge Groundwater
Boulder, CO

Re: Review comments – Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study; AME, Inc.; December 14, 2015

I have completed a review of the above referenced report, appendices and selected references. Overall the report provides a reasonable assessment of the hydrocarbon contamination of shallow groundwater within the Wind River Formation in the vicinity of the Pavillion Gas Field located east of the Town of Pavillion in Fremont County, WY. It is important to recognize that the Pavillion Gas Field is a large industrial operation which utilizes a variety of industrial chemicals which can infiltrate into the sub-surface and contaminate shallow groundwater. Production of gas has clearly resulted in enhanced migration of thermogenic gas which has contaminated shallow groundwater in the upper part of the Wind River Formation and contaminated a number of domestic/stock wells. Given the extent of the contamination I suggest that the Pavillion Gas Field be considered a major groundwater contamination site that should be regulated and remediated.

The report includes very specific recommendations (Chapter 6)for continuing investigation that are aimed at providing data that will more fully explain the occurrence and bio-geochemistry of the contaminants related to bio-degradation of hydrocarbon compounds. These recommendations should absolutely be adopted and completed.

Important findings

1. Significant commercial gas deposits occur in the Wind River Fm (and the underlying Ft. Union Fm.) at depths greater than 1500 feet. Non-commercial gas deposits occur at shallower depths – 500 fbgs. The report concludes that thermogenic gas is migrating upward into shallow zones in the Wind River Fm (less than 500 fbgs) that are being used by private domestic / stock wells. Upward migrating gas has been a primary cause of contaminated domestic / stock wells.

2. Migration is occurring along two types of pathways:

a. (1) Natural geologic pathways - the Wind River Fm has significant permeability in places and there is no regional low permeability lithologic unit to constrain the upward migration the gas. The most productive part of the Wind River Formation (for water well yields) is from 800-1800 ft. However most stock / domestic wells are less than 500 feet deep.
b. (2) Borehole related pathways – At least 17 of the 52 gas wells, located within 1420 feet of one of the 14 water supply wells sampled for this study, have an open annulus between the bottom of the surface casing and the top of the production casing cement. An additional 9 gas wells have an open annulus between the production casing and the surface casing. These vertical zones are often connect intermediate zones (with gas deposits) and shallow zones used for water supply. Gas can also migrate through channels in the production or surface casing cement. Gas can migrate laterally away from the open annulus into shallow water bearing zones within the Wind River Fm. At least 11 of the 52 gas wells had sustained Bradenhead pressure, indicating leakage. An additional 9 gas wells have an open annulus between the production casing and the surface casing.

3. Increase oil production activity, including the change in well spacing from one well per 640 acres to one well per 40 acres in 2000 has resulted in a huge increase in potential subsurface pathways for upward gas migration. This, more dense spacing, also increases the chance of encountering shallow non-commercial gas deposits.

4. A number of petroleum constituents, organic compounds, semi-volatile organic compounds and dissolved methane have been detected in groundwater from the 14 wells sampled for this study. While generally at low concentrations, these compounds are found in numerous products used in oil and gas development. Sources of these constituents include surface related production activities, well drilling and construction fluids and sub-surface gas deposits.

5. Bio-degradation of dissolved organic compounds, including natural thermogenic gas, by bacteria is an important bio-geochemical process in groundwater. Iron bacteria and sulfate-reducing bacteria growth is enhanced if there is a significant source of dissolved gas. At least one sample from 13 of the 14 wells included in the study had measurable, high counts of iron bacteria, sulfate-reducing bacteria, heterotrophic bacteria, and / or slime forming bacteria.) High counts of bacteria in well water produces constituents that foul water making it less palatable and may plug the well screen, reducing well yield.

6. There are approximately 55 unlined pits in Pavillion Gas Field and 25 are within 1420 ft of one of the 14 sampled wells. Only a few of these pits have been adequately characterized and remediated. These pits remain a potentially significant source of ground water contaminants.

<u>Major comments</u>

1. The WOGCC, WDEQ and industry have known about shallow gas deposits in the Wind River Formation in this part of the Wind River Basin for decades (since 1960s). Why have no institutional controls been put in place by WDEQ / WSEO to prevent / limit drilling and completion of stock /domestic wells in locations and at depths that might encounter shallow gas deposits? Why did WOGCC not require production casing to be cemented to surface?

2. Too few (14) water supply wells were sampled in the study. There are 97 water supply wells within the cistern area. The criteria used to select wells were too limiting and data from this limited set of wells cannot be used to: (a) assess how widespread the hydrocarbon contamination is within the shallow part of the Wind River Formation, (b) evaluate fate and transport of hydrocarbon compounds (petroleum products) and (c) design an adequate groundwater monitoring network to monitor groundwater within and around the Pavillion Gas Field.

3. I disagree with the conclusions (Sections 5.1.4 and 5.1.5) that: (a) "existing data is insufficient to demonstrate that the presence of methane or changes in water quality in domestic water supply wells is associated with gas development" and (b) "seepage of gas or other fluids from production zones along abandoned gas wells is unlikely". In my opinion the data, while limited spatially and temporally, clearly indicates hydrocarbon contamination of shallow groundwater, which if considered along with the increased gas well spacing density and the obviously common wellbore integrity pathways, is convincing evidence that the development of gas from the Pavillion field has increased the migration of thermogenic gas upward into shallow water bearing zones of the Wind River Fm. and resulted in contamination of numerous water supply wells.

4. Section 2.5.4 – this discussion is very confusing. How does WDEQ / WOGCC determine boundaries of water bearing zones within the Wind River Fm. that meet the definition of a USDW or WY Class 6 groundwater? Are these designations done only well by well basis? Or are boundaries established? If so are these designations available to the public? In this section it is also stated that WY Class 1,2,3 groundwater (TDS < 5000) is equivalent to the SDWA definition of a USDW. This is not true. the SDWA definition includes ground waters with TDS values < 10,000 mg/l.

5. The depth to water data (groundwater elevation) is not very useful. Depth to water data was collected for only five wells and only pumping water levels were obtained. These data cannot be used to evaluate the configuration of the water table, direction of groundwater flow, water level trends.

6. Section 5.3.3 - The distinction between "naturally occurring methane" and "gas seepage along wells bores" is misleading. The methane is all natural, in that it occurs in sub-surface deposits. The distinction is related to the migration pathways – which include "natural" geologic pathways and wellbore pathways.

7. The Wyoming Class I domestic standard for gross alpha is incompatible with the EPA MCL because the Wyoming standard is for "gross alpha particle radioactivity" – which excludes uranium and radon. The EPA gross alpha MCL standard applies to all gross alpha activity.
8. The report should include a more detailed discussion on fate and transport of gas and dissolved methane through the subsurface.

9. The selection criteria requiring that the water supply well was installed deeper than the surface casing of gas wells located within 1000 ft assumes gas will not migrate upwards past bottom of surface casing. What is the basis for this assumption? Why was 60F not sampled for water quality?

<u>Suggested edits and recommendations</u>

1. The groundwater contamination at the Pavillion Gas Field points out the clear need for pre-development groundwater monitoring to establish baseline water quality conditions. It also demonstrates the need for ongoing monitoring during operation and post-closure. WDEQ and WOGCC should strongly consider requiring groundwater monitoring where oil and gas development will occur.

2. Dissolved uranium concentrations exceed 15ug/l in 24 of the samples collected for this study. Activity values for gross alpha and radon are also high in numerous samples. This indicates significant uranium content in sediments that comprise the Wind River Fm. This should be discussed in more detail in the report with an assessment of the risk to domestic /stock water supplies.

1. Section 4.2.6.1 – It is stated here that analysis of DRO with SGCU results in data that are "more representative of petroleum products" because polar compounds are removed. It should be noted that polar organic compounds derived from bio-degradation of petroleum products are also indicative of petroleum hydrocarbons.

2. Soil gas surveys should be conducted on a regular schedule in areas around gas wells with high Bradenhead pressures to look for upward migrating gas. In addition a groundwater monitoring well should be installed downgradient of one of these gas wells.

3. Figure 5 is a poor geologic map. This map should have a better depiction of surficial deposits.

4. The table included in Section 2.5.3 should include the number of samples for each analyte.

5. On Table 9, in Column 5 – there should be information as to whether the septic tank is up-gradient or down gradient of the water supply well

6. The report should provide any existing data for hydrocarbon constituents (petroleum products) in Five Mile Creek water –DRO, GRO, methane, etc. If none exist, Five Mile Creek should be sampled for these constituents.

Mike Wireman
Granite Ridge Groundwater
Boulder, CO

COMMENTS ON THE PAVILLION, WYOMING AREA DOMESTIC WATER WELLS DRAFT FINAL REPORT AND PALATABILITY STUDY

AME and DEQ (December 14, 2015)

By: Sue Spencer, P.G.

General Comments

This report represents yet another thinly veiled attempt by the State of Wyoming and industry consultants to attribute the groundwater contamination in the Pavillion area to problems with private water supply wells rather than on improperly constructed gas wells and unlined surface disposal pits. The information and conclusions provided in the AME/DEQ report shed no new light on the underlying cause of groundwater contamination that local residents have been complaining about for over 20 years. The authors of the report admit that "palatability" issues are vague and undefinable. Therefore, the only possible outcome of continuing to address the "palatability" issues by sampling domestic wells that are unfit to be used as monitoring wells is more of the same: vague results that lead to ambiguous conclusions.

Despite years of water quality sampling and millions of dollars spent by EPA, DEQ, and their consultants, little has been done to actually characterize the nature and extent of contamination at the Pavillion site. Because of the extremely complex nature of the geology and hydrogeology of the Wind River Formation that underlies the Pavillion area, without a serious attempt to characterize the aquifer properties and groundwater quality in specific water-bearing zones of the aquifer, the questions regarding the source and extent of contamination can never be adequately addressed. A series of multi-level monitoring wells constructed for the specific purpose of assessing aquifer properties and water quality is required to accomplish this goal. In fact, the Phase VI study that was proposed by EPA and DEQ in 2011 and 2012 included plans for installation of such monitoring wells. However, for reasons unknown to the general public, the study was never implemented. Without data from properly targeted and installed monitoring wells it is impossible to determine the source and fate of contamination in the water supply wells within the Pavillion study area.

That the AME/DEQ study was paid for and controlled by Encana is evidenced by the fact that the two EPA monitoring wells that were installed in 2010 are only nominally mentioned and summarily dismissed in the report. The dramatic water quality results from three sampling rounds from the EPA monitoring wells MW01 and MW02 is not even acknowledged in the report. Water quality data from these wells indicate the presence of high concentrations of organic compounds, particularly BTEX, DRO, GRO, and dissolved gases in the Wind River Aquifer at depths of roughly 800 to 1000 feet within the study area. The fact that significant contamination was detected in EPA MW02 within the drinking water zone of the aquifer in question and within 1,100 feet of PGDW20 should have triggered a full-scale investigation to characterize the source and extent of contamination as well as the potential for communication between the shallower and deeper water bearing zones in the vicinity of the wells. At the very least, the EPA monitoring well data should have been used as a basis for developing a conceptual site model instead of being swept under the rug and ignored by this investigation. While a number of questions have been raised by industry consultants regarding problems with how the EPA monitoring wells were constructed and developed, none of the problems cited were serious enough to warrant the total dismissal of the existence of the wells and data obtained from them for three sampling rounds. (It should be noted that all of the reviewers cited in Section 5.9.1 that voiced concerns regarding construction of the EPA monitoring wells were industry-hired consultants). If the investigators were truly interested in addressing the Pavillion water quality issues, they would install new monitoring wells at the same locations as the old wells in order to verify the results.

The water quality data from the two EPA monitoring wells was disregarded based on the reasoning that samples developed from the wells would somehow not be representative of the aquifer. If the same reasoning were applied to data from the domestic supply wells that were actually sampled in 2014 for the

AME/DEQ study (and for at least five previous sampling rounds), the water quality results from many of those wells would also have to be dismissed. As noted in the report (Section 4.1.3 and 5.9.3), issues with obtaining representative samples from private water wells include:

- Well construction details are often not well documented or unknown.
- The geology of the formations encountered during drilling and completion are unknown.
- The wells are completed in multiple zones making it impossible to isolate and therefore evaluate the aquifer properties and water quality in specific zones.
- Some of the sampling points are located: (1) a long distance from the well; and (2) downstream of a pressure tank, a situation that would most likely not be representative of VOC concentrations in the aquifer due to the probability that most of the VOCs would volatilize prior to reaching the sampling point.
- In the case of LD02, no water was purged from the well prior to sampling because the well is not equipped with a pump. Although this situation is similar to EPA MW02, a low yield well that does not produce a sufficient volume of water to allow for adequate purging, MW02 was not even considered for sampling, whereas LD02 was sampled twice. Considering the many thousands of dollars spent on this investigation, it seems that the purchase of a portable sampling pump would have been worth the price if it meant obtaining a more representative water sample from LD02.

Because all of the issues cited above contribute to the inability of collecting samples that are representative of the aquifer, it is not appropriate to use samples collected from private water supply wells to make final decisions regarding the nature and extent of contamination in the Pavillion study area. It is time for DEQ to get serious about this investigation by installing purpose-designed wells that can be used to obtain aquifer property and water quality data to aid in developing a conceptual model for this site. Under normal circumstances, this approach would be an obvious prerequisite for a properly designed and implemented groundwater contamination investigation. The fact that it has been seven years since EPA began sampling water wells at the Pavillion site and over twenty years since the first complaints about water quality issues from residents were received by DEQ and a properly designed investigation has yet to be implemented should be an embarrassment to the State of Wyoming, not to mention a source of great distress to those residents who no longer have a potable water supply. After all, the stated mission of DEQ is *"to protect, conserve, and enhance the quality of Wyoming's environment for the benefit of current and future generations".*

As pointed out in the AME/DEQ report, the Pavillion area is unique in that the formation that is the sole source of drinking water for the communities of Pavillion, Riverton, and the surrounding rural residences is also the source of natural gas that supplies the Pavillion field. Whereas most natural gas fields lie several thousand feet below the ground surface and are normally overlain by an impermeable geologic formation that protects the shallow groundwater resources from contamination of gas and fluids, there is no such barrier in the Pavillion area. Produced gas zones are commonly as shallow as 1,500 feet below the ground surface. Because of the unique sensitivity of the groundwater resources in the Pavillion area and the higher potential for contamination resulting from improperly constructed gas wells and leaking surface impoundments, extra caution should have been exercised by regulators and industry to protect the shallow groundwater resources in this area. However, when oil and gas development began in earnest in the mid-1970s and 1980s continuing up until 2006, the importance of the Wind River Aquifer to local municipalities and landowners was apparently ignored by the Wyoming regulators and gas developers. An August 5, 1994 MOA between DEQ, WOGCC, and the SEO clearly states that "The intent of the agreement is to prohibit activities which would result in the degradation of the surface or groundwater resources of the state."… "Because protection of the waters of the state is a priority, no construction or action which is not protective of surface and groundwaters of the state shall be authorized by either the DEQ, WOGCC, or the SEO". Instead, industry was allowed to improperly complete wells without adequate cement, specifically below the shallow water bearing zones and above the gas production intervals, creating a potential for

communication of groundwater and/or gas between shallow water-bearing zones and intermediate zones. As stated in Appendix G of the AME/DEQ report "leaving an open annular space between the top of the production casing cement and the bottom (shoe) of the surface casing is not considered good practice".

The AME/DEQ report makes the claim that "existing WOGCC rules were followed for all gas wells at the time of their construction" (Page 2). However, based on a review of the application for permit to drill (APD) for selected gas wells near PGDW20, the condition that the production casing be cemented to the surface casing shoe or the ground surface was part of every approved permit that was reviewed. As illustrated in Figures 12A – 12K of the report, there are many instances where the cement was not brought up to the surface casing, leaving an open annulus in the gas wells that creates a potential for vertical flow of gas and fluids. In these cases the existing WOGCC rules were clearly not followed.

The analysis of shallow gas sources in the Pavillion field conducted by Dusseault (2015) and presented in Appendix G of the AME/DEQ report presents a very strong case for the role that improperly completed gas wells may have in causing thermogenic gas and fluids from intermediate zones to influence the water supply zones in shallow wells. However, even though the report clearly states that "seepage along the wellbore is the most probable pathway for gas or other fluids to reach shallow depths or even the surface in the Pavillion Gas Field" (Section 5.1.3) and that "seepage along the wellbore has the potential to cause communication of (gas and/or water) between shallow permeable zones and intermediate zones" (Section 5.1.4), the overall conclusions of the report seem to minimize this pathway in favor of naturally occurring methane that the investigators claim has always been present in the shallow aquifer zones.

As summarized in the report, the most likely conditions for vertical flow of gas and fluids to occur between intermediate and shallow zones via seepage along the wellbore include: 1) a gas well with an annular space without cement adjacent to production casing, 2) a relatively shallow surface casing in the same gas well, 3) an intermediate pressurized zone, and 4) a permeable groundwater zone that intersects the gas well below the surface casing shoe. Even though all of these conditions are present in most of the areas of interest studied during this investigation, the possibility that this pathway may have had a profound impact on the shallow aquifer zones is minimized by the conclusions in the report. Just because it is "not known with certainty if this has occurred and to what extent this has occurred based on existing information" (Section 5.3.5) is no reason to dismiss the possibility that this mechanism was responsible for some of the groundwater contamination that has occurred in the Pavilion field. Instead, the investigators seem to favor the easiest, yet least substantiated mechanism that "it is naturally occurring".

Despite the claims made throughout the AME/DEQ report that "shallow gas (just below 500 feet bgs) is widespread throughout the Study Area" before gas development began in the 1960s, only one example of pre-existing shallow gas is cited in the report (Section 2.6), the Camp 9 well in T4N,R3E Section 32 that was reported by the U.S. Bureau of Reclamation (1951). Not only is this the only example cited to support the claims of the widespread presence of gas in drinking water wells, the Camp 9 well was actually located a few miles north of the Pavillion gas field. Although the Meeks well blowout (near PGDW 45 and PGDW05) was cited as another example of the pre-existing presence of gas in the shallow aquifer zone at a depth of 540 feet, the report did not address the fact that there is ample evidence to suggest that the blowout was actually caused by an improperly constructed nearby gas well (24-02). Furthermore, if the Pavillion gas producers were actually aware of the presence of natural gas in shallow and intermediate zones why did they not take greater care to make sure that the production casing was properly cemented to the casing shoe or the ground surface to prevent upward migration of gas into the water zones?

The analysis of the potential for fracking fluids to impact shallow water quality only considers the potential for the hydraulic fractures themselves to propagate to the shallow zones due to the relatively low volumes of fluids and low pressures used in the Pavillion field. However, the analysis doesn't take into account the widespread presence of natural fractures that exist in the area that could potentially provide a preferential pathway for fracking fluids to migrate from depth. The analysis also did not take into account the large

volumes of acid used during fracking of the early gas wells at pressures that exceeded the bursting strength of the casing in some cases (WOGCC Well Integrity Report, 2014). In addition, without a closer inspection of hydraulic fracking practices for specific gas wells the statement that "no evidence exists that fracking fluids have ever risen from depth to interact with the groundwater protection zone" (Appendix G, Page 1) is premature. In fact, a close inspection of well records for TP 12-12, which is located approximately 600 feet west of EPA MW02, indicates that despite a CBL that indicated little to no bonding from the cement top of 950 feet to approximately 2,070 feet, the top perforation at 1,964 feet was fracked and the well was completed and put to sales. Three days later the well was taken off sales and repeated attempts to conduct a cement squeeze job at 850 feet were finally successful after several failed pressure tests. EPA monitoring well MW02 is completed just below the base of the coarse white sandstone at a depth of approximately 980 feet. It is likely that fracking fluids migrated up the uncemented annulus and into the coarse white sandstone and other shallow water bearing zones during and after the fracking process and before remediation. Based on this one example, it is likely that there are other instances where improperly completed gas wells may have introduced fracking fluids into the shallow aquifer zones.

The possible contaminant pathway resulting from infiltration of drilling and production fluids into the Wind River Aquifer from unlined surface pits is an important potential contaminant pathway that requires a great deal more scrutiny than offered by this study. Many of the pits in the Pavillion field were excavated directly into the Wind River Formation channel deposits. These channel deposits could effectively act as preferential flow paths for oil-based drilling fluids and production fluids, including high concentrations of salts that were discharged for many years into the unlined pits. Based on the degradation of water quality in the shallow aquifer in the Pavillion area, the addition of salt contaminated wastewater and production fluids may be the most harmful contaminant that was introduced into the shallow aquifer system. However, during excavation of contaminated soil for all of the pit cleanup projects conducted by Encana, no consideration was made for identification and removal of salt-contaminated soil.

A groundwater study conducted by Osiensky and others (1984) modeled the flow of contaminants in complex hydrogeologic settings such as the Wind River Aquifer. The results of mathematical modeling demonstrated that contaminants may migrate preferentially along highly permeable meandering sandstone channels, circumventing downgradient monitoring wells. The modeling was corroborated by a case study involving a uranium mill waste disposal impoundment in the central Wind River Basin. In the study, the highest contaminant concentrations of sulfate were detected over 3,500 feet downgradient of the monitoring wells located closest to the contaminant source which showed low levels of contamination.

A close inspection of the VRP pit studies for the 42X-11 and 22-12 sites indicate that these studies have inadequately addressed the complex hydrogeology in the area. As a result, the horizontal and vertical extent of soil and groundwater contamination has not been adequately identified. Failure on the part of the VRP investigators to understand the depositional environment that formed these deposits may result in ineffective monitoring well networks because the significance of buried stream channels may be overlooked. For this reason, it is essential that an expanded investigation to install monitoring wells at multiple depths be implemented at the VRP sites. In addition, ground penetrating radar or some other near-surface geophysical method should be implemented to identify preferential flow paths in the vicinity of the pits to evaluate whether a surficial pathway exists that might convey contaminants along a preferential flow path beyond the limits of the VRP investigation and into the underlying deeper sandstone units that supply local water wells.

In summary, the AME/DEQ investigation, which has continued to focus on the issue of "palatability" complaints by local water well users has focused a great deal of time and money in an attempt to attribute the Pavillion area water quality problems to issues with the water supply wells themselves. In fact, there is ample anecdotal evidence to suggest that most water well owners reportedly experienced a period of time where they enjoyed good water quality with no taste or odor problems. This anecdotal evidence suggests that the problems are coincidental with the onset of gas development in the area. Although the study reports

that the exceedances of water quality standards are generally for naturally occurring constituents, the elevated concentrations of these constituents nevertheless render the water not only “unpalatable” but also nonpotable. In the case of the Locker well (PGDW20), the only well with baseline data, the concentrations of “naturally occurring” constituents increased ten-fold over a period of just a few years with levels of sodium, sulfate, and TDS that far exceed the DEQ-WQD water quality standards for an aquifer that supplies water to domestic users. Although, as noted in the report, there is not widespread contamination of the aquifer by synthetic organic contaminants, it is true that low concentrations of DROs, GROs, VOCs, SVOCs, and dissolved gases as well as a wide variety of tentatively identified compounds have persisted in many of the wells over a period of several years. Just because there is not widespread contamination of synthetic organic compounds at concentrations above cleanup levels does not mean that the groundwater in the Pavillion area has not been severely impacted to the point of nonpotability. In fact, based on the data presented in Table 24A, organic analytes were detected during both 2014 sampling rounds in 14 of the 15 wells sampled for this study. However, the report conclusions dismiss the presence of these contaminants by attributing them to unsubstantiated sources including surface spills from fueling vehicles, laboratory contaminants, and “naturally occurring organic compounds and/or byproducts of bacterial growth” rather than the more likely sources of drilling and production fluids from improperly completed gas wells and unlined surface pits.

Because of the complexity of the geology and hydrogeology of the upper Wind River Formation and the fact that it serves as the sole source of drinking water for residents in the Pavillion area, this of all places warrants a well-designed investigation with purpose driven monitoring wells to evaluate the potential for communication between surficial channel deposits, shallow aquifer zones, and intermediate gas and water zones as the cause of water quality problems in the area. As acknowledged in the AME/DEQ report, these investigations won’t be simple but that doesn’t mean that these pathways should not be investigated. The report correctly states that there does not appear to be a single mechanism or pathway to explain the presence of contaminants in various water supply wells completed at varying depths. The most logical conclusion to derive from this analysis is that contamination in individual water supply wells is most likely a result of a combination of surface and subsurface sources that vary by well construction, local geology, gas well construction issues, etc. It is a highly complex area with multiple potential contaminant pathways that deserves more than arm waving and continued sampling of inadequate monitoring wells.

Specific Comments:

Information presented in Section 4.2.4.2 on page 51 with regard to well LD02 is incorrect. The text references samples collected from this well in 1979, yet the well wasn’t drilled until 1994.

Figure 12A: Well files for 22-12 indicate that the top of cement is 1,260 feet. Although a CBL has never been located for the well, this information was obtained from a 1979 prognosis report. This information should be reflected on the Figure.

Section 5.8.2, table on page 104 has a check under microorganisms for PGDW20. No microorganisms have been detected in samples from that well since EPA and DEQ began collecting samples in 2009.

References Cited:

Osiensky, J.L., G.V. Winter, and R.E. Williams, 1984. Monitoring and mathematical modeling of contaminated ground-water plumes in fluvial environments. Groundwater, Vol. 22, No. 3, May-June 1984, P. 298-306.

Tudor Marks

Studies of pollution issues in the Pavilion oil and gas field show: *Extensive migration and release of gas and toxic fluids from oil and gas operations. *Inadequate well casing contributing to spread of contamination. *Unlined production pits for oil and gas waste which contaminated soil and groundwater.
Industry must remediate the resulting pollution and pay for or provide clean, pure water for area landowners.

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MAR 18 2016

Mr. Todd Parfitt, Director
Wyoming Department of Environmental Quality
200 West 17th Street
Cheyenne, Wyoming 82002

Dear Mr. Parfitt:

I appreciate the opportunity for the U.S. Environmental Protection Agency to provide input on the Wyoming Department of Environmental Quality's Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study dated December 14, 2015.[1] Throughout Wyoming's sustained commitment to further investigation of groundwater quality concerns near Pavillion, the EPA has provided technical resources and assistance to support the state. For example, the EPA provided initial input to the state on pits and gas well integrity on August 16, 2013 and further provided comments on the state's gas well integrity and pits draft reports on September 5, 2014 and January 16, 2015 respectively. Continuing in that spirit, the EPA offers the enclosed comments on the Domestic Water Wells Draft Final Report for your consideration.

The EPA has reviewed the Draft Final Report and recognizes the extensive effort that it represents in compiling and analyzing available data on domestic water well water quality as well as collecting additional sampling data from some domestic wells. The EPA's detailed technical input is provided in the enclosed comments, which generally encompass the following issue areas: (1) The EPA suggests that the uncertainties in the analysis of health concerns associated with domestic well water quality be discussed in the Report; (2) the EPA concurs with recommendations made in previous state reports that a conceptual model of the geology/hydrogeology and potential contaminant transport pathways is critical to understanding potential source contributions and recommends this be addressed in the Report; and (3) several conclusory statements in the Report regarding fluid movement and potential sources of constituents would benefit from more robust supporting data and information and a discussion of uncertainties.

The EPA appreciates Wyoming's continued efforts to understand and address water quality concerns in the Pavillion area. I hope these comments are useful to you. If you or your staff have

[1]As the EPA has noted in previous communications providing technical input to the State of Wyoming on this matter, the EPA will continue to consult and coordinate with the Northern Arapaho and Eastern Shoshone Tribes of the Wind River Reservation, given the government-to-government relationship we have with the Tribes. EPA's transmittal of these comments to the State is intended to convey our technical considerations only and should not be construed as setting forth any position regarding the exterior boundaries of the Wind River Reservation or the exercise of State authorities in this area such as, for example, the applicability of State water quality limits or State authority with regard to gas well pits.

questions or wish to discuss these comments, please feel free to contact me at (303)312-6776 or hestmark.martin@epa.gov, or contact my Deputy, Sandy Stavnes, at (303)312-6117 or stavnes.sandra@epa.gov.

Sincerely,

Martin Hestmark
Assistant Regional Administrator
Office of Ecosystems Protection
& Remediation

Enclosure

cc: Darwin St. Clair, Jr.
Chairman, Eastern Shoshone Tribe

Dean Goggles
Chairman, Northern Arapaho Tribe

EPA provides the following detailed technical comments on the *Pavillion, Wyoming Area Domestic Water Wells Draft Final Report and Palatability Study* (Report). Each topic area is introduced with a general discussion of the issue, and in some cases is followed by bulleted points addressing more specific or detailed items related to that issue.

Domestic Well Water Quality Concerns

The Report indicates that the groundwater is generally suitable for domestic use, despite exceedances of some health-based comparison values (CV) and despite some significant uncertainties in the ability to evaluate the effects of drinking the water. The Executive Summary states that "Exceedances of drinking water standards or comparison values are generally limited to naturally occurring dissolved salts, metals, and radionuclides. Only two organic compounds…were detected at concentrations exceeding the applicable drinking water standard or comparison value." (p. 3) EPA suggests that a more comprehensive evaluation and discussion of the potential health risks and the associated uncertainties would be important additions to the Executive Summary and Section 5.5 of the Report. The Report's characterization of the exceedances of standards or comparison values as a palatability concern rather than a health concern may leave readers unclear regarding the significance of these exceedances. Further, the Report does not provide a clear discussion of the uncertainties associated with the evaluation of potential health concerns. Of the 19 organic constituents identified in domestic wells, nine do not have CVs identified in the Report. This is an information gap that EPA suggests be discussed in the Report as it discloses the limitations to reaching definitive conclusions about potential health risks from drinking the water. Given the number of detected compounds with no CV, uncertainty remains with respect to statements about health risk and suitability, and EPA suggests that any such statements be qualified accordingly.

- The Report indicates that only two organic compounds exceeded a Maximum Contaminant Level (MCL) or comparison value (p. 3). As mentioned, nearly half of the organics detected have no CV, contributing to the uncertainty involved in making a definitive statement about health risks associated with drinking the water from domestic wells. The WDEQ data in combination with previous sampling done by EPA highlights the spatial and temporal variability of detections in the domestic wells, another source of uncertainty in making definitive health risk statements. MCLs were developed for use in evaluating compliance of treated water from public water systems, which are routinely monitored, and take into account other factors unrelated to health (e.g. treatment cost and capability, analytical method availability and cost). EPA also notes that additional MCL exceedances (i.e. benzene) have been documented in shallow groundwater based on monitoring well data from pits enrolled in Wyoming's Voluntary Remediation Program (VRP). Absent ongoing regular monitoring for detected constituents, it is difficult to predict what concentrations will occur in domestic wells in the future. EPA suggests this finding regarding organics exceedances be qualified to reflect these uncertainties.

- The Report concludes that "exceedances of drinking water standards or comparison values are generally limited to naturally occurring dissolved salts, metals and radionuclides" (p. 3), but there is limited supporting evidence demonstrating that all of these constituents were present historically in the area, and that they were present at similar concentrations to those detected. There is limited

discussion in the Report that compares ranges of concentrations for the components found in historical data to components and concentrations in the wells studied. Historic data are primarily available for general chemistry parameters, and that data does indicate that the high levels of sodium and sulfate are characteristic regionally for the Wind River formation. However, there is limited or no historic data in the references cited in the Report to document naturally occurring levels of many other inorganic constituents such as arsenic, thallium, lithium and uranium, and the limited data suggest that the values seen in water wells are not consistent with background concentrations. For example, the WSGS Basin Study (WSGS 2012) shows that the median concentration observed in the six wells sampled for uranium was 0.54 ug/L, where the Report indicates that four water wells exceed the much higher value of 30 ug/L (Table 14A). Similarly, the 1995 USGS report on Fremont County water quality (USGS 1995) shows five arsenic samples, four with non-detects and one with 2 ug/L of arsenic, whereas the Report indicates that two of the sampled water wells exceeded the MCL of 10 ug/L. These values do not seem to corroborate that exceedances of inorganics are due to naturally occurring concentrations of these compounds. And there was no data for thallium or lithium in the references, so it is difficult to support a statement about naturally occurring levels with regard to the six wells exceeding the lithium CV and the five wells exceeding the thallium CV.

- The Report also states that "there is a potential for inorganic compounds (e.g. chloride, potassium, sulfate) from gas pits to be contributing to the high levels of salts and other compounds reported in the water supply wells" (p. 75). It should be noted that the altered reducing and associated oxidizing conditions resulting from the introduction of hydrocarbons and other organics can mobilize arsenic and other inorganic compounds, and could contribute to elevated concentrations. EPA notes that the highest levels of arsenic detected were in samples from a pit monitoring well where hydrocarbons were present at elevated concentrations (EPA 2010). Finally, EPA suggests that, in addition to the inorganics mentioned above, barium concentrations in water supply wells could also have been impacted by releases from pits. In EPA's Phase II sampling, barium in one of the domestic wells was anomalously high as compared to other domestic wells. This well is located near a pit location. Arsenic above the MCL and high barium were detected in the VRP pit monitoring wells.

- EPA recommends the Report include a discussion of the analytical detection limits and the implications of those limits with respect to characterizing health risk concerns. The 2014 semi-volatile organic compounds (SVOC) analyses were performed using an analytical method with a method detection limit greater than the EPA MCL for several constituents including hexachlorobenzene, pentachlorophenol, and benzo(a)pyrene. Tables 19A and 19B do flag the analytical results for these compounds as insufficient to determine whether the MCL was exceeded; however, the Report lacks a discussion of this issue in the text of Section 4. The analytical detection limits are not discussed until the end of Chapter 5 (Section 5.9.4) and that discussion seems to focus primarily on whether the SVOCs identified were associated with oil and gas production or hydraulic fracturing. The Report would benefit from a discussion of the analytical detection limits and highlighting of instances where the method detection limit exceeds federal or state standards or other CVs, perhaps in a separate table. We understand that WDEQ is planning to pursue further analyses to address this question; EPA recommends that the Report discuss the plan for resampling

to better characterize water quality in instances where the method detection limit exceeds federal or state standards or health comparison values.

- The Report states that "the US EPA concluded that most water supply wells did not have apparent health concerns" (p. 7). We suggest this statement should be qualified or omitted. This observation was made by EPA in a public presentation reporting Phase I results (https://www.epa.gov/region8/pavillion-wyoming-epa-sampling-results-january-2010-sampling). It was in reference only to the sampled wells that did not show detections of organics, metals or Tentatively Identified Compounds (TICs). EPA also stated that for 11 other wells there was insufficient data to support a finding regarding health concerns. Additionally, this observation was made by EPA after a single phase of sampling, and did not reflect the totality of the data now available.

- The Report discusses potential point-of-use treatment options that could be employed by residents, but only for inorganic compounds. Although "problematic water quality constituents" (p. 100) is not defined in the Report, constituents such as petroleum constituents, isopropyl benzene, tert-butyl alcohol, pesticide compounds, naphthalene, 2-butoxyethanol, methane and adamantanes might be considered problematic constituents and are missing from the table. EPA recommends the discussion of treatment options include treatment for organic contaminants present in water supply wells. The presence of both organic and inorganic compounds complicates potential treatment and typically requires multi-step treatment, which may be more costly and more difficult for homeowners to manage and maintain to achieve effective treatment.

Conceptual Model of Geology/Hydrogeology

EPA agrees with the statement in this Report (p. 75) and statements in WOGCC's previous reports regarding the need for a conceptual model that brings together available information on geology, geohydrology and potential pathways for movement of free gas and other dissolved contaminants.

> "A comprehensive geologic and hydrologic study of the Wind River Formation within the Pavillion Field should be undertaken using all available well logs, cores, and other pertinent data in order to better understand the structural and stratigraphic relationship between individual reservoirs, and to more accurately predict natural fluid flow pathways." (p. 10, WOGCC Pavillion Field Well Integrity Review, October 2014)
>
> "A comprehensive geologic and hydrologic study of the Pavillion Field area should be undertaken." (WOGCC Pavillion Field Pit Review, June 2015)

The Report contains statements that imply incongruent conceptual models. For example:

> "Investigation, monitoring and remediation at the pit locations are often limited to the zone of shallowest groundwater, reflecting the judgment that the relatively deep sandstone lenses in which most water supply wells are completed **are likely not in hydraulic connection** with the shallow alluvial/colluvial or Wind River deposits in which the pits are located." (p. 75)

"…groundwater has been shown in past Wind River aquifer studies to move through the less permeable materials." (p. 75)

"…existing **data is insufficient to characterize groundwater flow patterns and gradients and to assess the degree of hydraulic connection** between the surficial deposits and the Wind River aquifers in the vicinity of the water supply wells." (p. 75)

These inconsistencies point to the need for development of a clearly articulated and consistent conceptual site model based on existing data or on conclusions in published reports that are based on data. A conceptual site model can help provide a context and some predictive ability for movement of gas and liquid contaminants from any potential source (e.g. pits, open gas wellbores, etc.). A clear conceptual model could help better integrate all of the disparate pieces of information regarding potential contaminant movement, frame specific questions and data needs for future investigation, and might provide better support for statements regarding source attribution. In order to assist with understanding potential contaminant migration associated with open gas well annuli, EPA recommends the conceptual model encompass deeper subsurface zones below depths of water supply wells. A conceptual model would need to be based on all available data and published studies, and would benefit from testing of key hypotheses to confirm or refine its accuracy. Such testing could involve collection of data and the use of reservoir and aquifer modelling tools to confirm or refine the conceptual model.

- The Report indicates that Wyoming's groundwater classification system identifies water suitable for domestic, irrigation and livestock use (Class 1, 2 and 3) as groundwater with <5,000 mg/L TDS, and states that it is equivalent to EPA's definition of an Underground Source of Drinking Water (USDW) (p. 26). The Safe Drinking Water Act defines a USDW as: "…an aquifer or its portion (a)(1) Which supplies any public water system; or (2) Which contains a sufficient quantity of ground water to supply a public water system; and (i) Currently supplies drinking water for human consumption; or (ii) Contains fewer than 10,000 mg/l total dissolved solids; and (b) Which is not an exempted aquifer." (40 CFR Part 144.3) Based on available data, the Wind River formation appears to meet the definition of a USDW as it has sufficient yield and is <10,000 mg/L TDS throughout, is the principal source of water for domestic and livestock use in the area and is widely used as such, and is a single aquifer system given the demonstration of hydraulic connectivity within the aquifer system during the Riverton pump test (USGS 1959). The Report would benefit from a discussion of how the Wind River aquifer system within the study area is classified, and how that aligns with or differs from EPA's definition of a USDW. The Report states that EPA "delegated administration of the federal Underground Injection Control program to the state of Wyoming on July 15, 1983 and accepted Wyoming's regulations describing its groundwater classification system" (p. 25). EPA offers several suggestions for clarification on this point. First, the EPA approved (as distinct from delegated) Wyoming's UIC Class II program (wells related to injection of oil and gas production wastewater) on November 22, 1982, and Wyoming's UIC Class I-III and Class V program in July 1983[1]. Second, EPA did not approve regulatory language identifying groundwater with >5,000 mg/L as unusable or unsuitable for drinking water use; rather, the Wyoming program language that EPA approved contained a narrative reference that groundwater may be

[1] Consistent with our cover letter note, EPA's comments on the State's groundwater classification system should not be construed as setting forth any position regarding the exterior boundaries of the Wind River Indian Reservation or the exercise of State authorities in this area. EPA's approvals of Wyoming's UIC programs do not extend to Indian country as defined at 18 U.S.C. § 1151.

"unusable or unsuitable" "[d]ue to excessive concentration of total dissolved solids or specific constituents." (Wyoming Code R.020-080-008 § 4(ix)(A)) EPA could not, through approval of a state's primacy program, change the regulatory definition of USDW.

- The Report generally does not distinguish between free methane and dissolved methane when characterizing analytical results or discussing how dissolved phase and gas phase methane move within the subsurface. Understanding the behavior of methane in the subsurface is critical to the development of a conceptual model for contaminant fate and transport. Free gas can and does migrate through rock strata and liquids as a buoyant fluid. Alternatively, or additionally, dissolved methane would move according to the hydrologic conditions at the site. Methane in the gas phase would naturally migrate upward from deeper reservoirs. However, liquids containing dissolved methane could move according to groundwater flow direction both horizontally and vertically depending on the pressure gradient. For example, dissolved constituents including methane could move upward under an induced pressure drive from a high pressure zone to low pressure zone, as is reflected in some bradenhead pressure measurements or from pressures induced through hydraulic fracturing.

- The Report characterizes the Pavillion gas field as a conventional reservoir (p.2). This statement should be modified or explained. Although there is some conventional development elsewhere in the Wind River Basin, Pavillion field development is from Cretaceous-Lower Tertiary tight sands, which is generally considered unconventional (see US Energy Information Administration https://www.eia.gov/oil_gas/rpd/tight_gas.pdf).

- The Report (and documents referenced and reviewed in the Report) reference various distances that were used to define the scope of domestic wells, gas wells and pits to be evaluated in Wyoming's investigation. Some examples include:
  - "…determine if wellbore construction is adequate to protect those water supply wells within 1,320 feet of the oil and natural gas wellbore…" (June 20, 2013 framework document). Similar language is used to describe the pits evaluation process.
  - "Fifty-two of the 169 Pavillion Gas Field oil and gas wells are located within 1,420 feet (one-quarter mile or 1,320 feet plus a 100-feet buffer; surface distance) of the 14 water supply wells included in the study" (p. 30)
  - "The WDEQ used the following criteria to establish areas of interest (AOIs) within which water-supply wells would be considered for further study: … The water-supply well was within 1,000 feet of an earthen drilling or production pit…" (p. 10)

  The Report lacks a clear explanation of when these varying distances were applied to determine inclusion or exclusion of a gas well, pit or water-supply well in the investigation, and could benefit from a discussion of the technical basis for these setback distances.

Fluid Migration/Gas Well Integrity

The Report generally concludes gas is present in the shallow Wind River formation as a result of natural upward migration from source rock (though acknowledging that some potential contribution may have come from movement up gas wellbores); that gas was widely present in the shallow subsurface prior to

energy development; and that there is negligible likelihood that hydraulic fracturing fluids have migrated upward to depths utilized by water supply wells. All of these conclusions would benefit from additional support.

Widespread historic presence of methane in shallow subsurface

The Report states that gas was widely present in the shallow subsurface prior to gas development (e.g. pp. 2, 77-79). To definitively conclude this one needs to be able to determine what the gas flux was prior to development and the present day flux. Current flux can be determined but it is, as the Report notes, extremely difficult to directly substantiate historical gas flux. There is limited data to support the conclusion that gas was widely present in the shallow subsurface. Reference is made to a 3-page excerpt from a 1951 Bureau of Reclamation annual report, which contains this single statement: "a satisfactory aquifer was found near the 500 foot depth, but potability of the water was destroyed by gas". The well in question is 2.5 miles from the nearest water supply well study area (PGDW20). The excerpt does not contain or reference any supporting data or information, and there is no indication as to whether the gas was in fact methane, or something else (such as hydrogen sulfide). A USGS report covering the Midvale Irrigation District (a larger area encompassing the Pavillion field) noted the presence of hydrogen sulfide in the area: "The water from well A3-3-6cc, 270 feet deep, had a moderately low mineral content (272 ppm) but was reported unsatisfactory for drinking because of the strong hydrogen sulfide odor and the precipitation of sulfur... Although no gas analyses were made, the problem of hydrogen sulfide in water supplies, particularly in deep wells, was observed for new supplies in other tracts." (USGS 1959). Within the irrigation project area the USGS report identifies less than 20 water wells out of 359 water well logs that reported either "bad water" (eight well logs), "sulfur water" (nine well logs), or "sulfur water with gas" (two well logs). None of the wells with bad water, sulfur or gas were located within the Pavillion study area. In addition, the report evaluated over 50 water well logs from Township 3 North, Range 2 East which has a large portion of the study area. None of these wells recorded issues with water including no reports of "sulfur water" or "gas" within this area.

The Report further points to the indication of gas-filled porosity at depths between 600 and 900 feet from three mud logs from gas wells drilled between 1965 and 1973 as evidence of widespread gas at shallower depths (p. 26), and cites EPA's 2011 Draft Report as the source. EPA was able to locate and review ten mud logs from wells drilled before 1995; the logs did not indicate gas shows within 300 meters of the surface. (EPA 2011).

The final line of evidence referred to as supporting this conclusion is a 2007 letter from WOGCC, which the Report characterizes as stating a finding that most of the wells had exhibited gas just below surface casing, with many around 500 feet, based upon cement bond and porosity logs for 29 gas wells. The letter is not included as an attachment, nor could EPA locate it on the WOGCC website. EPA suggests that the logs and analysis used to reach this conclusion be made available to public reviewers of this Report. It should be noted that cement bond logs are not relevant to identifying gas presence, as they are run after there is casing and cement in the wellbore. Porosity logs by themselves have limited ability to distinguish between freshwater and gas zones, as both hydrocarbons and fresh water are non-conductive; additional information beyond porosity logs would be needed to determine if non-conductive zones identified were fresh water or gas.

If in fact the presence of natural gas in the intermediate zone was known or believed, this would have alerted the permitting agency to the potential for pressures above hydrostatic head gradients to be present, highlighting the necessity for the entire wellbore to be cased and cemented to the surface (or above the surface casing shoe) in order to prevent gas and liquid migration either from the production zone or intermediate zones to shallower zones used for drinking water: "…sufficient surface casing shall be set to reach a depth below all known or reasonably estimated utilizable domestic freshwater levels…and shall be set in or through an impervious formation and shall be cemented…with sufficient cement to fill the annulus to the top of the hole…" (Rules and Regulations of the Oil and Gas Conservation Commission promulgated July 23, 1951; effective August 21, 1951). This regulatory language was applicable to most of the wells drilled in the field. Also, rules promulgated in 1993 and 2000 required that "surface casing shall be run to reach a depth below all known or reasonably estimated utilizable domestic fresh water levels and to prevent blowouts **or uncontrolled flows**" (Wyoming Chapter 3, General Drilling Rules, 1993 and 2000). Many wells in the area are Tribal mineral wells subject to BLM's Onshore Order #2 requirement for isolation of water containing up to 10,000 ppm of TDS, which is generally the case for the entire Wind River formation. The gas well integrity expert retained by Wyoming, Maurice B. Dusseault, says the following in his report: "In modern well completion practice, this space [the bradenhead annulus] is intended to be cemented to the surface, or at least cemented a substantial distance above the surface casing shoe so that an effective flow seal exists between the two casings. Data from Pavillion Field reports show that primary cementing operations in many wells failed to lead to cement rising into the surface casing … In general, leaving an open annular space between the top of the production casing cement and the bottom (shoe) of the surface casing is not considered good practice (annum 2015), but wells drilled in the 2004-2005 campaign in Pavillion were not all cemented to above the surface casing shoe" (p. 13 Appendix G).

Source of gas in domestic water wells

The Report concludes that it is "almost certain" that part of the methane observed in water supply wells in the WDEQ investigation is naturally occurring and not a result of gas production (p. 78). This conclusion appears to be based solely on the limited data described above. There is often a question about prior gas migration or flux in regions producing hydrocarbon, particularly with gas reservoirs such as the Pavillion field that lack a clear confining layer above the hydrocarbon zone. In some cases it has been determined that even though there was prior migration of gas, energy development activities had increased the migration rate and volume causing noticeable increase in impacts (Coalbed Methane Development in the Northern San Juan Basin of Colorado-BLM 1999). The Report would benefit from a more robust basis for this conclusion and we encourage the development of a consistent conceptual model for the study area, and additional study to test key statements of finding. It would require multiple lines of evidence to distinguish whether the gas appearing in water wells is present due to natural migration or via movement up gas wellbores. Absent this, EPA recommends this conclusion be qualified to reflect the uncertainties inherent in the limited supporting data currently provided.

Source of gas in bradenheads

The Report concludes that bradenhead pressure and gas are most likely from non-producing intermediate zones within the Wind River formation. The Report states that the composition and isotope signature of the bradenhead gas is similar to the tubing or production gas, but then dismisses the potential for the gas to be sourced from the production zone without providing supporting information (pp. 70-73). The Report does not acknowledge or discuss the potential for gas to migrate up the wellbore from the production zone either through uncemented or poorly cemented annuli, or even to bypass sections of good cement by migrating through the formation around the wellbore. The Report points out that producing wells would be unlikely to allow gas migration due to the pressure sink induced by production, but does not consider shut in wells or wells that have been plugged and abandoned that do not have the induced pressure sink of a producing well. According to the information provided in Figures 12A-12K, four gas wells within the study area have been temporarily shut in, and nine have been plugged and abandoned, suggesting the importance of addressing the potential for gas wells not in producing status to allow gas migration up annuli.

This conclusion would benefit from additional investigation to provide a higher level of certainty. Improving the certainty of this conclusion is important for remediation already performed or under consideration as part of WOGCC's gas well integrity evaluation and follow-up. If the gas or liquids are sourced from intermediate zones placement of remedial cement would be located differently than if fluid from the production zone fluids is migrating up an open or poorly cemented bradenhead annulus.

EPA suggests the Report include a table identifying the gas wells exhibiting sustained bradenhead pressure. That information only appears to be presented in Appendix G.

Likelihood of movement of hydraulic fracturing fluids into shallower zones

The Report concludes that hydraulic fracturing fluids had a "negligible likelihood" of reaching shallower zones used for drinking water. This conclusion relies primarily on the relatively small fracturing fluid volumes reportedly used in the field- "often less than 200 bbls". No data or reference is provided for the fracturing volumes. This conclusion lacks supporting data, and given the short vertical distances between water supply well depths and gas well fracture depths relative to other production areas across the country, may need qualification. The study did not provide any additional data to evaluate the chemistry of the interval between water supply well depths and hydraulic fracturing depths to assist in evaluating the potential for hydraulic fracturing impacts in this deeper zone, and existing data for this interval from USGS and EPA were not considered in the Report. If this existing data is not used, the Report could benefit from development of additional data from this interval to evaluate the potential for impacts of hydraulic fracturing in this deeper zone.

Some wells in the field exhibit shallow surface casing and uncemented annular intervals; although the Report acknowledges that these conditions increase the likelihood of movement of groundwater or gas, it does not discuss or acknowledge the potential that these conditions could similarly enable movement of hydraulic fracturing fluids. In particular, the Report does not acknowledge or evaluate situations where older wells with shallow surface casing and open bradenhead annulus existed in

close proximity to newer wells with hydraulically fractured zones at similar depths. For example, gas wells 44-10 (API 49-013-20879, http://wogcc.state.wy.us/Wellapi.cfm?Oops=ID6869&nAPINO=1320879) and 43-10B (API 49-013-22420, http://wogcc.state.wy.us/Wellapi.cfm?Oops=ID87031&nAPINO=1322420) are approximately 520 feet apart. Well 44-10 was constructed in 1978 and although the top of cement is at 1918 feet below ground surface (bgs), top of good cement is located 404 feet deeper at 2322 feet bgs. The nearby well 43-10B constructed in 2004 was perforated and stimulated at 1810 feet which is 555 feet (adjusted for elevation difference of 46 feet) above the top of good cement in nearby 44-10. In addition, PGDW23, a domestic water supply well, is approximately 780 feet from gas well 44-10 and PGDW44 is approximately 1775 feet from 44-10. It should be noted that 44-10 exhibited bradenhead pressure of 150 psi when tested, and flowed liquid from the bradenhead during the entire 15-day test, including 410 barrels of liquid in the first 8 hours. Bradenhead monitoring in nearby wells was not conducted during hydraulic fracturing to detect pressure changes in the bradenhead annulus of these offset wells. As a result, there is no data to determine whether such inter-well communication may have occurred under a hydraulic fracturing pressure regime. EPA was unable to locate any bradenhead pressure monitoring data collected from the Pavillion field prior to the beginning of EPA's investigation; when WOGCC initiated bradenhead monitoring efforts in 2012, some of the gas wells were found to have bradenheads which were not accessible and had clearly not been previously open.

There are some inconsistencies in the Report with respect to information on hydraulic fracturing depths: "hydraulic fracturing intervals typically start below 1,500 feet bgs but have been performed as shallow as 1,060 feet bgs…" and that the "shallowest depth that was hydraulically fractured within 1,420 feet of the 14 water-supply wells included in the study is 1,397 feet bgs". This is followed by a statement in the next paragraph that likelihood is negligible that hydraulic fracturing treatments have led to fluids interacting with shallow groundwater in the study wells based on volume of treatments and depth with "shallowest hydraulic fracturing is generally deeper than 1,500 feet bgs" (p. 2). These statements are inconsistent and the reader would benefit from clarification. EPA further notes that there are some inconsistencies between Table 4 of the Report and data available on the WOGCC website or contained in the WOGCC Gas Well Integrity Review Report. Tribal 44-3 is identified in the Gas Well Integrity Review Report as being located within 797 feet of PGDW30, yet it is omitted from Table 4 of this Report, "Oil & Gas Wells within 1,420 feet of Water Supply Wells". The WOGCC report also indicates that Tribal 44-3 was perforated and acid stimulated with 500 gallons of 15% HCl at 699-711 feet in 1999. Though a cement squeeze was subsequently performed and this interval cemented off, it indicates stimulation occurred at a substantially shallower depth. Additionally, the data for depth of shallowest perforation in Table 4 of the Report do not all match data posted in the corresponding well files on the WOGCC website.

In summary, the data limitations and uncertainties discussed above suggest a need for additional investigation to provide support for many of the Report's conclusions related to fluid movement, gas source and well integrity. In addition to the specific points raised above, we encourage the state to consider recommendations for additional data collection provided previously by EPA in our comments on WOGCC's gas well integrity report (EPA 2014), which included:

- Additional sampling and analysis of bradenhead gas composition to improve the certainty of source identification
- Additional testing and analysis of bradenheads, including determination of hydrostatic head within the annulus, to better support an understanding about potential for and likelihood of fluid movement
- Additional evaluation of external mechanical integrity of wells exhibiting sustained bradenhead pressure using tools such as noise logs, temperature logs, or oxygen activation logs.

Groundwater Chemistry and Source Evaluation

One of the stated objectives of the investigation was to "assess the potential for impacts to the quality of water in the water-supply wells by oil and gas wells, related pits and other sources as appropriate." (p. 9) EPA suggests that additional lines of evidence would be needed to bolster many of the Report's conclusions regarding potential sources of constituents in water supply wells. Additionally, all data that might be pertinent to detections in a particular water supply well were not brought together to evaluate with respect to those specific detections. Such data might include, for example, existing production gas and bradenhead gas and liquid analyses from proximal gas wells conducted by WOGCC, EPA or the operator, as well as available soil and groundwater monitoring data from proximal pit sites.

- For example, there are shallow groundwater monitoring wells located at the VRP pit sites. The data from these wells (as well as soil sampling results from VRP pits) provides valuable information that would assist with understanding the hydrocarbon compounds detected in water supply wells throughout the area. The VRP information was not included in the contractor document summaries nor was it brought into the evaluation and synthesis. These sites have dedicated monitoring wells, which is described by WDEQ's independent petroleum engineering expert as a preferable source of groundwater information (Appendix G, p. i). EPA's previous comments on the WOGCC pits review advised inclusion of this information in the analysis.

- The Report does not accurately characterize the USGS sampling of MW01 (p. 8), stating that pH did not reach stability during sampling. The USGS report indicated that stabilization criteria were met: "…sample collection started as soon as values for both SC and pH met stabilization criteria (table 1). The stabilization criterion for temperature was not used because the water line was exposed to solar heating and air temperature, so by the time water temperature was measured it was not a good indication of conditions in the well" (USGS 2012 p. 4); thus, their samples from this well represent valid data. USGS and EPA data from MW01 provide data regarding groundwater quality deeper in the subsurface than most of the domestic wells, and as such these validated and quality assured data are an important source of groundwater chemistry information at depth. Additionally this data helps to inform the conceptual model regarding fate and transport pathways for contaminants in the subsurface and the question of potential sources of constituents observed in water supply wells.

- A number of USGS and WSGS reports have reviewed and synthesized historical data on general water chemistry. It would be helpful to undertake a comparison of pre- and post-oil and gas development general water chemistry to assess whether general groundwater chemistry

parameters have undergone statistically significant changes since energy development began. Additionally, the discussion of historic and current groundwater chemistry in the area could be supplemented with ion concentration data from the producing gas wells in the study area, either from WOGCC or from the U.S. Geological Survey produced water database (http://energy.usgs.gov/EnvironmentalAspects/EnvironmentalAspectsofEnergyProductionandUse/ProducedWaters.aspx).

- The Report posits that detections of Diesel Range Organics (DRO) and Gasoline Range Organics (GRO) could reflect naturally occurring compounds rather than petroleum hydrocarbons. EPA believes additional analysis is needed to support this hypothesis, which seems to be based largely on the fact that the DRO chromatograms from domestic well water samples do not resemble chromatograms from laboratory standards for diesel fuel. In the Pavillion area shallow hydrocarbon sources have been present over an extended time. It would be unlikely that petroleum hydrocarbons released from pits or other sources and subject to environmental weathering and degradation over time would resemble a fresh diesel chromatogram. EPA compared chromatograms from DRO and GRO in the VRP pit monitoring wells to fresh diesel chromatograms and found them to differ significantly. EPA's Phase II analysis also identified the presence of C2-C10 straight chain hydrocarbons in domestic wells with DRO and GRO, confirming a hydrocarbon source for the DRO and GRO detections (EPA 2010). EPA suggests this Report is premature in suggesting that DRO and GRO detections may reflect naturally occurring organic matter rather than originating from the hydrocarbon reservoir.

- The Report further observes that fresh petroleum fuels such as DRO and GRO consist almost entirely of non-polar compounds, and presents data from well water analysis done using a Silica Gel Clean-up (SGCU) method, which screens out polar compounds. Without understanding what those polar compounds are and whether they may be associated breakdown products of hydrocarbon compounds, EPA suggests that screening out those compounds does not provide an accurate understanding of what is in domestic wells water nor assist in discerning the source of the polar fraction.

  The Report states that "reported DRO concentrations with SGCU compared with reported DRO concentrations without SGCU in groundwater samples collected in June and August 2014 reveals that in most cases, the reported DRO concentration with SGCU was less than the MDL (Table 14). This suggests that the reported DRO concentrations in many of the samples are attributable to, or were predominantly non-polar compounds." (p. 87) It appears that the authors may have meant to say that the remaining DRO exhibits chromatogram peaks reflective of predominantly polar compounds.

- DRO and GRO were found in conjunction with other hydrocarbon compounds in previous EPA sampling (EPA 2009; 2010; 2014). EPA notes that the highest DRO and GRO concentrations were identified in gas well fluids sampled at the wellhead, and from shallow groundwater monitoring wells at VRP pit sites with demonstrated hydrocarbon contamination in groundwater. Additionally, products containing diesel fuel were used in hydraulic fracturing at Pavillion (EPA 2010). Encana, WYDEQ and EPA have all detected tentatively identified organic compounds for various wells tested

in the study area. This may be another indication that hydrocarbon compounds have been degraded to by-products that are not easily identified with standard methods. For example, adamantane compounds were originally detected as Tentatively Identified Compounds (TICs) in domestic wells in EPA Phase I (EPA 2009). Subsequent sampling of water supply wells and VRP pit monitoring wells In EPA Phase II (EPA 2010) confirmed and quantified these compounds. Based on these observations, there may be more lines of evidence to suggest the DRO and GRO detections are associated with oil and gas activity.

- The Report seems to suggest that biodegradation of dissolved unknown organic constituents by bacteria is a source of palatability concerns in domestic wells (p. 4). EPA notes that the highest levels of both DRO/GRO and of iron-related and other heterotrophic bacteria are those found in the shallow monitoring wells associated with VRP pits (EPA 2010). EPA concurs with the observed correlation between dissolved organic constituents and the proliferation of bacteria, but notes that the correlation does not establish that the source is degradation of non-hydrocarbon compounds. The Report notes that the dissolved organic compounds in some water wells (including dissolved gas) may be contributing to deteriorating water quality by promoting microbially-mediated reducing conditions resulting in increased mobilization of other constituents such as arsenic, and production of hydrogen sulfide (pp. 4 and 108). EPA concurs with this observation; however, the fact sheet accompanying the Report states: "…bradenhead pressures in several gas wells provide strong indication that gas and possibly liquid migration may be happening; however, there is no evidence that this migration has caused water quality issues." These statements appear to be contradictory, and EPA recommends the fact sheet statement be modified to reflect the lack of data demonstrating that the observed gas migration is not impacting water quality. EPA also notes that the highest arsenic levels were present in the VRP pit monitoring wells, which also had high concentrations of dissolved organics including petroleum hydrocarbons. This suggests that contaminant plumes from pits are a likely source of constituents such as arsenic and merit additional investigation (such as the installation of nested monitoring wells) to provide more definitive understanding of the vertical and lateral extent and the chemical composition of plumes associated with pits and their effect on domestic wells.

- The Report mentions that TICs in PGDW05 were attributed to decaying organic matter (p. 7). There is no data or analysis to support this statement, and EPA recommends it be removed or qualified. For example, adamantane compounds were detected in PGDW05 and originally identified as TICs, and confirmed and quantified in subsequent EPA sampling. The Report further states that adamantanes, because they are widely recognized as a component of petroleum hydrocarbons, "…may be from naturally occurring gas." (p. 90) EPA notes that adamantanes were also found in VRP pit monitoring wells and in production fluids (Phase II Analytical Results Report, August 2010), suggesting those as likely sources. EPA recommends this statement be modified accordingly.

- Although fuel spills can be a source of hydrocarbon contamination, there is no source comparability between a 50 gallon fuel tank that may have experienced incidental spillage, and a single unlined reserve or production fluid pit that received hundreds to thousands of barrels of fluids over a period of years and often decades (Figures 12A-12K illustrate that a number of oil-based mud reserve/production pits in the study area were operative for decades). In addition, there are at least

eight pits that have been enrolled in the VRP cleanup program, reflecting documented groundwater contamination associated with these sources. It is important when assessing possible sources to consider the potential for those sources to impact groundwater based on constituents, volumes and duration of potential releases from those sources, and to reflect that potential in discussion and conclusions regarding potential sources. For example, if septic systems were a source of water supply well palatability problems, nitrate would be anticipated as a major constituent in sampling results. However, nitrate has not been a constituent of concern for most wells in the area, suggesting that domestic waste and fertilizer use are not contaminating groundwater within the study area.

- The Report states that "2-butoxyethanol (2-BE) was reported at an estimated concentration of 3,100 J ug/L in the June 2014 sample collected from PGDW33. However, the reported concentration was near the MDL of 2,300 ug/l, and the analytical method employed (US EPA 8015A) uses a non-specific detector, so compound identification is less certain" (p. 89). The measured value is ~35% above the MDL, and it is unclear from the information provided why the identification of this compound is "less certain". The Report also states that "if present, potential sources of the 2-butoxyethanol reported in the sample from PGDW32 (sic) include the septic systems and surface releases" (p. 89). EPA notes that this reference to PGDW32 rather than PGDW33 appears to be a typo as 2-BE was not detected in PGDW32. EPA further notes that the pit located 577 feet from PGDW33 was utilized as an oil-based mud reserve pit and subsequently as a produced water/flowback pit for more than 20 years (Figure 12G). 2-BE was used as a constituent in fracturing fluids at Pavillion (EPA 2010) and may thus have been present in flowback managed in pits. It should also be noted that 2-BE was detected at 765-785 feet bgs in MW01 (EPA 2011). Given that there were no detections of E. coli and only low levels of nitrate (2.1 mg/L) in PGDW33, it seems that the pit may be a more likely source of this detection than septic system releases.

- EPA notes that some results for DRO and GRO were qualified as not detected (U) due to reported concentrations in the associated method blank or trip blank samples. The "B" qualifier should be used instead to avoid confusion and put the data in its proper context. EPA suggests these results be reviewed with respect to the magnitude of difference between the quality assurance (QA) sample detections (which could be due to lab issues) and the environmental samples, and reevaluated if that difference in magnitude is sufficiently large. EPA quality assurance and data validation protocols allow use of qualified data where the environmental sample detections exceed the concentration found in the blank based on the judgment of the investigator (http://www.epa.gov/sites/production/files/2015-03/documents/somnfg.pdf). In addition, prior to discounting DRO results with associated blank detections, EPA suggests previous sampling events be reviewed to determine if DRO or GRO detections were seen only during events with blank contamination.

- The inorganic chemistry data presented in the Report may not provide sufficient sensitivity for distinguishing sources of water potentially impacting the shallow zones used for drinking water and evaluating whether facilitated transport of formation water is or has occurred from deeper zones into shallower zones. Stable isotopes of strontium have been successful in this type of analysis, and

EPA recommends consideration of more targeted tracers such as these to assess potential migration of formation water into shallow zones.

- It may be useful to analyze irrigation water chemistry relative to data collected for water supply wells (e.g., included in Figure 17A). The chemistry of shallow groundwater is often influenced by irrigation in arid basins such as this, particularly if large-scale irrigation practices have been in place for many years. Evaluation of deviations from this anticipated pattern would be useful both for the pit investigations, as well as for assessing potential impacts from localized migration of groundwater from deeper zones. Incorporation of SAR data from soils or shallow groundwater from VRP pits investigations could help inform this evaluation and address resident concerns regarding potential impacts of garden irrigation using water from domestic wells. EPA notes that the framework document called for pre- and post-irrigation season sampling because of the potential effect of irrigation on shallow groundwater, yet both rounds of sampling occurred during irrigation season (due to concerns regarding weather). EPA recommends the Report discuss how results might be influenced by irrigation and if they are influenced, how that might be expected to influence conclusions.

- EPA offers some clarification with respect to domestic well sampling conducted by the Agency. EPA did not sample PGDW41B in 2009 as the Report indicates (p. 48). In January 2010, EPA's sample at PGDW41 was collected from the deeper well present at this location, rather than being a mixture of water from PGDW41A and PGDW41B, as the Report states (p. 59). Finally, the Report indicates that EPA hired a well service contractor to install a temporary pump/discharge line for PGDW41, and that this work may have contributed to DRO and TPH results in this sample (p. 88). EPA does not believe this to be the case. This sample was collected utilizing a SOP that called for flushing the water wells three well casing volumes to prevent sampling stagnant water so as to ensure there would be no artifacts from sampling components. These results were reviewed and validated without data flags and thus are considered valid data. Further, if artifacts from temporary sampling equipment were the source of DRO and TPH, it would not explain the fact that DRO is still present four years later.

Pits

The Report statement that "a pit without known groundwater contamination is no guarantee that it has not or will not cause groundwater contamination to a nearby well" and that a limited investigation conducted at a certain point in time is not likely to be fully representative (p. 74). EPA concurs, and notes that previous EPA input to WOGCC regarding pits (EPA 2013b and 2015) expressed concern about reliance solely on Total Petroleum Hydrocarbon (TPH) data to conclude that no further investigation is needed, and pointed out that the subsequent discovery of groundwater contamination in association with pits that had met TPH clean-up values seems to indicate that the initial investigation and closure was not sufficient to detect and address groundwater impacts. The Report authors acknowledge the validity of this EPA observation regarding data limitations (Appendix I, Section V-16). The Report additionally states that "further analysis is needed to assess whether investigations and/or remediation at pit locations was sufficient to protect groundwater quality at the water supply wells" (p. 75). EPA concurs, and has previously provided suggestions on additional investigation that would be helpful.

The Report observes that monitoring and remediation at the pit locations are often limited to the zone of shallowest groundwater, reflecting the judgment that these zones are not hydraulically connected to the somewhat deeper sandstone lenses in which many domestic wells are completed. Yet, as is also pointed out, pump tests conducted in the area reflected hydraulic impacts (drawdown) in wells as deep as 662 feet and as much as a mile away. Without further analysis and the development of a conceptual model as described above, the pump test results suggest that investigation and/or remediation at pit locations needs to encompass deeper groundwater, preferably by employing nested monitoring wells at pit sites with known groundwater contamination to enable characterization of the plume depth profile The lack of sufficient data to characterize groundwater flow patterns and gradients that the Report notes makes it difficult to assess over what distance impacts to groundwater from pits might occur.

- The Report states that 1984 Wyoming regulations prohibit the use of reserve pits as production pits. It subsequently states that "records indicate that some of these pre-existing production pits continued to be used [as production pits to store produced water] until approximately the mid-1990s" (p. 28). An explanation of the significance of this would be helpful.

- The Report states that WOGCC has primary regulatory authority over gas well pits and waste materials contained in the pits. Since BLM has authorities with respect to Tribal mineral wells, we suggest BLM's authorities with regard to those pits that are associated with tribal mineral wells be addressed.

- The Report discusses the lack of correlation between potassium and chloride concentrations in domestic wells and proximity to a KCl polymer type pit; however, though it does acknowledge that other factors such as well depth, transport pathway and natural variability of these constituents would affect migration and concentrations of potassium and chloride (p. 82). Given the significance of these factors (well depth and proximity and constituent concentrations in particular), EPA believes that some KCL pits might pose risks to water wells and merit further investigation. The intent of this discussion could benefit from clarification, and as EPA has previously commented, additional investigation of KCL pits could help establish a stronger basis for a conclusion about their potential contribution to groundwater contamination. The Report further notes that if these factors are considered, it will be more difficult to identify any spatial trends. This may be true when attempting to identify a trend that would hold true for a large spatial region; however, these are factors that would be useful in evaluation of whether a particular pit is a viable potential source of contamination for a nearby water well. EPA also notes that the Report refers to Figures 20 and 21 as a demonstration of this lack of correlation; however, Figure 20 presents Na + K, so it isn't possible to differentiate the contribution of K from wells close to KCL or other pits from this figure.

- The Report states that "additional analysis could be performed using existing data (e.g. groundwater results from WDEQ Voluntary Remediation Program (VRP) investigations[2])" (p. 4). EPA, as noted elsewhere, concurs with the need to incorporate such analyses into this Report to assess potential

[2] Consistent with our cover letter note, EPA's comments regarding the surface pits in the VRP are for technical purposes only and should not be construed as setting forth any position regarding the exterior boundaries of the Wind River Reservation or the exercise of State authorities in this area.

contributions from specific pits to constituents detected in proximal water wells and to better inform the overall conceptual model.

Analytical Methods

- Some of the analytical methods quoted aren't the most recent versions of the methods. The following refers to methods in Table 8A:
    - SVOCs Organochlorine pesticides – current method is 8081B (Feb. 2007) yet C&T lab used 8081A
    - SVOCs Organophosphorus compounds – current method is 8141B (Feb. 2007) yet C&T/APPL lab used 8141A
    - SVOCs – current method is 8270D (Jan. 2014) yet C&T used 8270C
    - Trace metal – current method is 6010D (July 2014) yet C&T used 6010B
    - Trace metals (Li and U) – current method is 6020B(July 2014) yet C&T used 6020A
    - VOCs – current method is 8260C (Aug. 2006) yet C&T used 8260B
    - VOCs (GRO and glycols) – current method is 8015D (June 2003) yet C&T and C&T/Weck used 8015B (or 8015A – page 89) (See comments below regarding Method 8015)

  The use of current methods might invoke different sections, caveats, and perhaps QA changes to the method.

- Method 8015 does not list glycols as tested compounds so the method would have to be adapted to analyze for these compounds. The sample introduction method is missing in the discussion.

- Method 8015 has known interferences for the glycols leading to low biased results. Here are some related references:
    - Baffi, P.; Elneser, S.; Baffi, M.; De Melin, M.; Baffi, P.; Elneser, S.; Baffi, M.; De Melin, M., Quantitative determination of diethylene glycol contamination in pharmaceutical products. J. AOAC Int. 2000, 83, 793-801.
    - Lawrence, J. F.; Chadha, R. K.; Lau, B. P.; Weber, D. F., Simplified routine method for the determination of diethylene glycol in wines by capillary gas chromatography with flame ionization detection. J. Chromatogr. 1986, 367, 213-6.
    - Yamini, Y.; Hojjati, M.; Haji-Hosseini, M.; Shamsipur, M., Headspace solvent microextraction A new method applied to the preconcentration of 2-butoxyethanol from aqueous solutions into a single microdrop. Talanta 2004, 62, 265-70.

- Section 4.2.12 discusses QA/QC samples but only for the field collected samples – field and trip blanks. The discussion of laboratory QA/QC is interspersed with each class of compounds and consists of initial calibration, continuing calibration verification, method blanks, MS/MSD, serial dilution and post-digestion spikes, and lab control samples. The discussion only indicates when a failure has occurred. For the accuracy samples MS/MSD and LCS, it would be helpful to include information on (1) how big the acceptance window was and (2) whether samples were biased all to the low side (or high side) but perhaps within the acceptance limits. Please see discussion on glycols.

- The measured turbidity of -6.1 NTU in PGDW45 is identified as artifact of meter calibration (p. 50). This is not an insignificant deviation from zero and may call into question the reliability of turbidity measurements.

Additional Work

Both of the WOGCC prior reports recommended numerous general and specific additional investigation steps, many of which EPA supported. EPA also provided additional specific input on investigation and data collection for both pits and gas well integrity, as expressed in our prior input to Wyoming on gas well integrity and pits (EPA 2013a, EPA 2013b, EPA 2014, EPA 2015). While this Report does offer a short discussion of considerations for additional work, including evaluation of methane seepage along gas wellbores and the contribution of pits to water quality concerns in domestic wells, the discussion is limited and general. EPA suggests that the final Report provide a more complete and detailed description of specific investigation and data collection that will be undertaken to address the uncertainties and questions discussed throughout this draft, including additional consideration of the suggested investigation steps previously described by EPA. As discussed above, we recommend that a specific plan for additional investigation be based on a thoughtful conceptual model of geology/hydrogeology and contaminant fate/transport pathways, from which specific data quality objectives could be derived for any additional investigation.

Further, EPA suggests that the Report include a discussion of remediation work already underway to address identified concerns with gas wellbores and pits, as well as additional work that Wyoming intends to undertake to further investigate and address these potential sources. For example, EPA notes that Pavillion Fee 12-11W, which exhibited bradenhead pressure of 150 psi and flowed 4,303 barrels of water from the bradenhead, underwent an attempt to place additional cement in the annulus in May 2013. (WOGCC 2014). It appears that this may have been in an effort to remediate the bradenhead pressure and fluid flow, but neither the WOGCC report nor the well file are specific regarding the purpose of the cementing or whether it achieved the intended purpose. Similarly, of the eight pits enrolled in Wyoming's VRP program, four have been given certificates of completion (p. 32). EPA was unable to locate information on WDEQ's website describing the nature and extent of contamination, the remedial action performed, or the groundwater clean-up levels achieved. To enhance public understanding and transparency regarding the full scope of investigation and remediation of pit and wellbore sources, the Report would benefit from a comprehensive discussion of these efforts.

Document Clarity and Readability

EPA suggests that the Report be revised to improve the clarity and readability of the document, particularly for a non-technical audience. Specific suggestions for improvement include:

- Reduce the length of the Executive Summary and focus it on a description of what was done in the study, what was found, what was concluded, and what were the unanswered questions, data gaps and uncertainties in those conclusions.
- Integrate tables and figures into the text of the document in the appropriate location. It is very difficult to find them in the large attachments and toggle back and forth between the text and the tables/figures.

- Reduce the length and complexity of the Report by pulling more of the detailed technical information into appendices- a specific example would be the sample collection methods but there are a number of others.
- Separate each appendix into a separate attachment to better enable readers to find material in the appendices.

REFERENCES

EPA 2009. Phase I Site Investigation Analytical Results Report, August 2009

EPA 2010. Phase II Expanded Site Investigation Analytical Results Report, August 30, 2010

EPA 2011. Investigation of Groundwater Contamination near Pavillion, Wyoming, December 2011

EPA 2013a. Pavillion Gas Well Integrity Evaluation, EPA Region 8, July 25, 2013

EPA 2013b. Pavillion Oil and Gas Field Pits Evaluation, July 25, 2013

EPA 2014. Letter to Grant Black dated September 5, 2014 transmitting EPA comments on WOGCC Pavillion Field Well Integrity Review report

EPA 2015. Letter to Mark Watson, WOGCC, dated January 16, 2015 transmitting EPA comments on WOGCC Pavillion Field Pit Review report

USGS 1959. D.A. Morris, O.M. Hackett, K.E. Vanlier and E.A. Moulder, Ground-Water Resources of Riverton Irrigation Project Area, Wyoming Geological Survey Water-Supply Paper 1375

USGS 1995. Maria Plafcan, Cheryl A. Eddy-Miller, George F. Ritz, and John P.R. Holland II, Water Resources of Fremont County, Wyoming, U.S. Geological Survey Water-Resources Investigations Report 95-4095

USGS 2013. Wright, P.R., McMahon, P.B., Mueller, D.K., Clark, M.L., 2012, Groundwater-quality and quality-control data for two monitoring wells near Pavillion, Wyoming, April and May 2012: U.S. Geological Survey Data Series 718

WOGCC 2014. Pavillion Field Well Integrity Review, October 8, 2014

WSGS 2012. Paul Taucher, Timothy T. Bartos, Keith E. Clarey, Scott A. Quillinan, Laura L. Hallberg, Melanie L. Clark, Melissa Thompson, Nikolaus Gribb, Brett Worman, and Tomas Gracias, Wind/Bighorn River Basin Water Plan Update Groundwater Study Level 1, Wyoming State Geological Survey, http://waterplan.state.wy.us/plan/bighorn/bighorn-plan.html

Wilma Tope

Mr. Kevin Frederick,

Thank you for allowing me to comment on the Pavillion Water Well Report and Palatability Study .

The citizens of the Pavillion area have been severely adversely affected by the huge oil and gas development in the area,and the State of Wyoming must respond to their needs. Their water has been ruined, and their property values have fallen extensively.

In the study it reports the water quality tests were from 2007. I think this is very significant, as this testing was done after the oil and gas had been developed in the area for many years. This water test could have been in no way called the baseline. Also, the Wyoming DEQ has allowed oil and gas development in drinking water aquifers in the area, which is a direct violation of the federal governments requirement to protect groundwater aquifers. Also, have all the old abandoned production and exploratory well holes from the beginning of exploration forward to the present been identified and completely plugged so comingling of aquifers can not happen? If not, is this issue going to be addressed?

As a Wyoming landowner and rancher, I understand the importance of water. Our Wyoming water is scarce, and we must protect it.

There have been casing leakages, leaking unlined pits, petroleum constituents found in drinking water and more in this area. According to your website, the "Wyoming Department of Environmental Quality (DEQ) has served as the state's regulatory agency charged with protecting, conserving and enhancing Wyoming's land, air and water for the benefit of current and future generations." This is a great mission, and I hope that it is carried out in the Pavillion contamination scenario.

Thank you,

Wilma Tope

Crook County Landowner and Rancher

Wyoming Outdoor Council

Please see attached pdf.

Wyoming Outdoor Council
wyomingoutdoorcouncil.org

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Wyoming Department of Environmental Quality
Attn: Water Quality Division, Pavillion Study
200 West 17th Street
Cheyenne, WY 82002

March 18, 2016

Dear Administrator Frederick,

On behalf of the Wyoming Outdoor Council, I write regarding the Pavillion, Wyoming Draft Report. The Outdoor Council has worked for nearly 50 years to protect Wyoming's clean air and water and the health and quality of life of Wyoming people.

The contamination of private water wells in the Pavillion area is a critical problem that threatens the health and well being of the affected residents. We urge the state to coordinate with Encana to ensure a reliable, long-term supply of clean water to rural Pavillion residents as well as the timely remediation of affected groundwater.

We understand that despite the studies undertaken, including this one, the precise cause of the contamination in every affected well in the area may be unable to be proven with perfect certainty. Indeed, the contamination of groundwater in Pavillion has been an unfortunate example for the need for baseline water testing prior to drilling operations. Whether the facts are more closely aligned to the EPA's initial findings or to this draft report, the state of Wyoming knows enough to require assertive and immediate actions to safeguard the health and well being of Pavillion residents.

This most recent draft study suggests that drilling activity could have been the cause of the water contamination, but does not rule out other possible causes. However, due to the presence of hydrocarbons in the water, which, anecdotally, appeared after the drilling took place, and due to the presence of old and faulty infrastructure, and due also to the fact that the drilling was taking place so unusually close in space to the drinking water aquifer (a situation, it's safe to say, the state should never allow to happen again) it is incumbent on the state to err on the side of protecting those residents whose lives and health have been negatively affected.

We also urge the state to continue to make progress in improving oil and gas regulations, such as strengthening the baseline water testing rule, as outlined below, to ensure that these instances occur with far less frequency—and if contamination does occur, to ensure that companies responsible for contamination are quickly and efficiency held accountable.

Here are a few suggestions for continued improvements to state regulations that would help prevent contamination in the first place and better address the problem of fault and accountability:

1) Require pitless drilling, or in the very least, ensure that all wastewater/drilling fluid/cutting pits are double lined.
2) Require mechanical integrity tests on wells in all cases to demonstrate each well meets performance standards.
3) Increase the radius from a water source in the baseline rule so that water wells within a mile of proposed oil or gas wells are tested for baseline data.
4) Require the use of tracers in fracking fluids when viable.

Thank you for your consideration.

Sincerely,

Amber Wilson
Environmental Quality Advocate
Wyoming Outdoor Council
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