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REPORT

American Petroleum Institute's Review of EPA's Pavillion December 8, 2011 Draft Report With Focus On Monitoring Well Drilling, Completion, Development, And Sampling Activities Related To Deep Monitoring Wells MW-01 And MW-02

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EXECUTIVE SUMMARY

This report comprises a detailed review by the American Petroleum Institute (API) of EPA's Pavillion groundwater investigations. API's review is concentrated on monitoring well drilling, construction, development, and sampling issues related to the two deep EPA monitoring wells MW-01 and MW-02.

Ultimately, the results of this review are expected to inform the public and provide decision-makers at all levels with high-quality scientific knowledge that can be used in decision-making processes regarding EPA's Pavillion investigation and their general scientific conduct related to unconventional oil and gas research.

API's review is important because these wells were drilled into, or near to, a known, non-commercial, natural gas producing reservoir and are significantly deeper than the typical nearby domestic water wells drilled in the area. Furthermore, this review shows that there are serious issues with drilling, construction, development, sampling, and apparent misinterpretation or inaccurate representations of groundwater quality results from these monitoring wells on the part of EPA.

The key general findings from API's review are: 1) the monitoring wells were so poorly constructed that it is very probable that the chemicals allegedly identified by EPA as groundwater contaminants associated with hydraulic fracturing were in fact introduced into the subsurface by the installation and construction materials of the monitoring wells themselves; 2) due to the flaws in the construction of these two monitoring wells, any groundwater quality data obtained from these monitoring wells is invalid; 3) EPA should withdraw the December 8, 2011 Pavillion study report and all associated data and conclusions related to these monitoring wells; and 4) the two EPA monitoring wells should be immediately abandoned since they are likely providing an ongoing source of groundwater impact, they cannot provide reliable data related to groundwater quality, and they cannot be remediated.

In using the terms "contamination" or "contaminants" within this report, it is in reference to EPA's drilling or monitoring well construction materials causing water-quality impacts to groundwater present within the monitoring well annulus and screen interval and any samples collected from these monitoring wells. It is not intended to be interpreted as meaning that there is widespread groundwater impact or contamination in the area, or in area domestic water wells.

The specific findings from API's review are:

- EPA's initial investigation in 2008 was focused on odor, taste, and water color complaints in groundwater from domestic water wells in the Pavillion area. EPA was not able to find any definitive connection to hydraulic fracturing in the early phases (Phases I and II) of the investigation. After construction of the two deep monitoring wells and development of methods to find glycols and alcohols at very low concentrations; EPA is still unable to find any of these or other compounds associated with hydraulic fracturing in the domestic water wells of the area and has not achieved the intended goal of the investigation;

- The depths to which these deep monitoring wells were constructed (785 and 989.5 feet below ground level) are far below the depths of typical domestic water wells in the area[2] and likely penetrated into non-commercial, naturally-occurring hydrocarbon/methane containing zones;

- The two EPA monitoring wells (MW-01 and MW-02) were designed and constructed in a flawed manner that is contrary to industry/regulatory standards and best practices, failing to follow EPA's own monitoring well construction guidance documents and Work Plan[5]. For example, standard annular seals (such as bentonite pellets or bentonite slurry placed over the sand pack interval) used to separate overlying cements from the well screen and formation interval were not used, resulting in probable contamination of groundwater in the screen intervals of both wells with cement. Commercially available cements contain glycols[25]. Glycols are compounds EPA is incorrectly attributing to hydraulic fracturing at Pavillion;
- Construction diagrams for these monitoring wells in the Draft Report[1] contained numerous and significant errors, such as representing the hundreds of feet of the 4-inch riser casing as stainless steel, when in fact it was black painted/coated carbon steel casing. While this some of this information has now been corrected, most peer reviewers are likely unaware of these corrections;
- Compounds EPA attributes to hydraulic fracturing at Pavillion; such as glycols, 2-butoxyethanol, total petroleum hydrocarbons, phenols, isopropanol, and other compounds likely were present in the drilling, completion, and construction materials used to install monitoring wells MW-01 and MW-02. Materials used down hole in monitoring well construction included painted/coated casing and painted sand baskets. Many of these compounds were not detected in the recent USGS study, but were allegedly found in some of the samples in EPA's studies;
- EPA incompletely documented their analysis of select additives/materials used down hole in the drilling of monitoring wells MW-01 and MW-02. Only 3 of 11 additives or materials used down hole were tested for organic compounds, and then only tested for approximately half of the organic compounds EPA is incorrectly attributing to hydraulic fracturing. EPA should have tested all 11 additives or materials used in monitoring well drilling or construction at Pavillion for all compounds they attribute to hydraulic fracturing. Analytical data is also present in the Draft Report[1] (table 2) that purports to show glycol analyses for 3 additives, but no laboratory analytical reports for these glycol analyses could be found on EPA's Pavillion website[12] which would support this finding;
- There is an apparent lack of adequate decontamination on equipment and materials used in monitor well construction at Pavillion as documented in the field notes from this project;
- The materials used in monitoring well construction (including chemical impurities) and lack of proper decontamination likely caused the contamination of the groundwater in these monitoring wells by numerous constituents, including many EPA claims are related to hydraulic fracturing, leading to inaccurate findings by EPA. These contaminants (if actually detected) were likely introduced into groundwater by EPA's monitoring wells;
- Groundwater from monitoring wells MW-01 and MW-02 may have been contaminated by EPA's use of non-filtered compressed air and surge blocks used in development of both wells. EPA has recognized[22] that hydrocarbon filters need to be inserted in the air stream to remove compressor oils (hydrocarbons), which can move with the air into groundwater and formation, causing contamination. There is no mention that hydrocarbon filters (or an oil-less compressor) were used by EPA in the Pavillion Draft Report[1] or field notes;

- USGS[4] refused to swab in their well development across the screen interval in MW-02 because of fear they would contaminate groundwater in this well with rubber materials scraped off the swabbing equipment. EPA apparently swabbed the screen intervals in both wells, potentially contaminating groundwater in both wells;
- EPA purposely developed very low analytical detection methods for this project specifically to find glycols and ethoxylated alcohols that are not available to standard commercial laboratories and which are not verifiable at these very low concentrations. EPA apparently failed to understand that some of the compounds they were targeting as being indicators of hydraulic fracturing were also present in materials or equipment used during their monitoring well construction, such as glycols in the cements used to construct their monitoring wells. That fact, along with an apparent basic lack of decontamination of their down hole materials, resulted in EPA likely contaminating the groundwater in these wells and incorrectly concluding that there is a connection to hydraulic fracturing and an aquifer impact at Pavillion;
- Whether or not these compounds are actually present in groundwater is also questionable since EPA's analytical methods have not been validated and the compounds were not always detected in samples from the same wells. Several other compounds such as isopropanol, ethanol, and naphthalene were detected in some of the drilling additives; while other compounds such as 2-butanone, acetone, xylenes, toluene, benzoic acid, benzyl alcohol, tetraethylene glycol, and diesel and gasoline range organics were found in trip, field, and/or equipment blanks;
- EPA failed to disclose in their Draft Report[1] that they had releases of anti-freeze (known to contain glycols), cement, and diesel fuel during field operations. It also appears certain field notes related to the alleged anti-freeze release may be missing from EPA's Pavillion website[12]. EPA should have been transparent and disclosed within the text of their December 2011 Draft Pavillion Report[1] that there was an allegation of an anti-freeze and cement release at monitoring well location MW-01 apparently caused by their operations. EPA should have further disclosed within this same Draft Report[1] their response, investigation, cleanup, and findings related to that allegation;
- EPA apparently used flawed sampling methods to collect samples from both of these monitoring wells, and data collected from these monitoring wells historically or in the future are fundamentally flawed and should not be used in technical evaluations. Data from EPA's low-flow sampling events show that key indicator parameters (pH, oxidation-reduction potential, and specific conductance) were never stable during sampling, and those data were ignored or misinterpreted by EPA. In addition, a key and critical component of low-flow sampling (drawdown measurements during well purging) was not done in monitoring wells MW-01 and MW-02 during the October 6, 2010 Phase III sampling event. During the Phase IV sampling event (April 19-20, 2011), no usable water level measurements were obtained during low-flow sampling of MW-02, and those obtained from MW-01 were not stable during low-flow purging and sampling;
- EPA's December 2011 Draft Pavillion Report[1] and all associated data should be withdrawn due to significant technical flaws in their investigation and apparent errors and/or misinterpretations of those data contained in that Draft Report[1]. Both monitoring wells should be immediately plugged and abandoned since they are likely providing an ongoing source of groundwater impact, they cannot provide reliable data related to groundwater quality, and they cannot be remediated;

- Based on the review of existing data, there does not appear to be a relationship between hydraulic fracturing and groundwater quality issues related to water supply wells in the Pavillion area. Once the existing 2 deep EPA monitoring wells are appropriately abandoned, API does not believe that further investigation of the area is warranted (including the drilling of additional deep monitoring wells) due to various well construction issues that have already been addressed in this report and EPA's own finding of the lack of hydraulic fracturing chemicals in the shallow water supply wells of the area; and
- If EPA continues to stand behind their Draft Report[1] and does not withdraw, then anyone who has submitted comments to EPA on Pavillion should be contacted by EPA directly and EPA should be required to let those commenters know of the apparent errors in their monitoring well construction diagrams, the errors in the associated discussion in their Draft Report[1], and missing facts and data not provided in that Draft Report[1] as identified and provided herein. In addition, those who provided comments and other interested stakeholders should be made aware of this API report.

AMERICAN PETROLEUM INSTITUTE'S (API) REVIEW OF EPA'S PAVILLION DECEMBER 8, 2011 DRAFT REPORT WITH FOCUS ON MONITORING WELL DRILLING, COMPLETION, DEVELOPMENT, AND SAMPLING ACTIVITIES RELATED TO DEEP MONITORING WELLS MW-01 AND MW-02

1.0 INTRODUCTION

American Petroleum Institute's (API) review of the United States Environmental Protection Agency (EPA) Pavillion investigation concentrated on monitoring well drilling, construction, development, and sampling issues related to the two deep EPA monitoring wells (MW-01 and MW-02) installed and developed by EPA contractor Shaw Environmental and Infrastructure (Shaw), with oversight from EPA, from June 7 to September 11, 2010 near Pavillion, Wyoming. This area is relatively unique in that the drinking water aquifer is in close proximity to commercial and non-commercial natural gas bearing zones. In most unconventional natural gas developments that utilize hydraulic fracturing within the United States, natural gas zones are typically separated from potable water zones or fresh-water aquifers by thousands of feet.

Ultimately, the results of this review are expected to inform the public and provide decision-makers at all levels with high-quality scientific knowledge that can be used in decision-making processes regarding EPA's Pavillion investigation and their general scientific conduct related to unconventional oil and gas research.

API's review is important because these monitoring wells were drilled almost 200 feet deeper than the Work Plan (Attachment 1, page 1-1) called for, into or near a known, non-commercial, hydrocarbon containing reservoir. These monitoring well depths are much deeper than the typical nearby domestic water wells drilled in the area. Furthermore, API's review shows that there are serious issues with drilling, construction, development, sampling, and apparent EPA's misinterpretation of groundwater results from these wells. All of these issues contribute to EPA erroneously finding a potential connection between hydraulic fracturing and groundwater impact in this area.

Documents reviewed included EPA's driller's field log notes (June 7 to September 11, 2010), EPA's on-site contract manager/geologist field notes (June 7 to September 11, 2010), EPA's December 8, 2011 Draft Pavillion Report[1] (Draft Report[1]), the S.S. Papadopulos and Associates April 26, 2012 report[2], the two new USGS reports[3,4] (2012) on Pavillion , and the Work Plans[5,6] (May, 2010) prepared by EPA/Shaw for the drilling/installation/development of deep monitoring wells MW-01 and MW-02 near Pavillion, Wyoming. Many of the findings below are new facts/observations derived from a detailed review of the drilling, installation, development, and sampling details for EPA Pavillion monitoring wells MW-01 and MW-02.

[1] http://www.epa.gov/region8/superfund/wy/pavillion/EPA_ReportOnPavillion_Dec-8-2011.pdf
[2] https://images.magnetmail.net/images/clients/IPAA_comm/attach/PavillionReport2012.pdf
[3] http://pubs.usgs.gov/ds/718/DS718_508.pdf
[4] http://pubs.usgs.gov/of/2012/1197/OF12-1197.pdf
[5] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/Workplan_For_Drilling/MW_Installation_Workplan_for_Drilling.pdf
[6] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/Workplan_For_Drilling/Attachment_1_Monitoring_Well_Installation_Narrative.pdf

The S.S. Papadopulos report information[2] has also been incorporated or expanded upon as it related to the issues of monitoring well drilling, installation, development, and sampling. Papadopulos[2] also conducted a detailed review of the laboratory analytical methods used by EPA, the analytical data itself, and EPA's interpretation of that data from their monitoring wells and apparently found numerous and significant flaws or errors in that Draft Report[1]. API's report focuses on a more thorough technical review of existing and new information obtained since the Papadopulos[2] report was completed concerning the drilling, completion, development, and sampling practices used by EPA in installation or sampling of their deep monitoring wells MW-01 and MW-02. The Papadopulos report[2] should be consulted and reviewed to understand the numerous technical flaws associated with the analyses of the groundwater samples and EPA's apparently flawed interpretation of those data.

Additional documents of record that discuss technical issues related to construction of EPA's monitoring wells are the Sterrett, R. L. report[7] dated March 2012 and the Mullen, M. report[8] dated April, 2012. These reports can be found in the comment section on EPA's Pavillion website[9] along with an April 18, 2012 letter[10] from Encana Oil and Gas providing these reports along with an analysis of the type of cement used in monitoring well construction at Pavillion for glycols.

The Sterrett report[7] provides a detailed hydrogeological evaluation of the Pavillion area and has concluded that both of EPA monitoring wells MW-01 and MW-02 were installed into known non-commercial natural gas bearing zones. In addition, Sterrett[7] provides a compelling analysis of why the groundwater from EPA wells MW-01 and MW-02 contain elevated pH values (between 11 to 13 S.U.), and concludes that it was related to cements used by EPA in the construction of these monitoring wells and their lack of appropriate development. The Mullen report[8] focused on the drilling and cementing operations related to EPA monitoring wells MW-01 and MW-02. Mullen concluded that the screen interval and adjacent formation interval in both wells are likely fouled with cement. As a result, cement is likely in contact with the water-bearing zones screened in monitoring wells MW-01 and MW-02, contaminating the groundwater (and causing very high pH).

Records were also reviewed related to EPA's shallow (between depths of approximately 8 to 48 feet) soil gas investigation conducted in the Pavillion area from July 14-22, 2010 as part of their Phase II investigation. Additional soil gas sampling at some locations was also conducted by EPA from September 22 to 26, 2010. However, EPA's Draft Report[1] provides no discussion or technical information related to that investigation, nor does it reference that an investigation of this nature was even undertaken. Although there are data from that investigation present on their website (field log notes and some analytical data), it appears that this investigation did not find significant methane or hydrocarbon presence in the shallow soil gases evaluated, a fact withheld and not disclosed in EPA's Draft Report[1].

Although EPA states in their Draft Report[1] (page 39) that ***"inorganic and organic constituents associated with hydraulic fracturing have contaminated groundwater at and***

[7] http://s398369137.onlinehome.us/files/Regulation.gov/PublicSubmission/2012%2f4%2f20%2fEPA%2fFile%2fEPA-HQ-ORD-2011-0895-0230-7.pdf

[8] http://s398369137.onlinehome.us/files/Regulation.gov/PublicSubmission/2012%2f4%2f20%2fEPA%2fFile%2fEPA-HQ-ORD-2011-0895-0231-7.pdf

[9] http://www.regulations.gov/#!docketDetail;dct=FR%252BPR%252BN%252BO%252BSR%252BPS;rpp=25;po=0;D=EPA-HQ-ORD-2011-0895

[10] http://s398369137.onlinehome.us/files/Regulation.gov/PublicSubmission/2012%2f4%2f20%2fEPA%2fFile%2fEPA-HQ-ORD-2011-0895-0227-7.pdf

below the depth used for domestic water supply.", they indicate that ***"further investigation would be needed to determine if organic compounds associated with hydraulic fracturing have migrated to domestic wells in the area of investigation."*** On page 27 of the Draft Report[1] EPA also states that ***"…the existing data at this time do not establish a definitive link between deep and shallow contamination of the aquifer."*** EPA's study did not find a definitive link between hydraulic fracturing and impact to domestic water wells in the area; a fact and important finding that EPA chose not to include in the "Extended Abstract" (similar to an executive summary) of their Draft Report[1].

The key general findings from this API review are:

1. EPA monitoring wells were intentionally drilled into, or near to, a known, non-commercial, natural gas producing reservoir and are significantly deeper than most of the nearby domestic water wells drilled in the area;

2. the chemicals identified by EPA allegedly as groundwater contaminants associated with hydraulic fracturing were in fact introduced into the subsurface by the installation and construction materials of the monitoring wells themselves;

3. any groundwater data obtained from these wells is invalid for EPA's intended purpose;

4. EPA should withdraw the Pavillion report[1], all associated data, and conclusions;

5. the two EPA monitoring wells should be immediately abandoned since they are likely providing an ongoing source of groundwater impact, they cannot provide reliable data related to groundwater quality, and they cannot be remediated; and

6. based on the review of existing data, there does not appear to be a relationship between hydraulic fracturing and groundwater quality issues related to water supply wells in the Pavillion area. Once the existing 2 deep EPA monitoring wells are appropriately abandoned, API does not believe that further investigation of the area is warranted (including the drilling of additional deep monitoring wells) due to various well construction issues that have already been addressed in this report and EPA's own finding of the lack of hydraulic fracturing chemicals in the shallow water supply wells of the area.

In using the terms "contamination" or "contaminants" within this report, it is in reference to EPA's drilling or monitoring well construction materials causing water quality impacts to groundwater present within the monitoring well annulus and screen interval and any samples collected from these monitoring wells. It is not intended to be interpreted as meaning that there is widespread groundwater impact or contamination in the area, or in domestic water wells.

Key technical issues pertaining to EPA's Pavillion investigation and EPA's December 8, 2011 Draft Report[1] are detailed in the following sections of API's report.

2.0 MONITORING WELL DESIGN AND CONSTRUCTION ISSUES

This section of API's report provides an evaluation and discussion of the design and construction or installation of EPA monitoring wells MW-01 and MW-02.

2.1 Failure to follow EPA'S approved Work Plan[5] in monitoring well design and construction

Shaw, on behalf of EPA's National Risk Management Research Laboratory (Ground Water and Ecosystem Restoration Division, Ada, Oklahoma), prepared a Work Plan[5] that provided design and installation details related to the drilling, completion, and development of the proposed deep and shallow monitoring wells that were to be installed as part of EPA's Pavillion, Wyoming groundwater study. This May 27, 2010 Work Plan[5] was titled ***"Final Monitoring Well Installation Work Plan, Pavillion, Wyoming.***" Specifically, this Work Plan[5] tasked EPA's on-site contractor (Shaw) with performing field activities associated with borehole drilling, monitoring well installation, monitoring well development, surface completions, and management of investigation derived wastes. The stated objective noted in the Work Plan[5] (page 1) was: ***"The objective of this investigation is to obtain data to determine if groundwater used for potable water at residences has been impacted by methane due to natural gas development (UOS 2008, 2009a,b.)"*** Monitoring well sampling activities were excluded from this Work Plan[5]. As stated within this Work Plan[5] (page 2, first bullet), a section included a separate attachment (Attachment 1[6] of the Work Plan[5]) that provided technical design and installation details as it related to monitoring well drilling, installation, and development. The Work Plan[5] was approved by both EPA and Shaw, with 3 members of EPA's project team signing or approving the document on June 1, 2010 and 3 members of the Shaw project team signing or approving the document either on May 27, 2010 or June 1, 2010. Field work began on June 7, 2010, approximately 6 days after formal approval of the Work Plan[5] by EPA. As outlined in Attachment 1[6] (page 1-1) of the Work Plan[5], the initial EPA investigation called for the drilling of up to 3 deep (800 feet) and 3 shallow (250 feet) monitoring wells. However, conflicting information as to deep monitoring well depth is also provided on page 2 of the Work Plan[5] where it states that the deep wells may be up to 1,000 feet in depth. In actuality, only 2 deep monitoring wells and no shallow monitoring wells were installed during this investigation; both of which were drilled approximately 200 feet deeper than the Work Plan[5] (Attachment 1[6]) called for.

API's review will show that the two deep monitoring wells were poorly designed with numerous technical deficiencies noted in the design, completion/installation, and development of these wells, along with a systemic failure to follow EPA's approved Work Plan[5].

A Quality Assurance Project Plan (QAPP[11]) was also prepared by EPA's contractor for the Pavillion investigation that covered mostly groundwater and soil gas sampling activities, and that QAPP (and later updated revisions) is available on EPA's Pavillion website[12]. The initial or revision "0" of this QAPP was prepared on April 19, 2010 by Shaw and approved by EPA on June 8-9, 2010. However, on page 13 of this QAPP it states that: ***"Shaw Inc. will develop a separate QAPP for drilling which will be reviewed independently of this document."***

A review of EPA's monitoring well installation Work Plan[5] and supporting documents appear to indicate that a separate QAPP (Appendix C of Attachment 1[6] to the Work Plan[5]) was prepared

[11] ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/QAPPs/SignedCopypavillionQAPPv0June09_2011.pdf
[12] http://www.epa.gov/region8/superfund/wy/pavillion/

specifically to cover the monitoring well drilling and completion activities; however, this specifically-referenced QAPP is not found on EPA's Pavillion website[12]. This specific QAPP should be provided for public review and comment, or if it does not exist an explanation should be provided as to why it was never prepared. The project QAPP also provides conflicting information on how deep the monitoring wells will be drilled, stating the monitoring wells will be drilled to depths between 800 to 1,000 feet.

Significant portions of EPA's approved Work Plan[5] (Attachment 1[6]) appear to not have been implemented or followed in the field during the Pavillion investigation as it related to monitoring well drilling, installation, and development. Work plans and various other types of plans (such as QAPP's) are integral parts of any large field investigation and typically are required to be prepared and approved by EPA or other state/federal regulatory agencies (such as on Superfund or RCRA projects) prior to starting investigative work. If done by the commercial sector, EPA and State regulatory agencies expect the approved work plans to be developed by experienced professionals and followed, and if deviations to the work plans are required, then those deviations should be approved by EPA or the oversight regulating agency before proceeding. That approval process should be thoroughly documented. Shaw, a contractor to EPA, was responsible for following the Work Plan[5] and overseeing the drilling, installation, and development of these deep monitoring wells, and there is no documentation relative to this process being followed at Pavillion.

No deviation requests from the approved Work Plan[5] have been provided by EPA, and no documents could be found that suggest a formal approval process was ever used at Pavillion when deviations from the monitoring well drilling and installation Work Plan[5] and Attachment 1[6] did occur. If such documents exist, EPA should provide them for public review and comment. In addition, there is no discussion provided in the Draft Report[1] that describes instances, or provides rationale, on why the Work Plan[5] was not followed. The following highlights significant examples of where EPA's approved Work Plan[5] was not followed:

- As noted in the Work Plan[5] (Attachment 1[6], page 1-1) the deep monitoring wells were supposed to be drilled to depths of approximately 800 feet below ground level (bgl). Instead they were drilled to depths of 987 feet bgl (MW-01) and 997 feet bgl (MW-02); far deeper than most of the domestic water wells in the area as pointed out in the Papadopulos report[2]. Papadopulos[2] noted (pages 5 and 6 of their report) that there are several instances where natural gas shows are present shallower than 1,000 feet bgl in the area of the monitoring wells, but as Papadopulos noted[2], EPA apparently failed to properly evaluate or understand the significance of that shallow natural gas occurrence, even though EPA knew that those shallow zones were potentially present. EPA's monitoring wells may have penetrated natural, non-commercial, hydrocarbon or methane containing zones or at least are far closer to those zones than typical domestic drinking water wells in the area.
- EPA's Work Plan[5], Attachment 1[6] (page 3-10), called for the use of ***"bentonite pellets"*** or a ***"bentonite slurry"*** to be placed immediately above the well screen sand or filter pack in both of the deep wells to a thickness of 5 feet **"…to *preclude transmission of grout from above into the sand pack or well screen."*** This statement clearly identifies that the preparer of this Work Plan[5] fully recognized the importance of providing a proper bentonite annular seal isolating the overlying cement grout from the well screen, associated sand pack, and formation. EPA failed to undertake this crucial step as discussed below.

The Work Plan[5] (Attachment 1[6]) also called for the well screen sand pack to extend 5 feet above the well screen followed by the bentonite seal. In addition, Attachment 1[6] to the Work Plan[5] states that if bentonite slurry were to be used, then at least 2-feet of fine sand would be tremied onto the top of the sand pack before placement of the bentonite slurry seal. The 5-foot bentonite seal was to set for a minimum of 10 hours before placement of the cement-bentonite grout mix on top of this bentonite seal. In both of EPA's monitoring wells, bentonite seals were not placed above the sand pack or well screen, a violation of known monitoring well construction practices and EPA's Work Plan[5]. The fact that no bentonite annular seal was used in monitoring wells MW-01 and MW-02 is confirmed and shown on EPA's own revised (November 6, 2012) and corrected well construction diagrams[13,14] for both of these monitoring wells. What actually occurred (but was not described in the Work Plan[5]) in these two monitoring wells was that a blue-painted sand basket was filled with approximately 1.8 feet of sand (unidentified as to type, source, or size) and cement grout slurry (apparently without the bentonite additive—another violation of the Work Plan[5]), was then placed (tremied) directly on top of the sand basket (welded to the top of the well screen), with only 1.8 feet of sand (and liner used in the sand basket), isolating the cement grout from the underlying well screen/sand pack interval and formation in both monitoring wells. The type, source, and size of sand used in the sand basket attached to the top of the well screen were not identified along with the composition of the sand basket liner. Failure to use the bentonite seal along with poorly placed sand resulted in grout penetration into the monitoring well screen and formation interval.

- The well screen consisted of a pre-packaged 4-inch, 20-foot long, 20-slot (0.020 inch), stainless steel screen surrounded by a pre-packaged sand filter pack (extending the diameter to 8.5 inches), therefore, only 1.8 feet of sand placed in the lined sand basket separated the well screen/filter pack and adjacent formation from the overlying cement grout. This completion is contrary to the design outlined in the Work Plan[5].
- In addition, as noted in Attachment 1[6] (page 3-11) to the Work Plan[5], a cement-bentonite grout mix was to be placed (tremied) above the bentonite seal to land surface. The mixture was described in the Work Plan[5] as consisting of 5 pounds of powdered bentonite for each 94 pound bag of Portland Type II cement and 7 gallons of water. Bentonite is typically added to cement grout to reduce the likelihood of small cracks occurring that may compromise the annular seal. However, this sealing does not appear to have been done. Instead, Portland cement without the bentonite additive appears to have been used; a violation of the Work Plan[5]. Further, the cement grout mix utilized was not well documented in the field notes (mixture volumes not documented) and the water to cement mix ratio appears to be incorrect as will be discussed later in this report.
- The monitoring well development outlined in Attachment 1[6] (page 3-11) of EPA's Work Plan[5] called for the monitoring wells to be developed as follows: ***"Monitoring wells will be developed by surging the screen interval with a surge block and pumping to remove sediment."*** Despite this, EPA appears to have also used unfiltered compressed air, water brought from offsite, and bailers to develop these monitoring wells. None of these other well development methods were described in

[13] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/CompletionSchematics/MW01CompletionSchematic.pdf
[14] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/CompletionSchematics/MW02CompletionSchematic.pdf

the Work Plan[5]. The addition of unfiltered air or water from another location into a monitoring well can introduce contaminants into the groundwater, cause changes in groundwater chemistry, cause changes in well yield due to air entrapment, and provide erroneous sampling data.

- The well development outlined in Attachment 1[6] (page 3-12) of EPA's Work Plan[5] also called for the removal of ***"A minimum of five times the well volume (saturated filter pack and standing water column) in each well will be removed during development. During monitoring well development, turbidity, pH, electrical conductivity, and temperature of the water will be measured at 30-minute intervals. Development of the monitoring wells will continue until water produced has a turbidity of no more than 10 nephelometric turbidity units. Field turbidity results will be reported on the final development log for each well. Three successive parameter readings within 10 percent of each other will be used as criteria for proper well development in conjunction with the turbidity reading. If, after 10 hours of well development, the turbidity criteria cannot be met, EPA will be notified. EPA approval will be required for monitoring wells that cannot meet the well development criteria of 10 nephelometric turbidity units."*** In EPA's 2011 Draft Pavillion Report[1] there is almost no discussion related to well development activities.

  Much of what was outlined in Attachment 1[6] of the Work Plan[5] for well development on monitoring wells MW-01 and MW-02 did not occur, was not documented properly, and/or related field notes are missing from EPA's Pavillion website[12]. A review of field notes taken during development from monitoring wells MW-01 and MW-02 show no documented measurements for temperature or specific conductance, as required by the Work Plan[5]. Other than sporadic measurements for pH in the drilling mud, only one measurement for pH during well development could be found, that in MW-02 on July 21, 2010. Limited turbidity readings were taken during development, and many of those were influenced by the introduction of fresh water from the surface to help remove heavy sediment loads in these wells during development, biasing the turbidity results.

  In the case of development for monitoring well MW-02, only approximately 1.6 casing volumes were removed during development, far less than the 5 casing volumes as required by the Work Plan[5]. There is no documented stability for pH, temperature, specific conductance, or turbidity in this monitoring well, or for water tested from well MW-01 during development and during subsequent sampling events. This lack of proper development is further evidenced during USGS's sampling event on April 24, 2012 where the pH declined significantly during the entire pumping and sampling event. USGS[3] correctly elected to not sample monitoring well MW-02 due to technical issues related to the development of that well, and being unable to utilize standard USGS sampling methods.

  The Work Plan[5] (Attachment 1[6], page 3-11) states: ***"Each monitoring well will be developed no sooner than 48 hours after completion but no later than 7 days after completion."*** Review of field notes actually show development in MW-02 started approximately 14 days following well completion, a violation of the Work Plan[5].

  The Work Plan[5] (Attachment 1[6], page 3-11) also states that: ***"Equipment inserted into any monitoring well shall be decontaminated before use."***

There is little documented evidence provided in EPA's December 2011 Draft Report[1] or EPA's Pavillion website[12] that decontamination of materials used down hole during development occurred for either well, another violation of the Work Plan[5].

- Standard equipment decontamination procedures do not appear to have been routinely followed during this investigation. The Work Plan[5] (pages 3-3 and 3-4 Attachment 1[6]) states: ***"All equipment that enters the borehole or could contact equipment that enters the borehole, will be decontaminated upon arrival at the site, between each borehole, and before demobilizing from the site."*** This decontamination procedure does not appear to have been fully followed, and materials routinely appear to have gone down hole without proper decontamination. The Work Plan[5] (page 3-10 of Attachment 1[6]) also stated what type of decontamination would occur: ***"All well completion materials shall be decontaminated by steam (plus non-phosphorous detergent if solids, oil, or grease are observed) and rinsed prior to installation."*** It appears from examination of field notes taken by the drilling contractor and EPA's on-site contract manager/geologist that decontamination procedures were not routinely followed, were woefully inadequate, and/or very poorly documented.
- The Work Plan[5] (page 3-10 of Attachment 1[6]) called for 2 centralizers to be used on the well screen, one at the top and one at the bottom of the screen. There is no record that centralizers were used on the well screen and photographs taken during screen installation show no centralizers on the screen. In fact, no centralizers appear to have been used during construction of either well, either on the well screen or on the riser pipe. Use of properly spaced centralizers is important in that it centers the screen or casing in the borehole, allowing for an adequate sand pack or grout seal placement.

There are several other areas where the Work Plan[5] apparently was not followed, or there was conflicting information presented in the Work Plan[5] such as one place which called for 4-inch diameter screen and riser (Work Plan[5], Work Sheet #14, page 1 of 3), and another place called for 5-inch diameter screen and riser (Attachment 1[6], page 3-10), but 4-inch was ultimately used. The Work Plan[5] (page 3-10 of Attachment 1[6]) also called for 5-inch threaded ***"steel"*** riser pipe (or Schedule 80 PVC pipe, glue welded joints) to be used from the top of the well screen to ground surface, and Teflon® tape was to be used on the threaded joints to insure a proper seal if steel pipe was used. Instead, no Teflon® tape was apparently used on the steel joints as shown by large gaps at the threaded casing joints visible on the down hole video camera log on monitoring well MW-02. These gaps can result in improper sealing in the area of the casing joints. Another area where the Work Plan[5] was not followed was that 10-inch diameter carbon steel casing was used in the well construction for the upper 100 feet of the well, whereas the Work Plan[5] (page 3-6 of Attachment 1[6]) called for 12-inch ***"steel"*** casing to be used. In addition, the Work Plan[5] (page 3-7 of Attachment 1[6]) indicated that fluid loss would be monitored and noted in the boring logs and field notes, but these very important observations do not appear to have been made or provided in the field notes.

2.2 Monitoring well construction material deficiencies

Figures 6a and 6b in EPA's December 2011 Draft Pavillion Report[1], show and describe details on how the two deep EPA monitoring wells (MW-01 and MW-02) were

constructed. Both of these monitoring well construction diagrams (and associated discussion within the text of that Draft Report[1]) have approximately 10 errors or inaccurate representations and/or missing details on how these monitoring wells were constructed. Most importantly: 1) EPA used carbon steel casing riser pipe, approximately 765 feet in MW-01 and approximately 969.5 feet in MW-02, which USGS reported[4] (page 2) as: ***"…4-in. inside diameter, threaded and coupled, black painted/coated carbon steel casing…"***; and 2) EPA used a blue-painted, 1.8 foot long lined sand basket in lieu of a bentonite grout seal above the well screen. The painted sand basket was welded to the top of screen in both wells.

Photographs provided in Appendix C[1] of that EPA December 2011 Draft Pavillion Report[1] confirm this statement by USGS[4]. The 4-inch black painted/coated carbon steel casing was used from ground level to the top of the well screen. EPA inaccurately represented this casing material as ***"4-inch stainless steel casing"*** from the top of the well screen to 100 feet bgl in their December 2011 Draft Pavillion Report[1] and in their well construction diagrams in that Draft Report[1] (figures 6a and 6b). If not for USGS[4] pointing out that ***"…4-in. inside diameter, threaded and coupled, black painted/coated carbon steel casing…"*** was actually used, this fact may have not come to light, because EPA failed to point out the discrepancy in the 2-plus years since these monitoring wells were constructed (constructed between June to September, 2010). Once EPA was shown this error, it subsequently placed newly corrected and revised well construction diagrams on its Pavillion website[12] (as of November 6, 2012). This casing is now described on the new well construction diagrams[13,14] on EPA's Pavillion website[12] as consisting of: ***"Thread and couple Hyundai Hysco ASTM A53A-E carbon steel pipe (4.03" I.D., 4.5" O.D.)."*** The importance of correctly identifying the casing materials is that coated casing may contain chemicals of interest and also require a higher level of decontamination (QA/QC) relative to stainless steel. This and other problems identified in this report are critical factors that need to be reported to individuals or stakeholders who provided earlier peer review comments on this EPA's Draft Report[1] since they would have been misled as to the actual monitoring wells construction details. A side-by-side comparison of the initial well construction diagrams (provided in the Draft Report[1]) compared to the revised diagrams is provided in **Appendix A.** The initial well construction diagrams found on EPA's website[12] are slightly blurry, and thus are slightly blurry when copied to **Appendix A**.

EPA[15] and others have published numerous articles on the use of various types of casing materials in monitoring well construction and their effect on groundwater quality. One key EPA document on this topic published over 20 years ago is titled ***"The Effects of Well Construction Material on Ground Water Quality",*** Llopis, J.L., Oct. 1991, USEPA 540/4-91/005[15]. On page 6, table 3, in this document[15] it states that for low carbon steel, galvanized steel and carbon steel use in monitoring well completions that: ***"These materials must be very carefully cleaned to remove oily manufacturing residues."*** EPA[15] has long recognized that carbon steel casing, such as used at Pavillion, should be extensively decontaminated to remove the oily manufacturing residues and the corrosion inhibitors typically used on the threaded joints.

[15] Llopis, J.L., Oct. 1991, The effects of well construction material on ground water quality, USEPA 540/4-91/005

EPA[16] and Nielsen[17], among others, have also recognized that use of carbon steel casing in monitoring well construction is problematic and not recommended due to the potential for the carbon steel to affect groundwater quality. Nielsen[17] notes (page 693) the following about the use of carbon steel in monitoring well construction: ***"On the basis of these observations, the use of carbon steel, low-carbon steel, and galvanized steel in wells used for ground-water quality monitoring should be discouraged in most natural geochemical environments."*** EPA[16] discussed the use of carbon steel in their Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells (EPA 160014-891034, March 1991, page 79) and reach a similar conclusion: ***"On the basis of these observations, the use of carbon steel, low-carbon steel and galvanized steel in monitoring well construction is not considered prudent in most natural geochemical environments."*** The addition of a coating on the carbon steel further complicates potential cross contamination and decontamination issues.

The painted sand basket was welded to the top of the screen in both wells. Welding flux and associated materials can contain metals and organics. There are no records to indicate that once the welding was completed, that the welded portions of the screen and sand catcher were ever decontaminated. If they were not decontaminated, chemicals associated with welding could impact groundwater. The picture (**Figure 1**) provided below (taken from the Draft Report[1]) below shows the blue-painted sand basket and black painted/coated carbon steel casing used by EPA at Pavillion.

Figure C21. Photograph of securing sand basket and casing above screen.

Figure 1. Photograph[1] of carbon steel casing and sand basket used in the construction of EPA's Pavillion monitoring wells.

[16] EPA , Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, EPA 160014-891034, March 1991

[17] Nielsen, D.M., Practical handbook of Environmental Site Characterization and Ground-Water Monitoring, Second Edition, 2006

Pictures of the blue-painted sand basket also show that something black (possibly rubber or plastic) was placed into the basket as a liner to retain the sand. EPA has not disclosed what type of material was used, its composition, what contaminants could potentially leach from it and if it was decontaminated and free of contaminants before going down hole.

The use of painted casing or painted sand baskets (or paint/coatings of any type) in monitoring well completions is essentially unheard of in the groundwater profession, and this fact alone makes any groundwater analytical data collected from either of monitoring wells MW-01 and MW-02 suspect. EPA still fails to point out (but USGS did in their report[4]) that this casing had a black paint/coating applied to it, and further, EPA still fails to point out on the new monitoring well construction diagrams[13,14] that the sand basket was painted blue and contained a black liner of some type, facts EPA were aware of when they posted these revised well construction diagrams[13,14] on their Pavillion website[12] on November 6, 2012, but apparently chose not to disclose.

The type of paint/coating used on this riser pipe and sand basket might be an epoxy, paint, varnish, primer, bituminous, coal tar, oiled/painted, zinc, or other types of paint/coating. Further, it should be determined if this riser pipe was also coated on the inside, as this particular pipe manufacturer appears to supply pipe of this type with interior coatings. This type of riser pipe may also have had rust inhibitors applied to the threads, and may have milling oils present, which needed to be removed through decontamination procedures.

Examination of water levels measured by USGS[3,4] in monitoring wells MW-01 and MW-02 shows that the water levels in both wells extended hundreds of feet above the screen interval and is in contact with the interior (and threads) of the 4-inch black painted/coated carbon steel casing. The down hole camera video of MW-02 clearly shows threads at most casing joints, and this indicated that the riser pipe was not fully seated, leaving many exposed threads. This same situation may exist in MW-01.

As briefly discussed previously, casing and cement baskets were not reported to have undergone significant decontamination before they were placed down hole. Decontamination of casing for hydrocarbons and other organic chemicals is critical if it is used in monitor well construction where volatile organic compounds (VOCs) and other organic compounds in sampled groundwater will be analyzed to the parts per billion (ppb) levels or lower. It is likely that this steel casing may have introduced to the groundwater organic and inorganic compounds, including hydrocarbons and 2-butoxyethanol (2-BE) allegedly reported sporadically in EPA's samples. It is essentially unheard of in the groundwater profession to use painted/coated materials down hole in an environmental monitor well completion, or casing of this type that has not undergone proper decontamination.

The limited distance between the top of the screen and overlying cement (only 1.8 feet), and lack of a bentonite seal, also likely resulted in cement invading portions of the well sand pack/screen interval, placing cement grout in direct contact with the well screen and the adjacent borehole wall in both monitoring wells, contaminating the sampled groundwater with cement (resulting in an elevated pH) and associated chemicals. This condition should be avoided in any monitoring well construction.

An examination of the field well construction drawings[18,19] provided by EPA's on-site contract geologist also show other discrepancies between what was reported on figures 6a and 6b in EPA's December, 2011 Draft Pavillion Report[1], and what was reportedly documented by EPA's on-site contract geologist, as described below for each monitoring well.

Monitoring well MW-01

EPA's on-site contract geologist reported that the top of the cement grout used as backfill below the well screen in MW-01 was at 797 feet bgl. This is in disagreement with the 785 feet bgl reported on figure 6a of EPA's December 2011 Draft Pavillion Report[1], a difference of 12 feet. In addition, the interval from 785 bgl (bottom of screen) and the top of the cement grout at 797 feet bgl as reported by EPA's on-site contract geologist was open and not filled with anything but drilling fluids/mud. This cement can also leach associated chemicals into the well screen interval.

On figure 6a, this interval (785 to 797 feet bgl) is inaccurately and incorrectly shown by EPA as being filled with cement grout. The fact that nothing was present other than drilling fluids in the borehole interval from 785 feet bgl to 797 feet bgl in MW-01 would increase the possibility of cement grout invading this open-hole interval and the well screen interval directly above. It would be virtually impossible to fully remove the drilling fluids left in this open interval through well development. Therefore, these fluids are almost certainly in contact with the well screen in well MW-01, along with cement.

Examination of the photographs provided in EPA's December 2011 Draft Pavillion Report[1] and **Figure 1** show the sand basket painted blue, approximately 1.8 feet long, possibly rubber/plastic lined, and welded to the top of the stainless steel well screen. A painted sand basket is not shown on figure 6a of EPA's Draft Report[1].

EPA's on-site contract geologist well construction diagram[18] shows centralizers were used at two locations on the riser pipe in MW-01 (none are being shown as used in MW-02), but no depths are provided. The centralizers are not reported or shown on figure 6a, (or on the November 6, 2012 revised well construction diagrams for MW-01) nor are they discussed in the field notes maintained by the on-site geologist or the driller, and their use is not described in EPA's December 2011 Draft Pavillion Report[1].

The well construction diagram (figure 6a) for MW-01 provided in the December 2011 Draft Pavillion Report[1] incorrectly indicates nothing but open space in the annular space between the 10-inch steel conductor surface casing set to 100 feet bgl and the 4-inch carbon steel casing, however, on the November 6, 2012 revised well construction diagram[13], this annular interval is shown to be filled with Portland cement. The new well construction diagram[13] for well MW-01 posted by EPA on November 6, 2012 also correctly shows that there is an open annular space between the borehole wall (9-7/8 inches) and the 20-foot long 8.5-inch pre-packed well screen, an open annular space of approximately 1-3/8 inches which, if evenly distributed, would surround the pre-packed well screen and borehole wall filled with nothing but fluids over this 20-foot interval. The fact that nothing was present other than fluids in this 20-foot borehole interval from 765 feet bgl to 785 feet bgl in MW-01 increases the probability that cement grout invaded this open-hole interval between the pre-packed sand pack and borehole wall. None of the

[18] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/DrillingLogsAndCuttingsDescription/CuttingsDescription-MW01.pdf
[19] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/DrillingLogsAndCuttingsDescription/CuttingsDescription-MW02.pdf

well construction diagrams for MW-01 indicate that powdered bentonite was added to the cement as required by the Work Plan[5], but rather, all construction diagrams for MW-01 indicate ***"Portland cement"*** was used.

Many of the inaccuracies and discrepancies highlighted above have been corrected on the newly posted (November 6, 2012) well construction diagram[13] for MW-01 on EPA's Pavillion website[12]. However, the new diagram[13] still does not show or disclose that painted/coated carbon steel casing or riser pipe (as first reported by USGS) and a painted sand basket (with some sort of black liner) was used down hole. Finally, it is very unlikely that previous peer reviewers are aware of these significant changes.

Monitoring well MW-02

Monitoring well MW-02 construction diagram provided in the Draft Report[1] (besides EPA's similar incorrect statements regarding use of the stainless-steel riser pipe versus what was actually used black painted/coated carbon steel), does not show the 1.8 foot long blue-painted (possibly black rubber or plastic lined) sand basket welded to the top of the well screen. No centralizers are shown on the on-site geologist field construction diagram[19] on figure 6b, or on the newly-revised (November 6, 2012) well construction diagram[14]. The well construction drawing (figure 6b) for MW-02 in the December 2011 Draft Pavillion Report[1] incorrectly indicates nothing but open space in the annular space between the 10-inch steel conductor surface casing set to 100 feet bgl and the 4-inch carbon steel casing. However, on the November 6, 2012 revised well construction diagram[14], this annular interval is shown filled with Portland cement. None of the well construction diagrams for MW-02 indicate that powdered bentonite was added to the cement as required by the Work Plan[5], but rather, all construction diagrams for MW-02 indicate only ***"Portland cement"*** was used.

There also appears to be a discrepancy in the screen placement interval. The on-site field geologist construction diagram[19] shows the depth of screen placement to be 960 to 980 feet bgl as does the well construction diagram provided as figure 6b in EPA's December 2011 Draft Pavillion Report[1]. However, additional work conducted by USGS in 2012 reported a discrepancy in this well's depth during down hole camera work. The revised well construction diagram[14] for MW-02 posted on EPA's Pavillion website[12] on November 6, 2012 show that the screen intervals has been revised downward by 9.5 feet, or the screen is now reported to occur from 969.5 feet bgl to 989.5 feet bgl. Open hole exists below the screen (screen bottom at 989.5 feet bgl) to 997 feet bgl (a distance of 7.5 feet) where the hole may be filled with drilling mud and/or cuttings.

The well construction diagram, for MW-02 provided in the December 2011 Draft Pavillion Report[1] and the on-site field geologist field diagram[19] reports the open hole interval below the screen to be filled with ***"cuttings and mud fill"*** materials, but the newly revised November 6, 2012 diagram[14] inexplicably states that that this material is now ***"mud recirculated prior to screen placement."*** It would be virtually impossible to fully remove the drilling fluids left in this open interval through well development. Therefore, these fluids are almost certainly in contact with the well screen in well MW-01, along with cement.

Many of the inaccuracies and discrepancies highlighted above have been corrected on the newly posted (November 6, 2012) well construction diagram[14] for MW-02 on EPA's Pavillion website[12]. However, the new diagram[14] still does not show or disclose that painted/coated carbon steel casing (as first reported by USGS) and a painted sand

basket (with some sort of liner) was used down hole. Finally, it is very unlikely that previous peer reviewers are aware of these significant changes.

The State of Wyoming Engineers Office and the Wyoming Board of Professional Geologists should conduct a review to determine if any well construction regulations or professional licensure requirements were violated. The State of Wyoming requires geologists who perform certain public groundwater investigations to be licensed through the Geologists Practice Act (Wyoming Statutes 33-41-101 through 33-41-121, Amended July 1997), and certain reports be sealed by a licensed geologist. EPA's 2011 Draft Pavillion Report[1] shows no indication that a Wyoming-licensed geologist or engineer sealed the Draft Report[1], and a recent search of the State of Wyoming registered geologist roster list[20] did not turn up anyone that was reported on-site (in field notes) for EPA or its contractors (non-EPA employees) during the investigation that was a licensed geologist in Wyoming. The Wyoming Board for Registration of Professional Engineers and Land Surveyors roster[21] was also searched to determine if EPA contractor field staff (non-EPA employees) used during EPA's field work at Pavillion were licensed and registered as engineers in the State of Wyoming. This search of the licensed engineering roster did not show anyone that was reported on-site (in the field notes) for EPA or its contractors during the investigation that was a Wyoming licensed engineer.

EPA's December 2011 Draft Pavillion Report[1] has undergone significant technical or peer review and comment by the scientific community in the past year and those technical reviewers and commenters almost certainly assumed the well construction diagrams and associated discussion in that Draft Report[1] were correct and accurate. Over 14,500 comments have been posted on EPA's Pavillion website[12] and almost all of them were provided prior to EPA correcting the well construction diagrams on November 6, 2012. These reviews also likely assumed that discussion and descriptions provided in EPA's December 2011 Draft Report[1] were accurate and correct, but as this review shows, many were not. If EPA continues to stand behind their Draft Report[1] and does not withdraw**,** then anyone who has submitted comments to EPA on Pavillion before November 6, 2012 should be contacted by EPA directly and EPA should be required to let those commenters know of the errors in these monitoring well construction diagrams, the errors in the associated discussion in their Draft Report[1], and missing facts and data not provided in that Draft Report[1] as identified and provided herein. In addition, those who have provided comments and other interested stakeholders should be made aware of this API Report.

2.3 Lack of centralizers on steel riser pipe and screen may affect annular seals

As discussed previously, centralizers appear to not have been extensively used (if at all) in the construction of the deep EPA monitoring wells MW-01 and MW-02. Centralizers position the riser pipe centrally in the borehole whereas a uniform placement of the cement grout would surround the pipe and provide a proper seal between the borehole wall and the riser pipe. Proper cement bonding and placement is important to prevent cross-communication between groundwater zones, or entry or movement of groundwater from/into zones other than the screen interval, which can provide misleading results. Without centralizers on the riser pipe, the pipe will be centered in some areas, touching the borehole walls in other, which results in an uneven cement placement surrounding the casing resulting in a poor annular seal. EPA's inadequate well completion likely created poor cement bonding in both of the deep monitoring wells.

[20] http://wbpg.wy.gov/RosterSearch.aspx

[21] http://engineersandsurveyors.state.wy.us/roster/rosterSearch.aspx.

Because both of these monitoring wells are completed into naturally occurring, but non-commercial, hydrocarbon and methane bearing zones, EPA's monitoring wells may be creating a conduit for groundwater (or gases) from these hydrocarbon zones to migrate into much shallower fresh water zones used by domestic users in the area. The newly posted (November 6, 2012) well construction diagrams[13,14] for EPA monitoring wells MW-01 and MW-02 show no centralizers were utilized.

3.0 MONITORING WELL MATERIAL ISSUES

This section of the report will focus on probable contamination of groundwater from EPA monitoring wells MW-01 and MW-02 by well drilling, construction, and/or or completion materials.

3.1 Probable presence of contaminants in monitoring well construction materials and drilling additives

Because of the manner that EPA drilled and completed its deep monitoring wells, the source of very small concentrations (ppb levels) of organic compounds purportedly measured in sampled groundwater from monitoring wells MW-01 and MW-02 cannot be determined precisely and scientifically. Such concentrations could come from contamination during well drilling, construction, development, and sampling; or natural sources. API previously discussed the probable lack of sufficient decontamination of pipe that was not made of stainless steel, the paint on the pipe and cement basket, and the proximity of cement to wells screens. Furthermore, there are additional problems.

On July 19, 2010 samples of six drilling additives were collected by Shaw in quart mason jars and included: 1) EZ Mud Gold, 2) dense soda ash, 3) Quik Trol Gold, 4) Penetrol, 5) Quik-Gel, and 6) Aqua-Clear PFD. The Shaw field notes state that these samples were hand delivered to EPA under chain-of-custody control. The laboratory analytical reports provided on EPA's Pavillion website[12] show additive samples were subsequently collected on both March 9, 2011 (for inorganic analyses) and again on July 7, 2011 (for limited organic analyses) and analyzed by EPA. It is not known if these additive samples were taken from the mason jars collected on July 19, 2010, but EPA should disclose the source of these samples analyzed between 8 to 12 months later. EPA should further disclose how and where these samples were stored (if collected from the mason jars) and preserved during the 8 to 12 month period and if they were processed under chain-of-custody control. The validity of analyses made 8 to 12 months after sample collection needs to be addressed by EPA.

EPA appears to have incompletely documented their analysis of select additives used down hole in the drilling of monitoring wells MW-01 and MW-02. Analytical data is also present in laboratory reports that purport to show additive analyses, but this data was not discussed in EPA's December 2011 Draft Pavillion Report[1], and some sample analyses were not referenced as to source or type. Problems identified in review of the additive analyses include:

- No analytical data could be found on EPA's Pavillion website[12] that provides measurements of ethylene glycol and diethylene glycol in drilling additives. EPA conclusions related to the potential for the natural gas industry to contaminate drinking water supplies relies in part on results that purportedly show non-detected values of these two compounds in the three drilling additives Aqua-Clear PFD, Penetrol, and EZ-Mud Gold (table 8 of EPA's December 2011 Draft Pavillion Report[1] shows non-detected (nd) values for ethylene glycol and diethylene glycol). Yet on page 35 of the same Draft Report[1] EPA states that: ***"ethylene glycol, which was widely used for well stimulations, required additional method modification and was not analyzed during this investigation."*** The results for ethylene glycol in table 8 of EPA's December 2011 Draft Report[1], contradict this statement. EPA should disclose and provide those glycol analyses. EPA should

also disclose if they tested any of the drilling additives for triethylene glycol, propylene glycol, and tetraethylene glycol, and if so, those results should be provided. Testing for propylene glycol, tetraethylene glycol, and triethylene glycol were routinely done or attempted on the groundwater samples collected during Phase IV sampling.

- EPA should disclose if they analyzed for 2-BE in any of the drilling additive compounds used during monitoring well construction, and if they did, those results should be publically provided, as well as those for all other compounds EPA considered potentially related to contamination by the natural gas industry at Pavillion and were found in samples collected from their monitoring wells. EPA routinely tested groundwater samples collected during Phase IV for 2-BE.
- There are two samples identified as Pav01 and Pav02 collected on July 7, 2011. The results for Pav01 showed elevated levels of acetone, with detections of ethanol, isopropanol, n-propanol, n-butanol, methylene chloride and tert-butyl alcohol. The results for Pav02 showed elevated levels of acetone, ethanol, isopropanol, isobutanol, tert-butyl alcohol, and benzene, with detections of n-propanol, methylene chloride, toluene, ethylbenzene, xylenes, trimethylbenzenes, and ethyl tert butyl ether. These results were not discussed in EPA's 2011 Draft Report[1], and no reference can be found on EPA's Pavillion website[12] that identifies the source water and type of these samples. These results were included with EPA's additive analyses. EPA should provide information as to the source and type of samples identified as Pav01 and Pav02, their significance, and why they were not discussed in their Draft Report[1]. In addition, no sampling of wells MW-01 or MW-02 occurred in July 2011, therefore the date that these samples were initially collected should be identified and EPA should discuss the validity of these sample results if they were collected previously and then analyzed 8 to 12 months later.
- Out of 11 additives or products used in the drilling or completion of these wells, organic analyses (which allegedly included glycols) were only done on 3 (Aqua-Clear PFD, Penetrol, and EZ-Mud Gold). Those not evaluated for organics included dense soda ash, Quik-Gel, Jet Lube Well Guard, Quik-Trol Gold, Portland cement, Quikrete (types I and II), calcium chloride, and sand. All of these materials were used down hole during monitoring well MW-01 and MW-02 completions.
- Table 2 (page 8) of EPA's Draft Report[1] provides analytical results for 5 of the 6 drilling additives collected for analyses, with the inorganic analytical data from Quik-Trol Gold missing from this table. Inorganic analyses were done for a select few parameters on 6 of the additives, but organic analyses done on only 3 of these additives. Review of analytical reports on EPA's website[12] shows that Quik-Trol Gold was analyzed for inorganics, including dissolved organic carbon (DOC), and those results should have been provided in table 2 of the Draft Report[1]. No organic testing results could be found for Quik-Trol Gold. EPA noted on page 7 of their Draft Report[1] that they did not analyze the drilling additives dense soda ash and Quik-Gel for organics by noting: ***"Organics were not analyzed in the dense soda ash and Quik-Gel because dissolved organic carbon concentrations were low and because of difficulties in analyzing the viscous gel (Quik-Gel)."*** EPA provides no rationale or discussion on why the Quik-Trol Gold was not analyzed for organics even though the DOC content was high, at 156 parts per million (ppm), 269 times higher than the DOC in the dense soda ash (0.58 ppm) and 75 times higher than the DOC in the Quik-Gel (2.11 ppm). EPA should provide

an explanation on why this product was not tested for organics, or if it was tested for organics, those results should be disclosed.

- EPA states in their Draft Report[1] (page 5) that it used City of Riverton, Wyoming municipal drinking water transported to the drilling site by ***"water truck"*** to mix with their drilling additives. The same water from the water trucks was also used in monitoring well development. Although EPA did some limited testing of the drilling additives, they appear to have done no independent testing of the water taken directly from the water trucks themselves used in drilling and development of both monitoring wells. It is common for water trucks to transport a wide variety of water types which can originate from different sources. To insure the water truck itself was not contaminated from past loads of contaminated water, samples are normally taken in environmental investigations to assess and document the water quality used in drilling or development of monitoring wells. EPA did not obtain samples of the water they actually used directly from these water trucks for analytical testing. Instead, after drilling of both wells were completed or substantially completed, and after development had begun or was finished on both monitoring wells MW-01 and MW-02, they obtained two municipal water-quality analyses from the City of Riverton which were apparently collected from locations within that cities municipal water system by city staff; one collected on July 26, 2010 (analytical report issued on August 11, 2010) and the other on November 10, 2010 (analytical report issued on November 24, 2010). Review of the City of Riverton analytical reports shows that limited organic testing was conducted on these samples, with only 5 of the approximately 21 organic parameters EPA is attributing to hydraulic fracturing at Pavillion actually analyzed in these water samples. Failure to sample the water actually used in drilling of monitoring wells is a departure from best industry practices and regulatory guidance.

EPA has so far failed to disclose whether the 1-inch PVC riser pipe (water-level tag line) placed several hundreds of feet into each monitoring well (to facilitate water-level measurement) were connected by threaded/coupled joints or glue-welded joints. EPA has disclosed how all other casing and piping used down hole was connected during this investigation (threaded/coupled) with the exception of this PVC pipe. Measurements of methyl ethyl ketone (2-butanone) and acetone in some of the monitoring wells sample, compounds used in PVC glues and primers, was detected in groundwater at elevated levels. EPA attributed the presence of 2-butanone and acetone to hydraulic fracturing. But if PVC glues and primers were used to connect the PVC pipe, they should be disclosed.

In addition, S.S. Papadopulos[2] note that glycols are widely used as cement grinding aids. The very cement used in the monitoring well construction could have contributed glycols to the sampled groundwater. All materials and additives used down hole should have been analyzed for organics by EPA, not just 3 of the 11 used, given the focus on potential organic contamination by the natural gas industry of drinking water supplies. Given the obvious importance of ruling out cross contamination by the drilling additives and well construction materials, it would have been prudent for EPA to analyze all compounds or materials used during these well installations for any organic or inorganic compound it attributes to hydraulic fracturing, including but not limited to Diesel Range Organic Hydrocarbons (DRO), Gasoline Range Organic Hydrocarbons (GRO), glycols, 2-BE, alcohols, VOCs, and semi-volatile organic compounds (SVOCs).

For example, the Material Safety Data Sheet (MSDS) for a widely used lubricant, reportedly used by EPA to lubricate drilling rod joints and the submersible pump casing joints, contains potassium aluminum silicates, calcium carbonate, castor oil, Di (2-ethylhexyl) dimerate, mica, organophyllic clay, titanium dioxide, mica, and polytetrafluorethylene (PTFE). The Di (2-thhylhexyl) dimerate itself contains synthetic hydrocarbon base oils, chloro-alkanes, dimer esters, ditridecyl adipate, and tritoly phosphate. Since EPA measured select organic compounds to the low ppb levels, the composition of all additive compounds or completion materials should be determined for the full range of analytical compounds evaluated by EPA at Pavillion down to these low ppb levels. EPA states in their Draft Report[1] (page 23) that the cause of detected tert butyl alcohol in groundwater from MW-02 is ***"unresolved."*** It seems doubtful that most of the down hole additive compounds used by EPA in well construction at Pavillion have been tested for this particular compound with detection levels down to the ppb levels.

An October, 2007 analysis of the lubricant (used by EPA) provided by the manufacturer shows that it was not tested for glycols, 2-BE, isopropanol and several other organic compounds allegedly found in groundwater by EPA at Pavillion. This product did contain total petroleum hydrocarbons (TPH) in the C12-C28 range at 8,000 ppm, and in the C28-C35 range at 8,000 ppm. A more recent analyses of this lubricant done as part of the NSF/ANSI Standard 61 testing (April, 2011), showed it also was not analyzed for isopropanol, tert-butyl alcohol, diethylene glycol, triethylene glycol, tetraethylene glycol, 2-BE, acetone, benzoic acid, acetate, formate, lactate, or propionate, compounds that have been allegedly detected in groundwater in the deep EPA monitoring wells. All lubricating compounds are not pure and can contain trace levels of contaminants not reported to the ppb levels that EPA is basing its conclusions on at Pavillion. A full list of organic compounds should have been analyzed on all additives used in the drilling and construction of these monitoring wells down to the ppb levels, especially those that are being attributed to hydraulic fracturing at Pavillion. The same should have been done related to the composition of the paints, corrosion inhibitors (if used), and oils on the 4-inch steel riser pipe and the sand basket used down hole. A sample of the compressor oils from one of the compressors used to develop these wells should also have been collected and tested for the full range of compounds analyzed at Pavillion since during development operations oil could have been introduced with the compressed air down hole.

As described above, at least 11 drilling and completion additives or materials were used down hole by EPA during the drilling of deep monitoring wells MW-01 and MW-02, but only 3 of the 11 compounds/additives appear to have been tested by EPA for diethylene glycol or other organics (benzene, toluene, ethylbenzene, xylenes, naphthalene, isopropanol, tert-butyl alcohol, acetone and trimethylbenzenes) that EPA attributes (see table 4 and page 26 of EPA's December 2011 Draft Pavillion Report[1]) to hydraulic fracturing at Pavillion to the very low ppb levels. However, these 3 additives do not appear to have been tested for approximately 11 other organic compounds EPA also attributed to hydraulic fracturing at Pavillion (see Table 4 and page 26 of EPA's December 2011 Draft Report[1]), specifically: 2-BE, phenols, benzoic acid, acetate, formate, lactate, propionate, 2-butanone, triethylene glycol, gasoline range organics, and diesel range organics, or those results were not provided.

The compounds naphthalene, ethanol, and isopropanol are found in some of the 3 additives tested. Other compounds such as 2-butanone, acetone, xylenes, toluene, benzoic acid, benzyl alcohol, tetraethylene glycol, and diesel and gasoline range

organics were found in trip, field, and/or equipment blanks associated with QA/QC programs.

Of the approximately 21 organic compounds (or compound groups) that EPA attributed to hydraulic fracturing (see table 4, page 26 of EPA December 2011 Draft Report[1]), only 10 of 21 were tested on materials or additives used (and only on 3 additives used down hole as described previously), and some of the test results could **not** even be found on EPA's Pavillion website[12] (glycols and 2-BE analyses in particular).

In fact, there is conflicting information on whether or not there were actually analyses conducted for 2-BE, ethylene glycol, diethylene glycol, triethylene glycol, propylene glycol, and tetraethylene glycol on the three drilling additives. Table 2 of EPA's December 2011 Draft Report[1] provide analytical testing results for ethylene glycol and diethylene glycol. But on page 35 of that same Draft Report[1], it states: ***"For instance, high performance liquid spectrometry/mass spectrometry was utilized for analyses of diethylene, triethylene, and tetraethylene glycols. Ethylene glycol, which required additional method modifications and was not analyzed during the investigation."***

It is believed that this statement is in reference to EPA's Region 3 Office of Analytical Services and Quality Assurance laboratory in Fort Mead, Maryland which did not analyze samples for ethylene glycol or propylene glycol during the Phase IV investigation, but did analyze samples for diethylene glycol, triethylene glycol, tetraethylene glycol, and 2-BE. As noted, the glycol and 2-BE analytical results for the three drilling additives are missing from EPA's website[12], but it appears these analyses were likely conducted by Shaw Environmental, an onsite contractor to EPA's Office of Research and Development laboratory in Ada, Oklahoma since all other analyses on the drilling additives were conducted by that laboratory. EPA's Shaw laboratory also conducted analysis for ethylene glycol, unlike the EPA Region 3 laboratory, which further suggests that EPA's Shaw laboratory conducted the glycol analyses on the drilling additives.

This ethylene glycol analysis is significant since EPA in their Draft Report[1] indicated that ethylene glycol was not analyzed during the investigation as noted previously. Yet, ethylene glycol test results (but no 2-BE) are reported for the three drilling additives (table 2, page 8 of the Draft Report[1]). It appears that EPA chose to selectively use glycol results from EPA's Shaw laboratory even though EPA had documented quality assurance issues related to that laboratory in association with 2-BE and glycol analyses during this project, and as a result chose not to use the glycol and 2-BE analyses conducted on groundwater samples collected during Phase IV in their Draft Report[1]. Further, if EPA's Shaw laboratory was used to test the drilling additives for glycols and 2-BE, then the quantitation limits for the glycols at the Shaw laboratory were at least two orders of magnitude higher that those low ppb levels reported at EPA's Region 3 laboratory. Although EPA routinely tested for 2-BE, no results are provided in table 2, page 8, of the Draft Report[1]**.** If analyses for 2-BE were conducted, they should be disclosed. In addition, other glycols were typically analyzed by EPA Shaw and Region 3 laboratories and those additional glycol analyses were not reported in table 2 of the Draft Report[1]. If additional glycol information exists related to the drilling additive analyses, they should be provided by EPA.

The quantitation limits during the Phase IV sampling event for the glycols at EPA's Shaw laboratory were 10 ppm for 2-BE, propylene glycol, ethylene glycol, diethylene glycol, and triethylene glycol. For tetraethylene glycol it was 20 ppm. The EPA Region 3 laboratory reportedly achieved quantitation limits of 10 ppb for 2-BE, triethylene glycol, and tetraethylene glycol. For the diethylene glycol it had an apparent quantitation limit of 50 ppb. EPA Region 3 did not test for ethylene glycol and propylene glycol.

If EPA, as it appears, chose to use and report the drilling additive glycol analyses from EPA's Shaw laboratory, then the suitability and credibility of those drilling additive results should be questioned. In addition, EPA should provide an explanation on why those data were used, when it was known by EPA that there was quality assurance issues associated with those particular analytes at that particular laboratory. Further, EPA's claim of not finding ethylene glycol and diethylene in the three drilling additive samples is misleading given the very high quantitation and method detection limits achieved at EPA's Shaw laboratory and the identified quality assurance problems associated with those analyses.

Table 2 of EPA's December 2011 Draft Report[1] has analyses posted for ethylene glycol and diethylene glycol as "nd", but there are no results posted for triethylene glycol or tetraethylene glycol, which also may have been analyzed. EPA concludes on page 36 of its December 2011 Draft Report that: ***"Glycols were not detected in concentrated solutions of drilling additives."*** The accuracy of this statement needs to be verified; only 3 of 11 additives used down hole were allegedly tested for glycols.

Further, EPA concludes on page 7 of their December 2011 Draft Report[1] that ***"…it is unlikely that ground water chemistry was impacted by drilling additives."*** EPA also states in their December 2011 Draft Report[1] (page 34) that ***"Contamination by drilling fluids and additives is inconsistent with analysis of concentrated solutions of bentonite and additives."*** Given API's review of EPA's additive evaluation program, these statements are an inaccurate representation of the facts. For example, no bentonite products used by EPA were tested for 2-BE, glycols, alcohols, or other organic compounds. It is probable that EPA impacted groundwater in their deep wells with materials and additives they used during drilling and in well construction, coupled with minimal decontamination procedures used during this project.

EPA guidance[22] (page 6-2) on testing additives used during drilling clearly states that: ***"Drilling fluids, drilling fluid additives, or lubricants that impact the analysis of hazardous constituents in groundwater should not be used. The owner/operator should demonstrate the inertness of drilling fluids, drilling fluid additives, and lubricants by performing analytical testing of drilling fluids, drilling fluid additives, and lubricants and/or providing information regarding the composition of drilling fluids, drilling fluid additives, or lubricants obtained from the manufacturer."*** In addition, EPA guidance[22] (page 6-16 and 6-17) on well materials state that: ***"Monitoring well casing and screen materials should not chemically alter ground-water samples, especially with respect to the analytes of concern, as a result of sorbing, desorbing or leaching analytes. Any material leaching from the casing or screen should not be an analyte of interest, or interfere in the analysis of an analyte of interest."***

[22] http://www.epa.gov/region9/qa/pdfs/rcra_gwm92.pdf

Glycols and 2-BE are not routinely analyzed in many environmental water samples, nor typically tested in products or materials that might be used in environmental monitor well installations. However, since these compounds were specifically targeted in this study by EPA and at very low ppb concentrations as indicators of contamination by hydraulic fracturing operations, it is imperative that these compounds should have been analyzed by EPA in the materials used in the deep monitoring wells installed at Pavillion. Both glycols and 2-BE are typically only tested upon special request, and commercial laboratory quantitation limits for these compounds vary significantly from what EPA's Region 3 laboratory claims to have achieved in their internal non-promulgated analytical methods. The commercial laboratories for the glycol compounds typically achieve a quantitation limit of approximately ±5 to 10 ppm, and for 2-BE typically ±10 ppb. EPA's Region 3 laboratory reports quantitation limits for glycols down to 10 ppb for tetraethylene glycol and triethylene glycol and 50 ppb for diethylene glycol (approximately 1,000 to 200 times lower than the commercial laboratories). EPA's quantitation limit for 2-BE is 10 ppb or approximately the same as the commercial laboratories. Currently, EPA laboratories are the only known laboratories that claim to get quantitation limits for glycol compounds down into the low ppb levels and it appears that these EPA test methods have not been adequately verified or validated.

EPA, during the Phase IV investigation, conducted glycol and 2-BE analyses on groundwater samples from monitoring wells MW-01 and MW-02 at both EPA's Region 3 and Shaw laboratories. Although these analyses were conducted at both EPA laboratories, there were significant differences noted between the two laboratories in the glycol and 2-BE results, quantitation limits, and method detection limits. Because of what EPA describes as quality assurance or false positive issues with EPA's Shaw laboratory, EPA's Region 3 laboratory analytical results were only used and reported in the Draft Report[1].

There is little information provided in the Draft Report[1] that indicated two separate EPA analytical laboratories were actually used for analyses of groundwater samples during the Phase IV sampling event. Likewise, there is minimal discussion on the differences in analytical results for glycols and 2-BE between the two EPA laboratories, which EPA attributed to false positives associated with the analytical test method used at EPA's Shaw analytical laboratory.

3.2 Cement grout mix used in monitoring well MW-01 and MW-02 completions not well documented and has impacted groundwater quality

The selection and formulation of annular sealants used in monitoring well construction is important to insure the annular space between the casing and borehole wall are properly sealed. Improperly formulated annular seals can lead to pathways for groundwater and contaminant movement through cracks or shrinkage of the seal or the material itself can contaminate the very groundwater it was designed to protect if not properly formulated and then isolated from the well screen interval. Nielsen[17] provides a detailed review of cement-based annular sealants and how they can affect the groundwater quality in a monitoring well if not properly formulated.

EPA's Work Plan[6] required the following cement mix: ***"Neat cement consisting of approximately 94 pounds portland Type II cement (in accordance with ASTM C-150), 5 pounds of powdered bentonite, and 7 gallons of water will be used."*** Neilsen[17], 2006 points out that it is important to have proper water to cement ratios to

insure proper and optimum reaction of the cement mix. Nielsen[17] further noted that: ***"Proper mix-water ratios should be adhered to as part of a documentable quality control program."*** However, no significant documentation of the cement-water mix appears to have been made during EPA's Pavillion investigation.

The cement-water mix proposed in EPA's Work Plan[5] (Attachment 1[6]) is contrary to the information and recommendations provided by Nielsen[17] (and by EPA[16]) which recommended a proportion of cement-to-water mix ratio of 94 pounds of Portland cement mixed with 5 to 6 gallons of clean water. EPA's Work Plan[5] (Attachment 1[6]) called for a water mix ratio of 7 gallons of water as noted above.

EPA's own technical guidance[16] also called for the use of 5 to 6 gallons of water per 94 pound bag of cement. Nielsen[17] further states: ***"Cement mixtures with more than 6 or 7 gal of water per bag of cement are not recommended, as they may develop voids which contain only water and may generate "bleed water" or "free water", which contains very high concentrations of soluble mineral matter from the cement. This may adversely affect water quality in the well for prolonged periods of time."***

Too much water added to the cement can also affect the physical properties of the cement. Nielsen[17] noted that: ***"If too much water is used (i.e., more than 6 gal), excessive shrinkage will occur upon setting, which means that the annulus will not be completely filled after the grouting operation."*** EPA's Work Plan[5] (Attachment 1[6]) called for 7 gallons of water per bag of cement, which is too much water, and thus, shrinkage and formation of "bleed water" may have occurred.

Nielsen[17] additionally states that: ***"Excess water that does not combine chemically with the cement, referred to as "bleed water" is very highly alkaline. This bleed water can separate from the slurry, percolate through or along the cement seal surrounding the casing, and infiltrate through or bypass the bentonite chip or pellet seal and secondary filter-pack sand, to contaminate water collected as a sample from the well (Evans and Ellingson, 1988)."*** Cement, because of its highly alkaline nature, typically has a pH between 10 to13 S.U.[17].

Neilsen[17] noted that: ***"All of these issues can result in severe and persistent effects on both the performance of the monitoring well (in terms of yield) and the quality of samples taken from the monitoring well. Placement of a thin grout directly on top of the primary filter pack, with subsequent infiltration, will result in the plugging of the filter pack (and potentially the well screen) with cementitious material upon setting. Additionally, the presence of high pH cement within or adjacent to the filter pack will cause anomalous pH readings in subsequent water samples collected from the well."***

Nielsen[17] indicated that: ***"Neat cement should never be placed directly on top of the primary filter pack in a monitoring well."*** However, cement grout appears to have been placed directly over the screen (the 1.8 foot sand basket) in both monitoring wells MW-01 and MW-02 by EPA, which likely resulted in movement of the cement (and alkaline cement bleed water) into the screened formation interval, contaminating any groundwater samples collected from these wells.

There is some limited documentation of the cement mixes in the on-site geologist field notes, but only for certain zones (they sometimes placed cement in stages). The best

documentation from monitoring well MW-01 is provided in the August 4, 2010 on-site geologist field notes[23] that state: ***"Used 16 bags @92.6 lb bags Quikcrete, Type I/II w/4 cups calcium chloride—mixed in 55 gal, drumed in batches of 4 bags-batch".*** This was a description of the cementing operations in MW-01 from 831 to 790 feet bgl, but this information does not provide the cement-water mix ratio since no volumes of water are noted that were mixed with the cement. The best documentation of the cement mix for MW-02 was provided in the on-site geologist field notes[24] for July 1, 2010 that state 13.9 pounds per gallon of cement grout mix was used in cementing from 940 feet to surface. Nielsen[17] states that for the mix ratio using 5 to 6 gallons of water to 94 pounds of Portland cement that: ***"Portland cement mixed with the water in proportions above yield a grout that would weigh from 14.5 to 15.2 lb/gal."*** The mix used by EPA is lower or lighter than this recommended weight to volume ratio, and is out of the recommended ranges.

The water quality of samples from monitoring wells MW-01 and MW-02 collected by EPA and USGS show elevated pH values (between 10 to 13 S.U.) typical of when too much water was used in the cement mix, and/or when the secondary filter pack or bentonite seal failed or were not used, bringing cement into direct contact with the sampled groundwater. This resulted in the intrusion of high pH cement and/or "bleed water" into the screen interval in both wells, affecting the water quality.

The analytical data collected from these wells should not be used in decision making, nor are the monitoring wells suitable for sampling; they should be plugged and abandoned.

3.3 Compounds EPA attributes to hydraulic fracturing at Pavillion present in monitoring well drilling additives and completion materials

Literature research would have shown that compounds EPA attributes to hydraulic fracturing at Pavillion, such as glycols, gasoline and diesel range petroleum hydrocarbons, diethylene glycol, phenol, 2-BE, phenols, isopropanol, and other compounds were likely present in their drilling/completion materials and/or drilling additives used in the drilling and construction of monitoring wells MW-01 and MW-02. For example, 2-BE and isopropanol are common in paints; glycols and phenols are impurities in most commercial cements. EPA only tested 3 of 11 additives or materials that were used down hole for organics, and they did not test those additives or materials that would have most likely contained compounds such as glycols, phenols, isopropanol, 2-BE, or gasoline and diesel range hydrocarbons.

The presence of most of the organic compounds (or their breakdown products as described in EPA's December 2011 Draft Report[1]) found in groundwater at Pavillion can also be present from contamination of groundwater by drilling/completion additives or well construction materials used by EPA in construction of these deep monitoring wells. The following table (**Table 1**) summarizes some of the likely contaminants present in well construction materials and additives used down hole by EPA at Pavillion and which are likely to have contaminated groundwater in EPA monitoring wells MW-01 and MW-02.

[23] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/DrillingLogsAndCuttingsDescription/FieldActivityLogE.pdf
[24] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/DrillingLogsAndCuttingsDescription/FieldActivityLogB.pdf

Table 1: Summary of probable organic contaminants present in well construction materials or additives used in construction of monitoring wells MW-01 and MW-02

Parameter allegedly detected in groundwater in EPA Pavillion Study	Source for compound in well construction materials or additives used in EPA monitoring wells MW-01 and MW-02
Ethylene glycol	Present in commercial cement. Present in anti-freeze. Used as a solvent in paints.
Diethylene glycol	Present in commercial cement. Present in anti-freeze. Used in paints.
Tetraethylene glycol	Present in commercial cement. In trip and field blanks at Pavillion.
Triethylene glycol	Present in commercial cement. Plastic manufacture. Present in anti-freeze.
Phenol	Present in commercial cement. Present in paints/coatings.
2-butoxyethanol	Present in paints, coatings, rust inhibitors, lubricants, hydraulic and oils milling/cutting
Naphthalene	Present in cutting oils and hydraulic oils.
Isopropanol	Present in paints, coatings, and rubber products. Present in anti-freeze.
Diesel range organics	Present in cutting oils and hydraulic oils. Present in Field Blanks. Present in lubricants.
Gasoline range organics and BTEX	Present in cutting oils and hydraulic oils. Present in Field Blanks. Present in lubricants.
2-butanone (MEK) and acetone	Present in PVC glues/primers. No information provided in EPA report on how the 1" PVC water line joints were connected, but if glue/primer used, then a source for the 2-butanone and acetone.
Acetate, benzoic acid, formate, lactate, 2-BE, phenols, propionate	Breakdown products of glycols, BTEX, or natural organics in groundwater

The compound 2-Butoxyethanol (also known as 2-BE, butyl cellosolve, and ethylene glycol n-butyl ether), was allegedly found in groundwater in the deep EPA monitoring wells during EPA's study at Pavillion. The 2-BE is soluble in water at tens of thousands of milligrams per liter (mg/L) and is very widely used as a solvent in most paints, spray lacquers, quick-dry lacquers, enamels, varnishes, latex paints and other protective surface coatings, as well as household cleaning products, cosmetics, cutting oils, hydraulic fluids, liquid soaps, herbicides, fabric dyes, dry cleaning fluids, silicon caulks, and inks. 2-BE is one of the most widely used compounds in the United States. The 4-inch threaded and coupled black painted/coated carbon steel casing and blue-painted sand basket used at Pavillion provide a potential source for this compound to contaminate the groundwater in these wells, especially at the low ppb levels. Further, 2-BE is found in hydraulic fluids and cuttings oils and is potentially a source since it

appears that no hydrocarbon filters were used to remove air compressor hydraulic oils during air development of both wells.

Little, if any, decontamination appears to have been done on the black painted/coated threaded steel casing and stainless steel screen. It is well known that this type of threaded steel pipe contains cutting or milling oils, which can contain this compound. Also, manufacturers of the type of threaded pipe (ASTM A53A-E) utilized by EPA may coat the threads with a rust inhibitor and then place plastic thread protectors over those threads. If used, the rust inhibitors frequently contain 2-BE and possibly isopropanol. Therefore, there are at least 3 materials (and probably many more) that were placed down hole that could contaminate the groundwater with 2-BE at the trace or low ppb levels reportedly found. Some information on this compound is also provided on the attached links.

- http://hpd.nlm.nih.gov/cgi-bin/household/search?tbl=TblChemicals&queryx=111-76-2 (references household cleaners and rust inhibitors);
- http://www.oilcenter.com/MSDS/0-2/1123.pdf (references pipe coatings); and
- http://www.astm.org/Standards/D330.htm (references ASTM standards related to 2-BE).

Published information concerning glycols, phenols, phenol-derivatives, and their association to cement can readily be found on the internet. Glycols are used in paint and plastic (non-rigid PVC and plastic) manufacture and substantially make up anti-freeze. Glycols and phenolic compounds (a source for phenols) are also widely used in the manufacturing of commercial-grade cement as a grinding agent. Grinding aids have been used for more than 50 years and the most common additives can consist of glycols, alkanolamines, and phenol type compounds. Cements are affecting the groundwater chemistry in monitoring wells MW-01 and MW-02, based at least on the high pH values, and EPA did not evaluate or analyze the cement used in well construction for glycols or phenolic impurities, nor did they even recognize or acknowledge in their December 2011 Draft Pavillion Report[1] that glycols or phenols could be present in the commercial grade cements used in their well construction. Encana has provided analysis[10] of the cement type allegedly used at Pavillion, and those results show diethylene glycol was detected at 8,000 ppb. The detection limits for the other glycols were approximately 4,900 ppb (not to the low ppb levels used by EPA).

EPA has the only known laboratory that has established analytical methods to analyze glycols down to the low ppb levels, and therefore, analyses to these levels should have been done by EPA on the various compounds and additives used down hole during the construction of these monitoring wells to ensure that false positives would not occur. Ervanne and Hakanen, 2007[25] provide a list of common grinding aids used in cement manufacture; those are noted below:

- **Ethylene glycol**
- **Phenol**
- **Diethylene glycol**
- Hydroxyethyl diethylenetriamine
- Tetraethylenepentamine

[25] http://www.posiva.fi/files/183/WR2007-15web.pdf

- Diethanolamine
- Triethanolamine
- Triisopropanolamine
- Aminoethylethanolamine

Some examples links are provided below that discuss glycols, phenols, and their association to cement:

- http://sciencelinks.jp/j-east/article/200518/000020051805A0703748.php
- http://www.posiva.fi/files/183/WR2007-15web.pdf
- http://www.wisegeek.com/what-is-a-grinding-aid.htm
- http://www.civilica.com/EnPaper-ETEC01-ETEC01_008.html
- http://www.ril.com/html/business/other_petrochemicals_deghome.html
  http://www.crushernews.com/grinding-aid-diethyl-gylcol-for-cement-mill/

3.4 Construction details of 1-inch PVC water-level tag line not disclosed

The November 6, 2012 revised monitoring well construction diagrams show that several hundred feet of a 1-inch I.D. Schedule 80 polyvinylchloride (PVC) water level tag line (installed for measuring water levels) was inserted into monitoring wells MW-01 and MW-02 to just above the pump. How these PVC pipe sections were connected was not disclosed in EPA's December 2011 Draft Pavillion Report[1] or revised well construction diagrams[13,14], although EPA clearly identified on these same diagrams that the 4-inch carbon steel pipe was threaded and coupled, and the 1-inch stainless steel pump pipe column was also identified as being threaded. There is also no mention in the driller's or EPA on-site contract manager/geologist field notes on how the 1-inch PVC pipe was connected. EPA should disclose how the PVC pipe was connected: 1) if threaded, or 2) if the pipe was connected by solvent welding using PVC glue and primer. It is well documented[26] that 2-butanone, tetrahydrofuran, cyclohexanone, 4-methyl-2-pentanone, and acetone (along with other organic compounds) occur in PVC glue/primer, and some of these compounds were also found in groundwater sampled from wells MW-01 and/or MW-02. The compounds cyclohexanone and tetrahydrofuran were not analyzed or reported during the Phase III and IV sampling events. Review of the Attachment 1[6] to EPA's Work Plan[5] actually allows solvent welding of the 5-inch I.D. Schedule 80 PVC pipe initially proposed as a possible casing material for the deep monitoring wells. Page 3-10 of Attachment 1[6] to the Work Plan[5] states: ***"The PVC pipe will be welded."*** Because solvent welding was proposed in EPA's Work Plan[5], almost unheard of in current environmental monitoring well practice when trace organics are being investigated, EPA needs to inform whether PVC glue/primer was used or not. EPA's own guidance[22] (page 6-38) on use of solvents to weld PVC pipe together states: ***"Solvent cementing of thermoplastic should not be used in the construction of ground-water monitoring wells."***

EPA, in their December 2011 Draft Pavillion Report[1] attributed 2-butanone and acetone in groundwater to possible breakdown products used in hydraulic fracturing. However, they could also have been in the glue and primer if used on the 1-inch PVC tag-line casing. Samples of any glue and primer used on the 1-inch PVC casing at Pavillion during EPA's study should have been analyzed for contaminants of concern to the ppb levels.

[26] http://www.spudfiles.com/spud_wiki/index.php?title=PVC_Glue

4.0 MONITORING WELL DRILLING ISSUES

This section of the report discusses problems identified during a review of monitoring well drilling, completion, and development field notes maintained by the driller or on-site field geologist or site manager. This section also describes details of incidents that occurred during the drilling of monitoring wells MW-01 and MW-02 that were either not documented in EPA's December 2011 Draft Pavillion Report[1], or documentation was limited.

4.1 Field notes were not properly kept and field notes for certain critical dates may be missing from EPA's Pavillion website[12]

Review of the field notes prepared by EPA's drilling contractor and EPA's on-site contract field manager/geologist during the drilling, installation, and development of EPA deep monitoring wells MW-01 and MW-02 (from June 7 to September 11, 2010) indicate that they were maintained on unbound single individual sheets of paper. This is highly unusual since EPA typically requires[27] field activities be documented in dedicated, bound, logbooks with sequentially numbered pages and entries made in water-proof ink especially for RCRA and Superfund investigations. If bound field logbooks cannot be used, then the field team should make provisions for the notes to be bound prior to going into the field. The same practice should be followed by the driller, although it is more common for drillers to maintain loose bound field notes.

In addition to the apparent violation of EPA's own guidance[27] on documentation of field investigations utilizing bound field books, field notes[28] are available from the driller and posted on EPA's Pavillion website[12] for June 7, 2010 to September 11, 2010 except for: June 13 (Sunday), July 2 (Friday) to July 12 (Monday), July 18 (Sunday), July 25 (Sunday), August 1 (Sunday), August 7 (Saturday) and 8 (Sunday), August 15 (Sunday), August 19 (Thursday), August 21 (Saturday) and 22 (Sunday), and August 28 (Saturday) to September 7 (Tuesday).

EPA's on-site contract manager/geologist field notes are available and posted on EPA's Pavillion website[12] for all dates between June 7, 2010 and September 11, 2010 except: June 13 (Sunday), July 2 (Friday) to July 12 (Monday), July 16 (Friday--second page of notes missing), July 18 (Sunday), July 22 (Thursday--upper portion of notes missing), July 23 (Friday--second page of notes missing), July 25 (Sunday), August 1 (Sunday), August 7 (Saturday) and 8 (Sunday), August 15 (Sunday), August 17 (Tuesday), August 19 (Thursday), August 22 (Sunday), and August 28 (Saturday) to September 7 (Tuesday).

The only dates when field notes were not provided jointly on EPA's Pavillion website[12] between the two EPA contractors were on August 17, 2010 where no notes are available for EPA's on-site contract manager/geologist (the driller worked that day and notes were provided) and the driller on August 21, 2010 (the on-site contract manager/geologist worked that day and notes were provided).

The field notes for the on-site contract manager/geologist on August 17, 2010, if collected, are of upmost importance, but may be missing from EPA's Pavillion website[12], since the driller was on-site on that date at well location MW-01 responding to a

[27] http://www.epa.gov/region8/qa/FieldOperationsGroupOperationalGuidelinesForFieldActivities.pdf

[28] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/DrillingLogsAndCuttingsDescription/DailyLogsFromDrillersJunSep2010.pdf

landowner complaint of an anti-freeze and cement release apparently caused by EPA's field operations. No field notes are available on EPA's Pavillion website[12] from the driller for August 21, 2010, but EPA's on-site contract manager/geologist worked that day and there are field notes on EPA's Pavillion website[12].

Neither EPA's on-site contract manager/geologist nor the driller have field notes posted on EPA's Pavillion website[12] for Thursday, August 19, 2010, two days following the report of both an anti-freeze and cement release, but notes are available on EPA's Pavillion website[12] for both EPA contractors on Wednesday, August 18, 2010 and Friday, August 20, 2010.

It is unknown if these EPA contractors were not onsite that particular day, or EPA just failed to provide field notes for that day on EPA's Pavillion website[12]. The same holds true for the dates of August 17, 2010 and August 21, 2010. The reason why no field notes are available or posted on EPA's Pavillion website[12] should be addressed for the dates in question.

It is noteworthy that for the 65 days EPA's contract driller was shown to be in the field working (per their field notes) on EPA monitoring wells MW-01 and MW-02 between June 7 and September 11, 2010, the only date where no EPA on-site contract manager/geologist field notes were found posted on EPA's Pavillion website[12] was on August 17, 2010, the day the driller was on-site at MW-01 investigating a landowner complaint of an alleged anti-freeze and cement release at that site apparently caused by EPA's field investigations.

Further, no field notes are available on EPA's Pavillion website[12] for either EPA contractor on August 19, 2010, even though notes show both firms worked on August 18 and on August 20, 2010. In summary, field notes may be missing from EPA's Pavillion website[12] for the following dates, mostly centered on the time of the reported anti-freeze and cement release and ***"cleanup effort"*** (see below for more detail) at MW-01 location:

EPA's on-site contract manager/geologist field notes potentially missing from EPA's Pavillion website[12]:

August 17, 2010

August 19, 2010

EPA's contract driller field notes potentially missing from EPA's Pavillion website[12]:

August 19, 2010

August 21, 2010

Dates of other missing field notes:

July 16, 2010:	EPA's on-site contract manager/geologist, second page of notes missing
July 22, 2010:	EPA's on-site contract manager/geologist, upper portion of notes missing on page
July 23, 2010:	EPA's on-site contract manager/geologist, second page of notes missing

Only portions of field notes are posted on EPA's Pavillion website[12] for EPA's on-site contract manager/geologist from July 16, 22, and 23, 2010, with pages either apparently missing or not fully copied onto that website[12]. All portions of those field notes should be made available, or explanations provided as to why no field notes exist for the dates noted.

All of the driller's field notes were reviewed and signed by EPA's on-site contract manager/geologist, so EPA's on-site contract manager/geologist should have been aware of any activities the drilling contractor was doing on-site, including investigating an alleged anti-freeze and cement release complaint apparently caused by EPA's field operations.

EPA also had a large group of employees that either visited the site on occasion, or were onsite a significant amount of time. Any field notes maintained by these employees pertaining to the Pavillion investigation should be made publically available and posted on EPA's Pavillion website[12]**.**

Both the anti-freeze and cement allegedly released during EPA's field investigation may have contained the same or similar chemicals that EPA is associating with hydraulic fracturing at Pavillion, such as glycols and phenols. If there was a verified anti-freeze and/or cement release, EPA should disclose if they followed their own spill or release reporting requirements to the Wyoming Department of Environmental Quality, EPA, or other State or Federal agencies. A check on the Wyoming DEQ website found no reporting of a glycol or cement release. If there were other EPA contractors or sub-contractors involved in the site investigation and cleanup of the anti-freeze and cement (outlined in driller's field notes in Section 4.2), they should be identified by EPA and copies of any field notes, investigation activities, cleanup activities, or testing results disclosed and made public. If any contaminated material was removed (such as contaminated soil) and disposed of offsite (potentially indicated in field notes ***"mob to town to city dump"***), then manifests or analytical results related to that material disposal should be disclosed and made public as would be required by any comparable contamination investigation

EPA should have been transparent and disclosed within the text of their December 2011 Draft Pavillion Report[1] that there was an allegation of an anti-freeze and cement release at monitoring well location MW-01 apparently caused by their operations. EPA should have further disclosed within this same Draft Report[1] their response, investigation, cleanup, and findings related to that allegation.

4.2 Apparent landowner complaint concerning anti-freeze and cement release at MW-01 well site on August 17, 2010

Field notes found on EPA's Pavillion Website[12] were examined and the following discussion relates to those particular notes found. EPA's **driller notes**[28] on August 17, 2010 at the MW-01 monitoring well site indicates a landowner allegation that requires further investigation and evaluation. The driller's notes[28] state: ***"Mob to Site. Site cleanup and investigation on anitfreez*** **[sic: antifreeze]** ***and cement acuazations*** **[sic: accusations]** ***from Property owner."*** This excerpt from EPA's driller field notes is provided below.

Shift? N/D | Date: 8-17-10 | Day of Week: Tue | Job #: 0072 | Rig # 2507 Parole V | Well# MW-1

START	END	LABOR DESCRIPTION
11:30	12:00	mob to site.
12:00	3:30	site clean up & investigation on Anit-freeze and cement Excavations from Property owerner.
3:30	4:00	mob to town to city dump.
4:00	4:30	unload at city dump.
4:30	5:00	pick up Nitrogen at Airgas & ~~Jeff~~ shipment at WY. rents.

In EPA's December 2011 Draft Report[1] there is no mention of an anti-freeze or cement release, or claim of a release by a land owner. Further, there are no EPA on-site contract manager/geologist field notes provided for this day (August 17, 2010) on EPA's Pavillion website[12] even though EPA's on-site contractor field notes are provided for the day before and day after this incident. A review of the August 18, 2010 on-site contract manager/geologist field notes (or any other of the on-site contract manager/geologist field notes) make no mention of an anti-freeze or cement release at MW-01 location, however they do suggest some sort of cleanup was occurring at monitoring well location MW-01 by the following entry noted below and taken from the August 18, 2010[23] on-site contractor field notes: ***"Mob to Randall MW-1 to check out Boarts cleanup effort."***

Shaw Shaw Environmental, Inc.

FIELD ACTIVITY DAILY LOG

DAILY LOG | DATE 8 18 10 | NO. | SHEET 1 OF

PROJECT NAME: EPA PAVILLION DRILLING | PROJECT NO.: 139703

FIELD ACTIVITY SUBJECT: METHANE PURGING FROM LOCKER MW-1 ~~PURGING STIMULATION~~

DESCRIPTION OF DAILY ACTIVITIES AND EVENTS:

0700	ARRIVAL ONSITE
0730	CHECK GAS METER ON LOCKER MW-1 READING 17 % LEL FID 3352 PPM
0745	TAILGATE SAFETY MEETING
0800	HOOKING UP NITROGEN ASSEMBLY
0830	MISSING PART OF ASSEMBLY - MOB TO RANDALL MW-1 TO CHECK OUT BOARTS CLEANUP EFFORT
0920	BOART OFFSITE FROM RANDALL MW-1 TO PICK UP PARTS AND WEIGH ONE TRAILER FOR DEMOB
1015	READING 17 % LEL ON LOCKER MW-1

It is highly unusual that EPA and/or its on-site contract manager/geologist would not be present to document this release complaint on August 17, 2010 or soon afterward, but instead leave it up to the drilling crew to investigate and possibly cleanup as the field notes seem to suggest. Normally, this complaint would be investigated, and if a release did occur, soil samples would be collected to document the depth and areal extent of the release impact. In addition, determinations would have been made of the quantities lost, the area and depth of impact, and the date(s) or duration of the release. Based upon regulatory requirements, this release may have been required to be reported to Wyoming or Federal regulating agencies. Finally, these areas should have been isolated from site operations in order to minimize potential cross contamination.

Similarly, if the allegation (or portions of the allegation) proved to be false upon investigation, then that fact should have been noted, along with the rationale for determining the allegation to be false or unfounded. Although monitoring well MW-01 drilling, installation, and development was completed by August 14, 2010, the submersible pump and associated piping were installed on August 25, 2010 and sampling occurred several times subsequent to this date.

At a minimum, any allegation of a release or cleanup of this type should have been documented prominently given the fact that glycols (anti-freeze) were some of the key compounds of interest by EPA in the Pavillion study, and in particular in groundwater from MW-01. Finally, there is a notation of a trip to the city dump following the statement about the site investigation and cleanup related to anti-freeze and cement. EPA should disclose what was taken to the city dump.

4.3 Leak of diesel fuel and other repairs referenced to coolant line replacement and fuel line replacement at MW-02

EPA reported in their December, 2011 Draft Pavillion Report[1] (page 5) that: ***"There were no incidents of fuel spillage used to power pumps and generators."*** This notation on page 5 in EPA's December 2011 Draft Report[1] is very specific as to fuel spillage related to pumps and generators fueling, but fails to mention other on-site equipment that could run on fuel, such as the drill rig engines, vehicle/equipment engines, or the air compressor engines.

Field notes collected by EPA's on-site contract manager/geologist and driller suggest that there was fuel spillage at the site. On July 13, 2010, at MW-02 location, the driller's field notes[28] state: ***"Put new fuel lines on rig."*** EPA should disclose why the fuel lines were replaced, and if any releases of fuel occurred prior to, or during, that fuel line replacement on the ***"rig."***

On the very next day, July 14, 2010 at 1655 to 1705 hours, EPA's on-site contract manager/geologist field notes[29] state: ***"diesel fuel lost from loose fitting, repaired."*** EPA should provide an explanation for any fuel loss that occurred at this site related to line replacement or repairs (reason, quantity, areal extent, and duration) and whether or not this loss occurred as a result of the fuel line replacement the day before. EPA should further disclose how the fuel loss was cleaned up, the type of equipment or materials impacted, the area impacted, the decontamination procedures (if any) used to clean the impacted equipment/materials and area, and whether any fuel impacts were noted on equipment that could have been used down-hole during the drilling of monitoring well

[29] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/DrillingLogsAndCuttingsDescription/FieldActivityLogC.pdf

MW-02. Samples of the fuels that were released at Pavillion during EPA's study should have been analyzed for a wide variety of contaminants to the low ppb levels. This analysis becomes very important when the chemicals of interest in an investigation include those that could be potentially present in the released fuel products, as in this case. There is no mention of a fuel loss or line repair in the driller's field notes[28] for July 14, 2010. If fuel losses occurred at any other time during this investigation, they should also be disclosed and discussed in the December 2011 Draft Pavillion Report[1].

On June 14, 2010 the driller's field notes[28] state: ***"change coolant hose on MS-1."*** It appears that drilling occurred at MW-02 on June 14, 2010. EPA should disclose why this coolant hose was changed and if there was a release or leak that caused the hose to be changed. If a release of coolant (typically anti-freeze, which contain glycols) did occur, what type of coolant was released and an explanation should be provided as to the quantity lost, areal extent of release relative to the monitoring well location, equipment or materials impacted, and duration of any release. If there was a release EPA should also disclose what was done in the way of cleanup and decontamination of the impacted area and on affected equipment/materials. Samples of the coolants that were released at Pavillion during EPA's study should have been analyzed for a wide variety of contaminants to the low ppb levels. This is very important because the chemicals of interest in this investigation include those that could be potentially present in the released coolant products. There is nothing in EPA's on-site contract manager/geologist field notes related to this coolant hose change.

In addition, the driller's field notes[28] on August 17, 2010 indicate that there was an allegation where anti-freeze and cement was released at monitoring well site MW-01. This release was discussed in Section 4.2. Again, there is nothing in EPA's on-site contract manager/geologist field notes on this alleged release.

EPA should have been forthcoming and transparent in discussing these incidents in their Draft Report[1].

4.4 Lost metal object down hole during drilling of monitoring well MW-02

In drilling of monitoring well MW-02 the drilling bit failed on June 18, 2010 at a depth of approximately 220 feet, which resulted in loss of a portion of the bit down hole. EPA's on-site contractor field notes[30] on June 18, 2010 state: ***"Drill bit was worn down by metal object in hole."*** The driller lowered a magnet into the borehole (on June 19, 2010) to retrieve the metal object and it was reported that 2 carbide teeth were removed by the magnet. It is further stated in EPA's on-site contractor field notes[30] on June 19, 2010 that: ***"put on tri-cone mill tooth 9 7/8 bit and going down to get through the rest of the metal obstruction at 220 Ft-BGS. Drilling at 220 Ft-BGS. Drilling at 230 Ft-BGS. Appears to have gone by object."*** These notes indicate that not all metal lost down hole was recovered, nor do they indicate what the metal object was that originally was lost down hole which apparently caused the drill bit to fail. There again is no discussion on this incident in EPA's December 2011 Pavillion Draft Report[1], and EPA should disclose what might have been lost down hole.

[30] ftp://ftp.epa.gov/r8/pavilliondocs/WellDrillingInformation/DrillingLogsAndCuttingsDescription/FieldActivityLogA.pdf

4.5 Inadequate documentation of water lost down hole during drilling and monitoring well development

In drilling with water or mud rotary, the on-site field geologist or driller usually attempts to document water losses down hole during monitoring well drilling. This is an important measurement to help identify more permeable zones. Those losses are documented as a standard practice to insure that when developing the monitoring wells, that volume, at a minimum (and usually several casing volumes more), is removed during well development. Review of field notes provided on EPA's Pavillion website[12] show this critical measurement was not made or was not well documented on either monitoring well, and therefore there is no way to know how much drilling water was lost to the formation during drilling. In addition, water was added during or following monitoring well completion to displace drilling fluids in the boreholes, and to aid in well development. There was a lack of detailed documentation that showed how much water was circulated down hole and how much water was returned, therefore, water or drilling fluid loss to the formation cannot be accurately documented or determined, however, loss to the formation is believed to have been in significant quantities. As noted earlier, the Attachment 1[6] (page 3-7) of the Work Plan[5] called for documentation of these fluid losses by stating: ***"Fluid loss will be monitored and noted in the boring log and field notes."*** EPA's December 2011 Pavillion Draft Report[1] made no mention that the Work Plan[5] was not followed on this issue.

4.6 Drilling timelines MW-01 (Randall site) and MW-02 (Locker Site)

A review of the field notes allowed for the development of general drilling and completion timelines for each of these monitoring wells. This general timeline is noted below for each monitoring well as developed to better understand the progression of drilling at each of the monitoring well sites.

MW-01 (Randall Site):

7/15-16/10:	Site setup and equipment staging
7/17/10:	Continue setup and start drilling
7/19/10:	Air drill to 20 feet, switch to mud rotary at 20 feet to TD
7/20-21/10:	Drilling mud rotary and setting shallow surface casing to 100 feet
7/22-28/10:	Mud rotary drilling to 984 feet
7/29/10:	Conditioning borehole
7/30/10:	Borehole Logging--CoLog
7/31/10:	Conditioning borehole, circulating mud
8/2-4/10:	Placing grout in over-drilled portion of borehole 797-984 feet
8/5-6/10:	Setting 4-inch casing and screen and cementing
8/09/10:	Site cleanup and rig down

MW-02 (Locker Site):

6/8/10:	Crew on site
6/8-13/10:	Site setup and equipment staging
6/14/10:	Start drilling, air to 20 feet, switch to mud rotary from 20 feet to TD
6/14-24/10:	Drilling mud rotary and setting shallow surface casing to 100 feet
6/24/10:	Reach TD at 997 feet

MW-02 (Locker Site Cont.):

6/25/10: Borehole logging—CoLog
6/26/10: Conditioning borehole, circulating mud from borehole
6/27/10: Set pre-packed screen and 4-inch casing
6/28-29/10: Attempting to grout, tremie stuck in hole
6/30/10: Grout borehole 14 cubic yards cement
7/1/10: Well finished, less development
7/2-12/10: Not on site, time off?
7/13-14/10: Site cleanup and rig down

5.0 MONITORING WELL MATERIAL DECONTAMINATION ISSUES

This section of the report provides a detailed evaluation of drilling equipment and well completion material decontamination procedures used in monitoring well construction at Pavillion. Lack of adequate and standard decontamination procedures has caused apparent contamination of the sampled groundwater from these monitoring wells.

5.1 Inadequate decontamination of monitoring well construction materials and down hole equipment

A major issue with EPA's drilling and construction of their monitoring wells at Pavillion appears to be an almost complete lack of adequate decontamination of materials used. EPA's Work Plan[5] specifically called for equipment and well materials to be decontaminated prior to placement down hole. Decontamination procedures are normally part of standard work plans and routinely noted in the site field notes by both the drilling contractor and the on-site geologist or manager. QA/QC plans associated with decontamination typically require water samples at various points to document that adequate decontamination occurred, and to identify potential contaminants that could be introduced into groundwater if decontamination was not adequate. These types of samples do not appear to have been taken and are an extremely important part of the QA/QC process to insure that contaminants present on well materials are removed prior to going down hole and contaminating the groundwater.

In the drilling of these two monitoring wells, there is a significant lack of field notes related to documentation of decontamination of equipment, well materials, and other materials/equipment that were used down hole. The only significant comment made by the drillers concerning decontamination was made on July 31, 2010 (MW-01) at 1:30pm where they state[28]: ***"…washed 4" in well casing with garden hose and covered with plastic."*** Use of a garden hose to clean casing is woefully inadequate and violates the Work Plan[5] that specifically called for steam cleaning of equipment and well materials along with phosphate-free soap.

The only other significant comment noted in the driller's field notes[28] on decontamination of equipment concerns decontamination of the piping used to connect the down hole submersible pump for MW-02. This notation[28] was made on September 8, 2010 as it was stated: ***"13:30-1:30 was deconing the stainless at car wash."*** This also was not the steam cleaning required in the Work Plan[5] and again violated the Work Plan[5]. Using a pressure washer at a car wash has the potential to introduce a wide range of contaminants associated with washing prior cars and engines.

The only significant notations made by the on-site manager or site geologist concerning equipment or well materials decontamination were made on June 27, 2010 at 13:00 hours on MW-02 where it is stated[24]: ***"deconing tremie pipe."*** The on-site geologist made a notation on July 31, 2010 (MW-01) sometime after 1220 hours that stated: ***"…began decon of riser for well. Stacked riser on plastic and covered. Complete decon on pipes not performed (pressure washer, soap). Pipes new. Caps on end. Road dust washed from pipes. No visual signs of O/G."*** The 4-inch black painted/coated carbon steel riser pipe used in MW-01 appears to have been stacked on plastic and a garden hose then used to wash off accumulated road dust. The field notes actually document that no decontamination was done on the 765 feet of painted riser used in that well. Decontamination of iron pipe is especially important since experienced

groundwater professionals know that this type of pipe often contains cutting or milling oils (and thread rust inhibitors) that are not visible to the naked eye. These cutting or milling oils and rust inhibitors must be removed through extensive decontamination efforts. This fact is even documented[15] in EPA's own guidance as noted earlier.

No mention is made of doing any decontamination of the stainless steel screen in either well, the blue-painted sand basket in either monitoring well, the black liner used in the sand basket, the 100 feet of 10-inch steel surface casing used in either well, the 960 feet of the 4-inch painted carbon steel riser pipe in well MW-02, the tremie pipe in well MW-01, the down hole logging tools used in both wells, the PVC "tag line" for water level measurements used in both wells, the bailers used down hole during development in both wells, drilling bits, air development lines in both wells, the swabbing tools/wirelines used down hole during development in both wells, the pumps used down hole in both wells, or the pump piping used down hole in well MW-01. The EPA should also disclose what the tremie pipe consisted of and how individual joints were connected.

Yet, EPA in its December, 2011 Draft Report[1] (page 8) states that: ***"Well Screens, sections of casing and tremie pipe were mounted above ground (never touched soil) and power washed (no detergents used) prior to deployment."*** This statement in EPA's December, 2011 Draft Report[1] contradicts what they reported in the field notes. EPA made apparent errors in presentation of decontamination procedures in at least 1 other place in EPA's December 2011 Draft Report[1], on page 34 of that report it states: ***"Well construction materials (screen and sections of casing) consisted of stainless steel and were power-washed on site with detergent-free water prior to use."***

Another mention of decontamination occurred on August 21, 2010 at 0930 where the on-site geologist field notes state[23]: ***"Sorting & Decon of piping started."***, but this note appears to reference decontamination of piping before it leaves the site as both wells were completed by this time. The field notes[23] in late August, 2010 also discusses some decontamination of the drilling rig and equipment, presumably before it left the site since construction of both wells was completed by then.

In summary, one of the most important parts of this project, proper decontamination of well materials and down hole equipment, was woefully inadequate, and procedures outlined in EPA's Work Plan[5] were not followed. The lack of decontamination has resulted in the probable impact to groundwater in these monitoring wells with a variety of chemical constituents. Lack of decontamination can result in detection of constituents in groundwater from drilling, well completion materials, or because of poor development or sampling protocols. In the Pavillion monitoring wells, the lack of decontamination and use of materials that contain contaminants could have allowed glycols, 2-BE, phenols, gasoline and diesel range hydrocarbons, and other compounds to impact the groundwater, especially at trace ppb levels.

6.0 MONITORING WELL DEVELOPMENT ISSUES

This section of the report describes details of monitoring well development and problems related to that development that likely caused apparent contamination of groundwater in both wells.

6.1 Well development prior to sampling inadequate for monitoring wells MW-01 and MW-02

Details pertaining to well development for EPA monitoring wells MW-01 and MW-02 must be understood in order to fully evaluate the results from subsequent groundwater sampling events. Development information from EPA's driller and contractor field notes have been summarized below for EPA Pavillion monitoring wells MW-01 and MW-02.

Development details MW-01 (Randall Site):

8/10/10: WL 168'. Trip into hole to 766.5'. Air lift water, bail below 766.5', no recovery noted.

8/11/10: WL 247.5'. Bail well, 12 bailers (36 gallons), then jet with water, trip rods to 766' and airlift. Reach bottom at 785'. Jet in 150 gallons of water and Aqua-clear from 777'.

8/12/10: WL 185'. Swab screen for approx. 1 hour, air-lift well to remove Aqua-clear, making water

8/13/10: WL 235', airlift well for approx. 8.5 hours, removed 7,369 gallons total

8/14/10: WL 243'

8/15/10 to

8/24/10: No development occurred

8/25/10: Set pump into well. Intake at 763.4'

8/26/10: Pump well 26 gpm for 1 hour, 10 gpm for 1 hour, and 7 gpm for 1 hour and 45 minutes. [Estimated total removed by pumping: 2,890 gallons]

Note: text in brackets is estimate made of purged water volumes made by API.

The total estimated volume of groundwater removed from MW-01 during development was likely a mix of drilling fluid water, introduced development water, and formation water and is conservatively estimated at approximately 10,259 gallons. Based upon likely static groundwater conditions in this well, a single casing volume is estimated at approximately 421 gallons. Therefore, approximately 24 casing volumes may have been removed during well development, although this figure is likely influenced by the drilling fluids lost and the water added and later recovered during development. In any event, all data reviewed strongly suggests that well MW-01 was not adequately developed to eliminate the affects to groundwater quality caused by the drilling fluids/cements and water introduced during attempts to develop this well.

Further, it appears that water from this well is turbid and is affected by the cement grouts used, as evidenced by the high pH (>12.0 S.U.) of the groundwater from this well. In addition, these initial very high pH levels are not indicative of background pH in groundwater in this area as the EPA has alluded to. Sampling by USGS[3] on April 24, 2012 further supports the evidence that this well was not fully developed as proven by the steady decline in pH during the purging of this well for that sampling event, when approximately 3 casing volumes were removed (to be discussed more fully in Section 7.1). This well had not been properly developed or purged prior to EPA sampling events

that occurred on October 6, 2010 and April 20, 2011, and the recent April 24, 2012 USGS[3] sampling event.

Development details MW-02 (Locker Site):

7/14/10: Unload hole of drilling fluids/muds (air lift), no volumes reported

7/15/10: WL >500'. Added 700 gallons water and Aqui-Clear to flush well

7/16/10: WL reported at 16.6 'bgl. Swab well screen 1 hr. Trip in rod to air lift water added to well, no recovered volumes reported

7/17/10: Report of only 94' (WL 886') of water in hole, swab screen 1 hour

7/20/10: Water level 771.2', bailing well 5 hours, recovered volumes reported to be approximately 48 gallons (full bailer is 3 gallons). Ending WL 842'. 21 bailer trips made. [Estimated formation removal 48 gallons]

7/21/10: Water level 822', bailing 10 hours, 21 gallons reported recovered, appears not all volumes reported. 63 bailers removed, 7 bailers had no water in them. Ending WL 970'. [Estimated formation removal 168 gallons].

7/22/10: Water level 938', swab screen 1 hr, 10 min; bailing well 2 hrs, removed 15 bailers, no volume reported, well dry [estimated formation removal 45 gallons]

7/23/10: Water level 928', bailing well 2 hours to dryness, 20 minutes, no volumes Reported [Estimated formation removal 31 gallons]

7/24/10: Water level 928', no development

7/26/10: Water level 874", bailing well, recovered 103 gallons in 36 bails [Estimated formation removal 103 gallons]

7/25/10 to 9/08/10: No development activity except occasional water level measurements

8/12/10: Water level 55 7' bgl, last measurement before 9/9/10

9/09/10: Fill well with 250 gal of water and install pump, pipe column, and sounder line

9/10/10: WL 14' bgl. Pump well 3 hours, 5 minutes, drop water level to 879.5', no volume reported but water removed combination of formation water and added water [Estimated formation removal 350 gallons]

9/11/10: Water level 845'. Lower pump 15 feet into screen; pump 1 hour at 1 gpm. No volume reported WL 949'; add 200 gallons of water and pump out, WL at 944 feet, Shaw takes water samples. [Estimated formation removal 60 gallons]

Note: text in brackets is estimate made of purged water volumes made by API.

The total estimated volume of groundwater removed from MW-02 during development was likely a mix of drilling fluid water, introduced development water, and formation water and is conservatively estimated at approximately 805 gallons. Based upon likely static groundwater conditions in this well, a single casing volume is estimated at approximately 515 gallons. Therefore, approximately 1.6 casing volumes may have been removed during well development, although this figure is likely influenced by drilling fluids and the water added and later recovered during development. In any event, all data reviewed strongly suggests that well MW-02 was not adequately developed to eliminate the affects to groundwater quality caused by the drilling

fluids/cements and the water introduced during attempts to develop this well. Further, it appears that groundwater from this well is highly turbid and is affected by the cement grouts used as evidenced by the high pH (>12.0 S.U.) of the groundwater and low yield of the well.

Following final development activities from September 9 to 11, 2010, where off-site imported water was added to the monitoring well, it appears that approximately 45.5 feet of this imported water was left in the bottom of well MW-02 from 944 to 989.5 feet bgl (including the screen interval), which represents approximately 64.2 gallons or 243 liters.

USGS[3] estimated that recharge of groundwater to this monitoring well is 0.44 gallons per hour (0.007 gallons per minute) or about 10.6 gallons per day. Using this value, it would take approximately 48.6 days for this well to fully recharge to static conditions or recharge to the equivalent of one casing volume (515 gallons). Given that development occurred over a 59 day period from July 14 to September 11, 2010, using the recharge rates cited by USGS[3], the recharge over a 59 day period would equal about 623 gallons (1.2 casing volumes) versus the 805 gallons (1.6 casing volumes) estimated from development notes. This well had not been properly developed prior to EPA sampling events that occurred on October 6, 2010 and on April 19, 2011. USGS[3] did not sample this well in April, 2012.

6.2 Probable contamination of groundwater during well swabbing

USGS[4] (in April-May, 2012) refused to swab in their monitoring well development across the screen interval in MW-02 because of fear they would contaminate this well with rubber materials scraped off the swabbing equipment. USGS stated (on page 88) in their Sampling and Analysis Plan[4] on redevelopment attempts on MW-02 that: ***"Note: Did not run block inside well screen as the screen's internal ribs would have cut the rubber block rendering it useless and leaving rubber material in the bottom of the well."*** It appears that USGS was concerned that any rubber ripped from the surge block (by the well screen) could have resulted in leaching of chemicals into the groundwater. The compounds 2-BE and phenols can occur in rubber products.

EPA apparently swabbed the screen intervals in both monitoring wells, potentially contaminating the groundwater in both wells. It has been reported that pieces of white plastic or rubber-like material have been found in well MW-02[31].

Samples of the surge block material that were potentially released at Pavillion during EPA's study should have been analyzed for a wide variety of contaminants to the ppb levels. This becomes important when the chemicals of interest in an investigation include those that could be potentially present in the surge block materials, as in this case.

6.3 Probable contamination of groundwater during air development

EPA has long recognized[22] that air compressors introduce hydrocarbons into the groundwater and on pages 6-10 and 6-11 the noted EPA guidance document states: ***"Unless an oil-less compressor is used, the risk exists for introducing some quantity of compressor oil into the borehole. This can occur even when oil***

[31] http://www.energyindepth.org/enormous-differences-between-epas-pavillion-data-and-usgss/

removing filters are used, because their effectiveness depends on careful maintenance. At best, the issue of whether oil has been introduced into the aquifer will remain suspect. There is generally no way to tell when compressor filters need changing because most drilling equipment has safety bypass valves that route the air around plugged filters." EPA's guidance[22] on using air goes on to state that: ***"The air from the compressor should be filtered to ensure the compressor oil is not introduced into groundwater. The QAPjP should specify when and how the filters should be monitored to prevent breakthrough."***

The use of air compressors in air drilling (same would hold true for air development) is also not recommended in this same EPA guidance document since it could alter the groundwater chemistry, as noted in more detail on page 6-10 of that document[22].

Review of the field notes indicate that commercial air compressor(s) were used for the drilling (upper 20 feet only) and then in the development of both monitoring wells.

There is no mention that hydrocarbon filters were used during EPA's Pavillion study. As noted previously, the Work Plan[5] did not call for these monitoring wells to be developed with air. It is unknown if hydrocarbon filters were used, but if they were not, the air stream would contain oils that would contaminate the groundwater with hydrocarbons, 2-BE, and possibly other organic/inorganic contaminants. Hydrocarbon filters are commonly used in the environmental drilling industry when drilling with air, or using compressors for air development of a well.

EPA should disclose and provide proof that hydrocarbon filters were indeed used during both the drilling of the upper 20 feet of borehole at each location, but more importantly, if they were in use, monitored, and maintained during the well development activities on monitoring wells MW-01 and MW-02. It does not appear that oil-less compressors were used at this site during this investigation.

Samples of compressor oils should have been collected from the compressors used at Pavillion during EPA's study and tested for a wide variety of contaminants to the low ppb levels. It becomes even more important to evaluate the compressor oils when the chemicals of interest in an investigation include those that could be potentially present in these oils, as in this case.

EPA provides virtually no discussion on the how these wells were developed, and fails to point out possible contamination of the groundwater or alteration of the groundwater chemistry by their well development methods.

7.0 GROUNDWATER SAMPLING ISSUES

This section of the report evaluates the monitoring well field sampling data for EPA's Phase III (October 6, 2010) and Phase IV (April 19-20, 2011) groundwater sampling events, and contrasts some of those data to the April 2012 USGS field sampling data. This review focuses on EPA's representations made in the Draft Report[1] regarding stability of groundwater quality field parameters during EPA's sampling events.

7.1 Groundwater quality not stable during monitoring well sampling and is affected by cement used during well construction

There have been 6 revisions (Revisions "1" to "6") on the initial QAPP[32] (Revision "0") developed for this project. The QAPP[32] mostly outlines the soil gas and groundwater sampling methodology and analytical methods. Version "0" (submitted on April 19, 2010 and approved on June 8-9, 2010) of the QAPP was the version in place during the deep monitoring drilling and development activities. Revisions "1" and "2" were prepared after the last monitoring well development activity was completed on September 11, 2010 but prior to the October 6, 2010 sampling of monitoring wells MW-01 and MW-02. Revision "2" (revised and approved on September 15, 2010) to the QAPP was the last revision prior to the October 6, 2010 groundwater sampling event. QAPP revisions "3" and "4" were prepared after the October 6, 2010 groundwater sampling event but prior to the April 19-20, 2011 groundwater sampling event on monitoring wells MW-01 and MW-02. Revision "4" (prepared and approved on April 13, 2011) was the last version prior to the April 19-20, 2011 groundwater sampling event. Revisions "5" and "6" were prepared after the April 19-20, 2011 groundwater sampling event on MW-01 and MW-02 and will not be discussed further. Therefore, revisions "2" and "4" were the versions of the QAPP in place prior to the October 6, 2010 and April 19-20, 2011 groundwater sampling events on monitoring wells MW-01 and MW-02, respectively. The initial QAPP and the 6 subsequent revisions can be found on EPA's Pavillion website[32]. The monitoring well sampling was evaluated by API to determine if the QAPP in place prior to sampling was followed.

In order to understand and evaluate EPA's sampling methods on monitoring wells MW-01 and MW-02 an important piece of information is the measurement of static groundwater levels, which are used to calculate purge volumes and to determine drawdown during low-flow sampling.

No information could be found on the Pavillion website[12] or the Draft Report[1] that showed static water levels were measured in association with the October 6, 2010 EPA groundwater sampling event on monitoring wells MW-01 and MW-02. However, static groundwater levels were measured by EPA in wells MW-01 and MW-02 in April 2011, after the wells had been sitting idle for approximately 7 months (since EPA's Phase III sampling that occurred on October 6, 2010). The static groundwater level in MW-01 was reported at 200.8 feet below measuring point (bmp) and in MW-02 at 264.2 feet bmp. The screen intervals in these wells are several hundred feet below these static levels (765-785 feet bgl in MW-01 and 969.5-989.5 feet bgl in MW-02). Therefore, approximately 564.2 feet of riser pipe interior are in contact with groundwater in

[32] ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/QAPPs/

monitoring well MW-01 and 705.3 feet of riser pipe interior are in contact with groundwater in MW-02.

The large difference in static water levels from the screen intervals could indicate two conditions: 1) the groundwater in the screen interval is under confined conditions, or 2) the groundwater from shallower zones is communicating with the screen interval. A poor cement annular seal or leaking casing joints/threads could allow groundwater from shallower depths to communicate with groundwater from deeper depths, or vice versa. These shallow groundwater levels also indicate that the interior of the riser pipe and associated threads are in direct contact with the groundwater in both monitoring wells. As noted, it is not clear if the interior of this pipe was treated with any paints or coatings, and the threads (and the casing itself) likely contain milling oils and/or rust inhibitors. There are no records to indicate that the interior of the riser pipes in either monitoring well were decontaminated; information strongly suggests no decontamination occurred.

Based upon the April 2011 static groundwater level readings the groundwater volume present in the casing, screen sand pack, and annular space between the sand pack and 9-7/8 inch borehole wall in well MW-01 is approximately 421 gallons (1,594 liters), and in MW-02 it is approximately 515 gallons (1,949 liters) using the screen depth reported on the newly posted well construction diagrams[13,14] on EPA's Pavillion website[12]. Therefore one casing volume in MW-01 is approximately 421 gallons (1,594 liters) and in MW-02 it is approximately 515 gallons (1,949 liters).

Calculation of the volume of water in just the 20-foot screen interval is also important since EPA is using the groundwater volumes only contained within the screen interval as a gauge for estimating volumes removed during low-flow sampling from the screened formation interval. A pre-packed well screen was used that is 8.5 inches in diameter and surrounds the 4.03-inch stainless steel screen The 20-foot screen interval in both wells contains approximately 47.6 gallons (180 liters) of groundwater. This includes water in the 4.03-inch inner diameter (I.D.) well screen, the pore water in the pre-packed sand surrounding the well screen, and the groundwater in the open annular space between the 8.5 inch diameter well screen and sand pack and the 9-7/8 inch borehole wall.

EPA's December 2011 Draft Pavillion Report[1] puts significant technical weight on the sample results from monitoring wells MW-01 and MW-02, which were sampled twice, once on October 6, 2010 (Phase III) and again on April 19-20, 2011 (Phase IV). The analytical results from these 2 sampling events provide the major basis for the findings outlined in EPA's December 2011 Draft Report[1]. Therefore, a discussion is needed to bring the sample results into better perspective and to evaluate compliance to the QAPP revision in place prior to these sampling events. The USGS and EPA also sampled these monitoring wells in April 2012, but after EPA's December 2011 Draft Pavillion Report[1] was issued.

Field notes of EPA's Phase III and IV sampling events are posted on EPA's Pavillion website[12]**.** Critical field notes related to these sampling events are missing from this website[12]. For example, figure 8 on page 12 of the December 2011 Draft EPA Report[1] shows water level measurement data for MW-01 collected during the Phase IV sampling event, but this data was not found on EPA's Pavillion website[12]. Therefore, there is no way to confirm the accuracy of this diagram.

No water level drawdown field data are found on EPA's Pavillion website[12] for either monitoring well during the Phase III and IV sampling events. Such records are critical to evaluate if EPA did their low-flow sampling correctly, and are needed to validate results and findings in their Draft Report[1]. In addition, field sampling data for MW-02 during Phase III sampling shows that some of those data were posted on the back sides of field notes, and those notes were not copied onto EPA's Pavillion website[12]. EPA should post those missing notes on the Pavillion website[12].

Revision "2" to the QAPP (page 13) required that water level drawdown be measured during monitor well purging and sampling during the April 6, 2010 Phase III sampling event by stating that "***The pumping rate will ideally maintain minimal drawdown. Drawdown will be manually measured using a Solinst Model 101 water level indicator before sampling and at a minimum of every 30 minutes during well purging."*** This critical and vital component of low-flow sampling appears to not have been done during the Phase III low-flow sampling event on monitoring wells MW-01 and MW-02, a non-compliance issue with the QAPP.

Neptune and Company, a contractor to EPA, conducted 3 field audits in September and October, 2010 to evaluate compliance with the QAPP. The September 23, 2010 audit was conducted related to EPA's gas sampling activities (soil and well head gas). A September 30, 2010 audit was conducted of Isotech Laboratories, and an October 5, 2010 field audit was conducted on EPA's groundwater sampling activities at Pavillion. The groundwater sampling field audit on October 5, 2010 did not actually observe sampling activities associated with deep monitoring wells MW-01 or MW-02. It appears that groundwater sampling at one shallow domestic water well was observed during this field audit. EPA, on Page 15 of the Draft Report[1] discusses this audit but fails to point out that sampling activities on both deep monitoring wells (conducted on October 6, 2010) were not actually observed by the audit team. The audit team did intend to observe a deep monitoring well sampling, but the equipment would not work on the day the audit team was in the field (October 5, 2010). No records could be found that indicated independent audits were conducted of EPA's sampling activities during the April 19-20, 2011 sampling event.

The Draft Report[1] (page 11) appears to provide inaccurate information regarding drawdown measurements taken during sampling of the deep monitoring wells. On page 11 of the Draft Report[1], it states (in context to sampling of both monitoring wells) that ***"Drawdown during pumping was measured with a sonic water level sensor obtained from Eno Scientific, Inc. (Model WS2020RPO)."*** This statement is inaccurate. Based upon the field audit conducted on October 5, 2010 (one day before actual sampling occurred) by Neptune and Company[33] (November 28, 2010 report[33], page 4), at monitoring well site MW-01 they state: ***"The deep well on the Randall property*** **[MW-01]** ***does not have a port that allows the sampling team to drop a water level monitor into the well, a planned component of the sampling operation. The lack of a port may also be the case at other deep wells but that was unknown during the audit. This prevents the sampling team from monitoring the water level with the Solinst Model 101 indicator during pumping."*** This lack of a means to measure water level changes during low flow sampling was noted as a

[33] ftp://ftp.epa.gov/r8/pavilliondocs/QA_Documents/Field_Audits/PavillionFINALTSAreport11_8_2010.pdf

"Nonconformance-Observation" and as ***"Deviations from the QAPP"*** in this field audit report[33] (page 4)***.***

The Draft Report[1] makes no mention that water level measurements could not be made during the October 6, 2010 sampling event on monitoring wells MW-01 and MW-02, but appears to instead provide inaccurate or vague statements that make it appear that water level monitoring did occur. EPA's own low-flow purging and sampling criteria (along with their QAPP) were not followed, which requires measurement of water levels during pumping while maintaining minimal and stable drawdown[34,35].

No usable water level drawdown data was obtained during the Phase IV low-flow sampling (April 19, 2011) of monitoring well MW-02. EPA in their Draft Report[1] states ***"The Eno Scientific well sounder was unable to measure the depth to water during most of the purging cycle perhaps due to a more rapid rate of decline in the water level in the casing."*** EPA's own low-flow purging and sampling criteria were not followed, which requires measurement of water levels during pumping while maintaining minimal and stable drawdown[34,35]. EPA's QAPP (Revision "4") deleted the water level measurement criteria prior to the April19-20, 2011 Phase IV sampling event, but EPA, apparently realizing the importance of this measurement in their own guidance documents on the low-flow sampling method, attempted to obtain drawdown readings.

During the Phase IV sampling event (April 20, 2011) on monitoring well MW-01, drawdown during the first 30 minutes of well purging was approximately 108 feet. The pump rate was decreased and the water level recovered approximately 56 feet of the 108 feet by the time sampling commenced. Again, EPA's own low-flow purging and sampling criteria were not followed, which requires measurement of water levels during pumping while maintaining minimal and stable drawdown[34,35]. In this case the drawdown was excessive and a stable drawdown was not achieved.

Improper application of the low-flow sampling method can result in samples being collected which are not representative of formation groundwater quality and/or those samples may include a significant fraction of the stagnant water present in casing storage. EPA did not follow its own guidance in low-flow sampling during the Phase III and IV groundwater sampling events. Any data collected from these wells during either event is viewed as suspect and should not be used in decision making.

When EPA sampled on October 6, 2010 (Phase III), EPA (page 11, December 2011 Draft Report[1]) stated that: ***"Purge volumes prior to sampling ranged from about 200 to 450 liters (Phase III)…"*** for monitoring wells MW-01 and MW-02. But the Draft Report[1] (or available field notes) does not specify which purge volume goes with which monitoring well. Therefore, assuming the 450 liter volume (119 gallons) conservatively applies for each monitoring well, less than 28%, but greater than 10%, of the full casing volumes were purged from either of monitoring wells MW-01 and MW-02 during the October 6, 2010 sampling event. The 450 liters would only be 2.5 times the screen interval volume and the 200 liters would be 1.1 times the screen interval volume. The QAPP (Revision "2") called for the removal of three times the water volume in the screen interval; therefore, the requirements of the QAPP were not met. There is no way to verify

[34] http://www.epa.gov/region6/qa/qadevtools/mod5_sops/groundwater/sampling/r1_lowflow.pdf
[35] http://nepis.epa.gov/Adobe/PDF/2000G23N.pdf

these purge volume numbers since field data related to the low-flow well purging/sampling is missing from EPA's Pavillion website[12]. EPA should post these field notes on the Pavillion website[12].

Water-quality data in EPA's December 2011 Draft Pavillion Report[1] for April 19-20, 2011 (Phase IV) show that samples were collected from MW-01 after purging 1,117 liters (295 gallons) or 70% of a full casing volume. In MW-02 sampling occurred after purging 1,249 liters (330 gallons) or 64% of a full casing volume. For the April 19-20, 2011 EPA sampling, the 1,117 liters purged from well MW-01 would be 6.2 times the screen interval groundwater volume, and in MW-02 the 1,249 liter casing volume purge would be 6.9 times the screen interval groundwater volume. As noted previously, there is no way to verify these purge volume numbers since field data related to the low-flow well purging/sampling is missing from EPA's Pavillion website[12]. EPA should post these field notes on the Pavillion website[12].

The pump in monitoring well MW-01 was set approximately 1.5 feet above and outside of the screen interval, at a depth of approximately 763.5 feet. In monitoring well MW-02, there is conflicting information where the pump was set. Information in EPA's December 2011 Draft Report[1] shows it set approximately 758 feet deep and about 2 feet above the screen (figure 6b). However, on EPA's Pavillion website[12], the new MW-02 well construction diagram[14] shows the pump set at 975 feet and within the screen interval, which is consistent with what the driller's field notes state as to pump setting. The screen interval on this newly posted construction diagram[14] also shows the screen 9.5 feet deeper (969.5 to 989.5 feet bgl) than shown in EPA's December 2011 Draft Report[1] (960-980 feet bgl), which would make it consistent with the down hole video log depth interpretation. The drawing in EPA's December 2011 Draft Report[1] may also have errors related as to the pump setting and screen placement in monitoring well MW-02. If the pump setting of 758 feet is accurate, the pump would be about 11.5 feet above the well screen in MW-02. But if the 975 foot pump setting depth is correct, then the pump would be within the well screen. This discrepancy should be resolved because the pump location affects the water quality from sampling because often, dissolved solutes and other constituents stratify in heterogeneous aquifers and accurate knowledge of the pump setting is also important in low-flow purging. Typical low-flow purging guidance requires the pump to be located within the screen interval[34,35]. However, revisions "2" and "4" of the QAPP required the pump to be located above the screen interval in both monitoring wells, an apparent conflict with EPA's own guidance[34,35] related to low-flow sampling.

EPA, on page 7 of their December 2011 Draft Report[1] states: ***"…because large volumes of ground water were removed during development and prior to sampling, it is unlikely that ground water chemistry was impacted by drilling additives."*** Based upon a review of the actual stated purge volumes from the October 6, 2010 and the April 19-20, 2011 sampling events, plus the volumes removed during well development (particularly from well MW-02), this statement is inaccurate. The fact that EPA purged far less that even one single casing volume from these wells back during their sampling on October 6, 2010 and April 19-20, 2011 casts doubt on the accuracy of their results and the accuracy of the above-noted statement on page 7 of their December 2011 Draft Report[1].

EPA also makes the comment for MW-01 for the April 20, 2011 sampling that ***"…ground water obtained during sampling was derived from the formation with***

no component of casing storage." This statement is also inaccurate because a full casing volume was not removed from this well (only 70% of a full casing volume was removed). To imply that all the water collected during the April 20, 2011 sample event was recently released from the formation is incorrect, because obviously there would be some contribution from casing storage (7 month old stagnant water). Also, the pump in well MW-01 was set outside of the screen interval and up into the casing removed from where formation water actually enters the well. In addition, figure 8 of EPA's December 2011 Draft Report[1] shows that there was not stabilization of the groundwater levels during low flow pumping, an EPA requirement for proper and accurate low-flow sampling.

Interestingly, EPA did not make the same argument for well MW-02 with respect to the extent to which it removed water from the casing prior to sampling, but instead relied on what they believed was equilibrium in pH and dissolved oxygen to imply that only formation water was sampled. USGS's April-May, 2012 study[3] shows that recharge to well MW-02 occurs at an extraordinarily slow rate of approximately 0.44 gallons/hour (0.007 gallons/minute). Therefore, during the 75 minutes the well was pumped by EPA on April 19 2011, somewhat less than one gallon would have recharged into this well; nearly 100 percent of the water sampled from this well on April 19, 2011 must have been water in casing storage, this seven month old stagnant water.

The sampling results for the October 6, 2010 Phase III event would have similar issues related to the portion of water derived from casing storage since even far less water was purged from either well (between 10% and 28% of a full casing volume). Therefore, the groundwater collected from wells MW-01 and MW-02 on October 6, 2010 would contain even higher percentages of water from casing storage, with nearly all of the water sampled from MW-02 being derived from casing storage. This water in casing storage is in direct contact with the interior of the painted riser pipe (including exposed threads), cement, drilling fluids, painted sand basket, lubricated pump column and pump, PVC tag line, and well screen in both wells. The contaminants in those materials could easily contaminate the groundwater with various compounds, especially glycols, hydrocarbons, phenols, and 2-BE. Following last attempted development on monitoring wells MW-01 (August 26, 2010) and MW-02 (September 11, 2010), the water is this casing set idle or stagnant for 41 and 25 days respectively, before sampling was attempted (on October 6, 2010), and then only a very small percentage of water in casing storage (far less than 1 casing volume) was removed prior to sampling.

EPA states in their Draft 2011 EPA Pavillion Report[1] (page 20) that: ***"Prolonged purging did not show decreasing pH trends (e.g., figure 9) and water chemistry results indicate that groundwater from the wells was highly undersaturated with respect to cement phases (e.g., portlandite), suggesting that cement was not the cause of the elevated pH."*** This statement is incorrect and inaccurate. EPA uses figure 9 (Phase IV field sampling results MW-02) of their December 2011 Draft Pavillion Report[1] to support their statement, but they also could have provided the same graphs as figure 9 for the Phase III and IV sampling events on monitoring well MW-01 (or the same graphs for MW-02 for the October 6, 2010 Phase III sampling event) all of which show unstable trends during purging/sampling for pH, oxidation-reduction potential, and specific conductance. In addition, purge times were short prior to initiating sampling during the Phase III and IV sample events (between 21 to 73 minutes), not prolonged.

Although the Phase IV sampling data for MW-02 are incomplete, what data that does exist does not suggest that the groundwater chemistry was stable during that April 19, 2011 sampling event on MW-02. Instead, EPA chose to use the one and only set of data that appears to support their sampling contention and ignore the three other sampling data sets that do not provide that same support.

Tables 2 and **3** summarize EPA's low-flow well purge/sampling data (pH, oxidation-reduction potential, and specific conductance) from MW-01 during the Phase III and IV sample events, respectively; **Figures 2** and **3** are the respective plots of those data.

Table 2: Summary of EPA's low-flow purge volume data for specific conductance, oxidation-reduction potential, and pH in MW-01, Phase III (October 6, 2010).

MW-01 Time of Measurement 10/6/2010 Phase III	Time Since Pumping Began, Minutes	Pump Rate Through Flow Cell, L/min	Specific Conductance µS/cm	pH, S.U.	Oxidation-Reduction Potential, Millivolts	Comments in Field Notes
9:09	0		5,090	12.46	196.4	Start Purge; degas alot
9:11	2		5,020	12.47	181.6	
9:13	4		4,561	12.38	165.3	
9:15	6	0.8 L/min	4,339	12.36	150.2	0.8 L/min
9:17	8		4,122	12.33	140.9	
9:19	10		3,845	12.29	132.5	
9:21	12		3,725	12.27	127.5	Less degassing
9:23	14		2,583	12.24	122.6	
9:25	16	0.7 mL/min	3,445	12.22	118.7	
9:27	18		3,265	12.18	114.7	
9:36	27		*3,265	*11.91	114.3	
Sample 9:30-10:00	21-51	---	---	---	---	Sample 9:30-10:00

*: Reported field parameters at sample collection

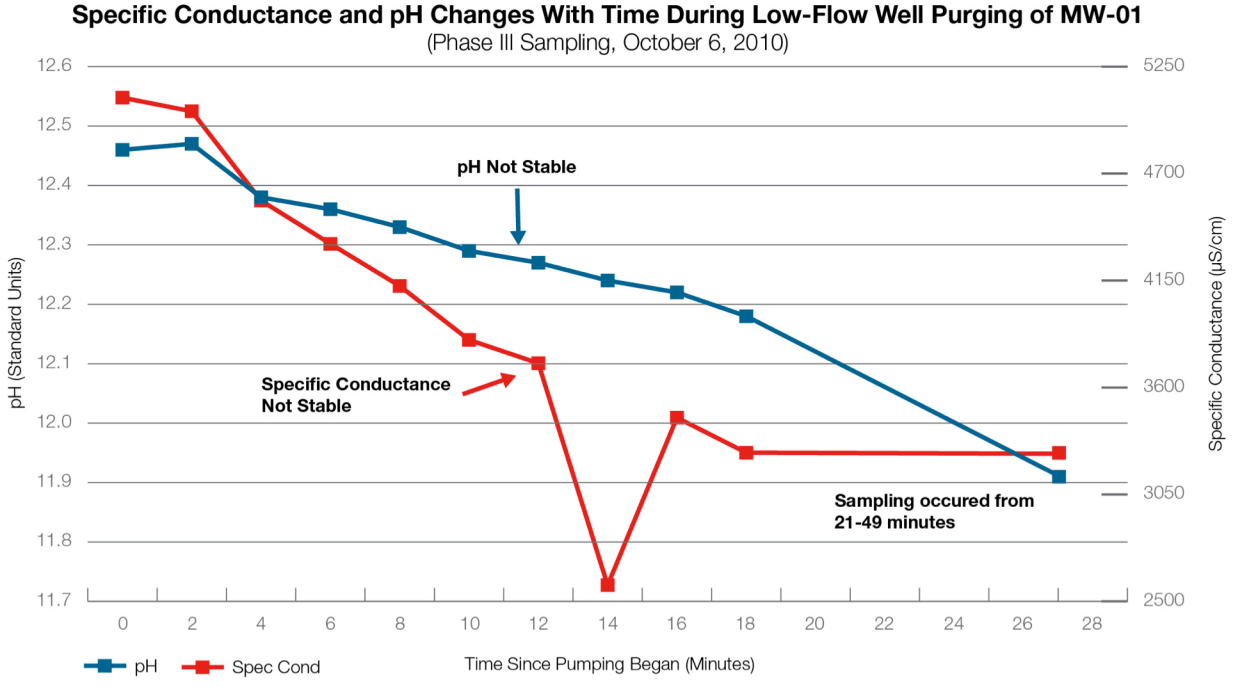


Figure 2. Graph of pH and specific conductance readings taken during low-flow sampling of MW-01 by EPA during Phase III (October 6, 2010).

Table 3: Summary of EPA's low-flow purge volume data for specific conductance, oxidation-reduction potential, and pH in MW-01, Phase IV (April 20, 2011).

MW-01 Time of Measurement 4/20/2011 Phase IV	Time Since Pumping Began, Minutes	Pump Rate Through Flow Cell, L/min	Specific Conductance µS/cm	pH, S.U.	Oxidation-Reduction Potential, Millivolts	Comments in Field Notes
9:27	0		3,788	12.21	-10.2	Start Purge
9:32	5	1.06L/min	5,270	12.28	-53.8	1.06 L/min
9:37	10		4,717	12.21	-63.9	
9:42	15		4,030	12.12	-72.0	
9:47	20		3,722	12.08	-79.0	
9:52	25		3,323	11.99	-86.8	
9:57	30		2,957	11.91	-95.7	
10:02	35		2,563	11.86	-102.2	Lost flow in between 9:57 and 10:02
10:07	40	1.55L/min	2,478	11.84	-108.0	1.55L/min
10:12	45		2,415	11.80	-113.8	
10:17	50		*2,352	11.79	-116.2	
Sample time not noted in notes	---	---	---	*11.24	---	Sample time not noted in notes

*: Reported field parameters at sample collection

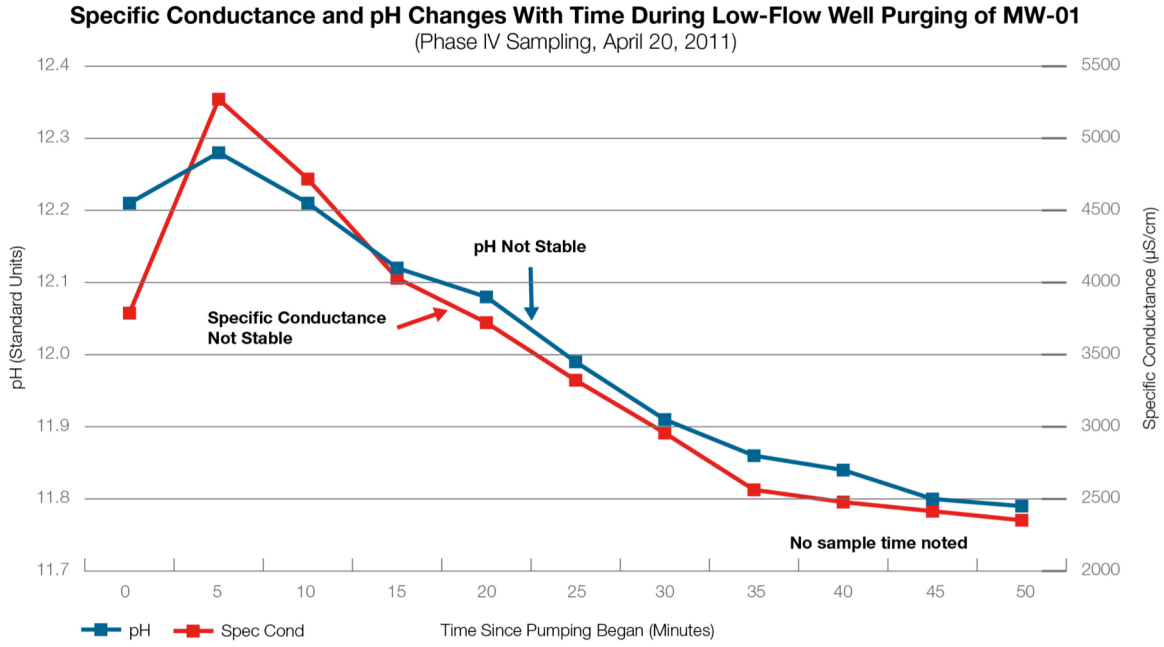


Figure 3. Graph of pH and specific conductance readings taken during low-flow sampling of MW-01 by EPA during Phase IV (April 20, 2011).

Data provided in **Tables 2** and **3** clearly and concisely show that the pH, oxidation-reduction potential, and specific conductance were not stable in well MW-01 during either of the Phase III or Phase IV sampling events, contrary to EPA's statement noted earlier on page 20 of their Draft Report[1]. **Figures 2** and **3** are plots of the pH and the specific conductance data from MW-01 during these Phase III and IV sampling events, respectively, and show the pH and specific conductance instability.

Table 4 is a partial summary of EPA's Phase III (October 6, 2010) low-flow purging results from MW-02 during low-flow sampling; but some data is missing from EPA's Pavillion website[12] for this event for the time period between 2:41 to 2:50 hours. **Figure 4** shows a plot of the pH and specific conductance values measured in MW-02 during this Phase III low-flow sampling event and the instability of the pH and specific conductance values. These data also shows that the pH, oxidation-reduction potential, and specific conductance were not stable during sampling by EPA.

Table 4: Summary of EPA's low-flow purge volume data for specific conductance, oxidation-reduction potential, and pH in MW-02, Phase III (October 6, 2010).

MW-02 Time of Measurement 10/6/2010 Phase III	Time Since Pumping Began, Minutes	Pump Rate Through Flow Cell, L/min	Specific Conductance µS/cm	pH, S.U.	Oxidation-Reduction Potential, Millivolts	Comments in Field Notes
2:05	0	1.06 L/min	680	9.51	138.8	Start Purge 1.06 L/min
2:07	2		674	9.61	138.8	
2:09	4	1.06L/min	672	9.57	142.9	Flow Purge 1.06L/min
2:11	6		674	9.55	144.3	
2:13	8		675	9.51	146.3	
2:15	10		677	9.54	147.2	
2:17	11		680	9.55	146.8	Pump off at 2:16
2:25	20		710	9.58	145.5	Well ?? (unreadable)
2:27	22	0.90 L/min	694	9.62	147.6	Flow = 0.90 L/min
2:29	24		700	9.62	148.1	
2:31	26		709	9.65	148.4	
2:33	28		725	9.70	148.1	
2:35	30		756	9.75	147.7	
2:41	36		3,810	12.22	121.2	Sample
Missing data Between 2:41 and 2:50	>36 minutes		Missing data	Missing data	Missing data	Missing data
Sample time also noted at 2:50 in field notes	---	---	*3812	*12.01	---	Sample time also noted as 2:50 in field notes or at approximately 45 minutes into pumping. Second page of notes missing on Pavillion website.

*: Reported field parameters at sample collection

The instability in pH shown in data from **Tables 2**, **3**, and **4** likely relates to cement contamination of groundwater in monitoring wells MW-01 and MW-02. Any and all groundwater quality data from wells MW-01 and MW-02 should be disregarded as inaccurate and invalid because pH is considered a key geochemical variable and highly controls many geochemical reactions involving both inorganic and organic dissolved solids.

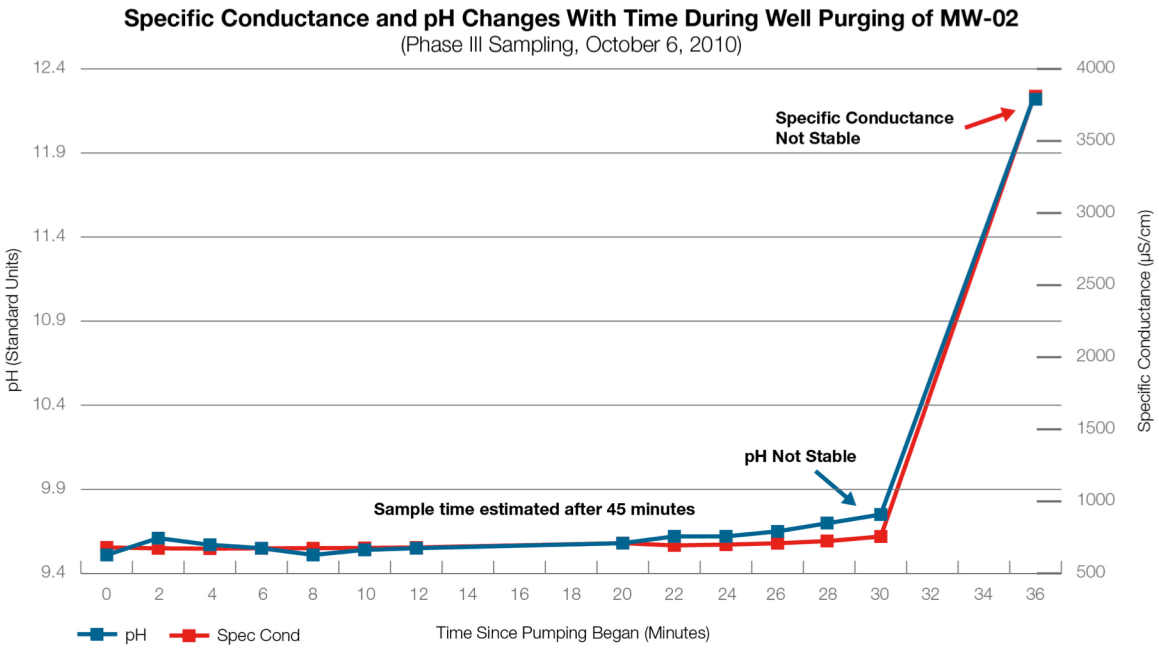


Figure 4. Graph of pH and specific conductance readings taken during low-flow sampling of MW-02 by EPA during Phase III (October 6, 2010).

During Phase III sampling of well MW-02, a major change in pH, oxidation-reduction potential, and specific conductance occurred between 30 to 36 minutes into the low-flow pumping period. EPA does not point out this change or discuss possible reasons for the dramatic increase in pH and specific conductance (decrease in oxidation-reduction potential) in MW-02, consistent with cement contamination. Likewise, EPA fails to discuss or point out the lack of stability in the pH, oxidation-reduction potential, and specific conductance during sampling of MW-01 during both Phase III and Phase IV sampling events. The low pH between 9.3 to 9.8 and low specific conductance in monitoring well MW-02 may be due to imported water added and left in the monitoring well during development on September 11, 2010.

Figure 5 is a graph of the oxidation-reduction potential (ORP) measured in groundwater from monitoring wells MW-01 and MW-02 during the Phase III and IV sampling events. These graphs also show that the ORP was unstable during the low-flow sampling events. **Figure 5** also shows that there is a large discrepancy between the ORP measured in each well between the Phase III and Phase IV sampling events. For example, the ORP measured in monitoring well MW-01 during the Phase III sampling event on October 6, 2010 ranged from 114.3 millivolts (mV) to 196.4 mV. During the Phase IV (April 20, 2011) sampling event, the ORP in this same monitoring well ranged from -10.2 mV to -116.2 mV. A similar discrepancy occurs in the ORP reading from monitoring well MW-02. EPA fails to discuss how such a large difference in ORP readings can occur in groundwater from the same well.

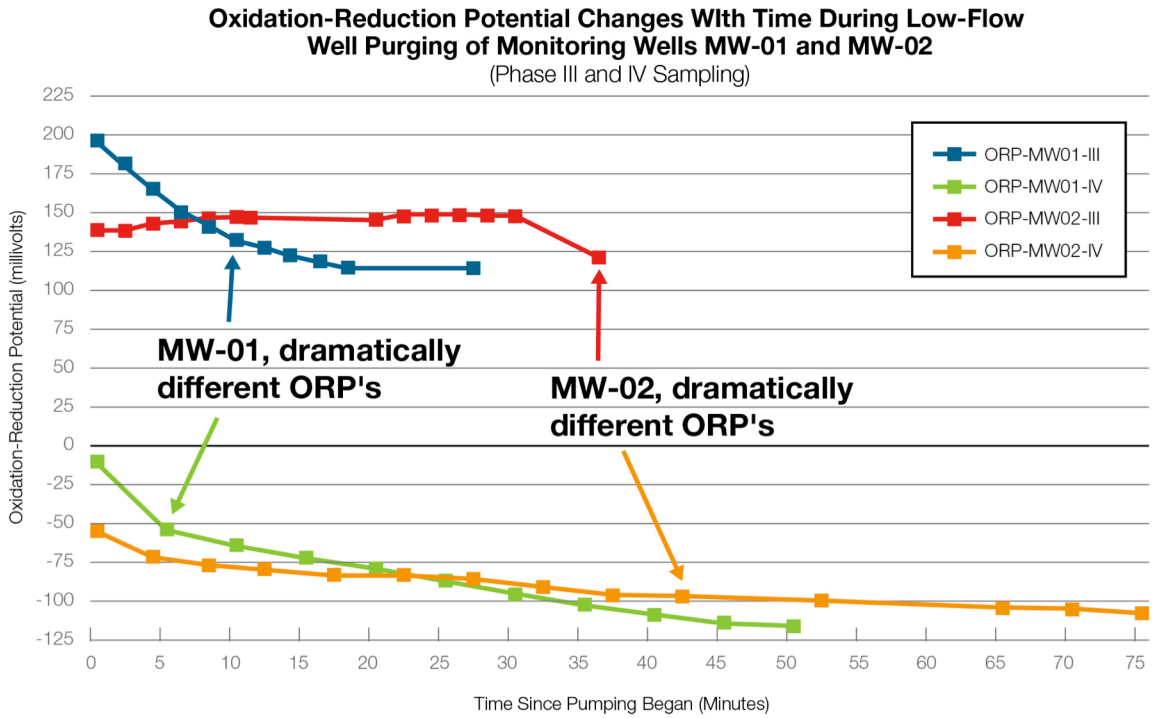


Figure 5. Graphs of oxidation-reduction potential from low-flow sampling data from monitoring wells MW-01 and MW-02 during the Phase III and IV sampling events.

Although EPA maintains the groundwater was stable (contrary to their own data) during their short-term sampling events on October 6, 2010 and April 20, 2011 from monitoring well MW-01, data from USGS's 2012 report[3] (**Figure 6**) shows that the pH could not have been stable in monitoring well MW-01(sampled by USGS on April 24, 2012), especially since groundwater from this well was not yet stable even after removing approximately five times the volume as removed by EPA on April 20, 2011 and over 12 times the volume removed by EPA on October 6, 2010. The occurrence of cement contamination in the monitoring well water is not unexpected given that the well screens are in contact or near contact with cement. In MW-01, cement is located immediately above and below the screen interval. In MW-02 cement is located immediately above the well screen and drilling mud and cuttings are located immediately below the well screen. Cement also likely invaded the screen interval in both monitoring wells.

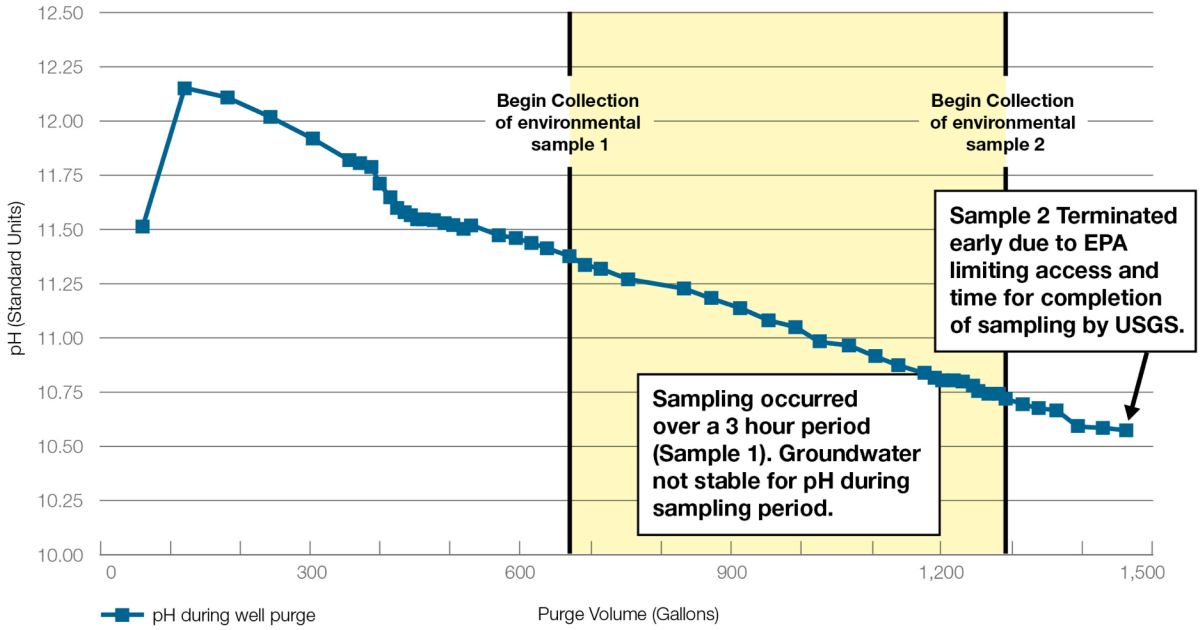


Figure 6. Modified after USGS Figure 2, Data Series Report 718 (samples collected by USGS on April 24, 2012)

In well MW-02 the same situation is likely true, but USGS refused to sample this well because it could not apply standard USGS sampling methodologies, and EPA never developed (or purged during sampling) this well long enough to show the expected instability in pH and a change in specific conductance. In other words, the groundwater quality (as evidenced by the high pH) in wells MW-01 and MW-02 is so contaminated by cement that prolonged and lengthy pumping and purging of these wells would be necessary to properly develop.

The water quality of samples from monitoring wells MW-01 and MW-02 collected by EPA and USGS show elevated pH values typical of when too much water was used in the cement mix, or when the secondary filter pack or bentonite seal failed or were not used, bringing cement into contact with the sampled groundwater. This resulted in the intrusion of high pH cement “bleed water” into the screen interval in both wells, affecting the water quality.

The analytical data collected from these wells should not be used in decision making, nor are the monitoring wells suitable for sampling; they should be plugged and abandoned.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The following is a list of conclusions from this investigation into the drilling, completion, development, and sampling of groundwater from monitoring wells MW-01 and MW-02. In addition, recommendations as to the use of groundwater data collected from these monitoring wells have been made.

Conclusions:

1) The depths to which these monitoring wells were constructed (785 and 989.5 feet below ground level) were far below the typical depths of domestic water wells in the area[2] and likely penetrated into non-commercial, naturally-occurring hydrocarbon/methane containing zones.

2) The two EPA monitoring wells (MW-01 and MW-02) were constructed in a flawed manner that is contrary to industry/regulatory standards and best practices, including failing to follow EPA's own monitoring well construction guidance documents and Work Plan[5]. For example, standard annular seals (such as bentonite pellets or slurry placed over the sand pack interval) used to separate overlying cements from the well screen and formation interval were not used, resulting in probable contamination of groundwater in both wells with cement (which contains glycols);

3) Construction diagrams for these monitoring wells in the Draft Report[1] contained numerous and significant errors, such as representing the hundreds of feet of riser casing as stainless steel, when in fact it was black painted/coated carbon steel casing;

4) Compounds EPA attributes to hydraulic fracturing at Pavillion, such as glycols, diethylene glycol, phenol, 2-BE, total petroleum hydrocarbons, phenols, isopropanol, and other compounds were likely present in the drilling/completion materials and/or drilling additives used in the drilling and construction of monitoring wells MW-01 and MW-02. Materials used down hole in monitoring well construction included painted/coated casing and painted sand baskets; the cements used likely contained glycols. Many of these compounds were not detected in the recent USGS study, but were allegedly found in some of the samples in EPA's studies;

5) EPA incompletely conducted their analysis of select additives/materials used down hole in the drilling of monitoring wells MW-01 and MW-02. Only 3 of 11 additives or materials used down hole were tested for organic compounds, and then only tested for approximately half of the organic compounds EPA is incorrectly attributing to hydraulic fracturing. EPA should have tested all 11 additives or materials used in monitoring well drilling or construction at Pavillion for all compounds they attribute to hydraulic fracturing. Analytical data is also present in the Draft Report[1] that purports to show glycol analyses for 3 additives, but no laboratory analytical reports for these glycol analyses could be found on EPA's Pavillion website[12] which would support this finding;

6) There is lack of adequate decontamination on equipment and materials used in monitor well construction at Pavillion as documented in the field notes from this project;

7) The materials used in monitoring well construction (including chemical impurities) and lack of proper decontamination are the likely cause of contamination of the groundwater in these wells by numerous constituents, including many constituents that EPA claims are related to hydraulic fracturing, leading to inaccurate findings by EPA. These contaminants (if actually detected) were likely introduced into groundwater by EPA's monitoring wells;

8) Groundwater from monitoring wells MW-01 and MW-02 may have been contaminated by EPA's use of non-filtered compressed air and surge blocks used to develop both wells. EPA has recognized[22] that hydrocarbon filters need to be inserted in the air stream to remove compressor oils (hydrocarbons), which can move with the air into groundwater and formation, causing contamination. There is no mention that hydrocarbon filters were used by EPA in the Pavillion Draft Report[1] or field notes. USGS[4] refused to swab in their well development across the screen interval in MW-02 because of fear they would contaminate this well with rubber materials scraped off the swabbing equipment. EPA swabbed the screen intervals in both wells, potentially contaminating the groundwater in both wells;

9) EPA failed to disclose in their Draft Report[1] that they had releases of anti-freeze (known to contain glycols), cement, and diesel fuel during field operations. It also appears certain field notes related to the alleged anti-freeze release may be missing from EPA's Pavillion website[12]. EPA should have been transparent and disclosed within the text of their December 2011 Draft Pavillion Report[1] that there was an allegation of an anti-freeze and cement release at monitoring well location MW-01 apparently caused by their operations. EPA should have further disclosed within this same Draft Report[1] the response, investigation, cleanup, and findings related to that allegation.

10) EPA used flawed sampling methods to collect samples from both of these wells. Data from EPA's sampling events show that key indicator parameters (pH, oxidation-reduction potential, and specific conductance) were not stable during sampling, and those data were ignored or misinterpreted by EPA. In addition, a key and critical component of low-flow sampling (drawdown measurements during well purging) was not done in monitoring wells MW-01 and MW-02 during the October 6, 2010 Phase III sampling event. During the Phase IV sampling event (April 19-20, 2011), no usable water level measurements were obtained during low-flow sampling of MW-02, and those obtained from MW-01 were not stable during purging and sampling;

11) EPA has developed very low analytical detection methods for glycols and ethoxylated alcohols that are not available to standard commercial laboratories and which are not independently verifiable at these very low concentrations. EPA failed to understand that some of the compounds they were targeting as being indicators of hydraulic fracturing were also present in materials or equipment used during their monitoring well construction and development, such as glycols in cements. That fact, along with a basic lack of decontamination of their down hole materials, has resulted in EPA potentially contaminating the groundwater in these monitoring wells and incorrectly concluding a potential connection to hydraulic fracturing and aquifer impact at Pavillion. Whether or not these compounds are actually present in groundwater is also questionable since the compounds were not always detected in samples from the same wells. Several other compounds such as isopropanol, ethanol, and naphthalene were detected in some of the drilling additives, while other compounds such as 2-butanone, acetone, xylenes, toluene, benzoic acid, benzyl alcohol, tetraethylene glycol, and diesel and gasoline range organics were found in trip, field, and/or equipment blanks. Regardless, data collected from these monitoring wells historically, or in the future, are flawed and should not be used in technical evaluations. Data collected by EPA from these wells should be withdrawn;

12) EPA's initial investigation in 2008 was focused on odor, taste, and color complaints in groundwater from domestic water wells in the Pavillion area. EPA was not able to find any definitive connection to hydraulic fracturing in the early phases (Phases I and II) of the investigation. After construction of the two deep monitoring wells, development of methods to find glycols and alcohols at very low concentrations, EPA is still unable to find any of

these compounds in the domestic water wells and has not achieved the intended goal of the investigation; and

13) Based on the review of existing data, there does not appear to be a relationship between hydraulic fracturing and groundwater quality issues related to water supply wells in the Pavillion area.

Recommendations:

1) EPA's December 2011 Draft Pavillion Report[1] and all associated data should be withdrawn due to severe technical flaws in their investigation and errors and/or misinterpretations of those data contained in that Draft Report[1];

2) Both monitoring wells should be immediately plugged and abandoned since they are likely providing an ongoing source of groundwater impact, they cannot provide reliable data related to groundwater quality, and they cannot be remediated;

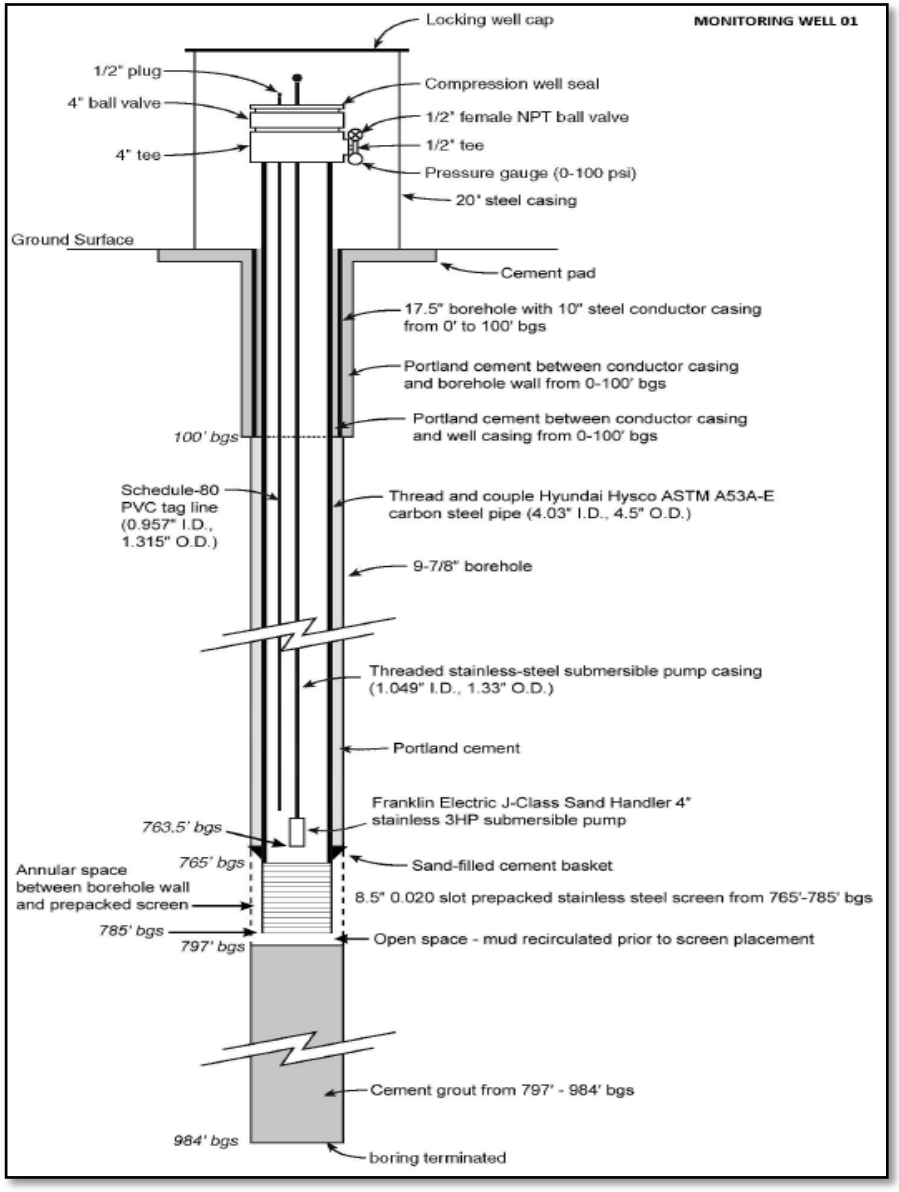
3) Once the existing 2 deep EPA monitoring wells are appropriately abandoned, API does not believe that further investigation of the area is warranted (including the drilling of additional deep monitoring wells) due to various well construction issues that have already been addressed in this report and EPA's own finding of the lack of hydraulic fracturing chemicals in the shallow water supply wells of the area;

4) If EPA continues to stand behind their Draft Report[1] and does not withdraw, then anyone who has submitted comments to EPA on Pavillion should be contacted by EPA directly and EPA should be required to let those commenters know of the errors in their monitoring well construction diagrams, the errors in the associated discussion in their Draft Report[1], and missing facts and data not provided in that Draft Report[1] as identified and provided herein. In addition, those who have provided comments and other interested stakeholders should be made aware of this API report; and

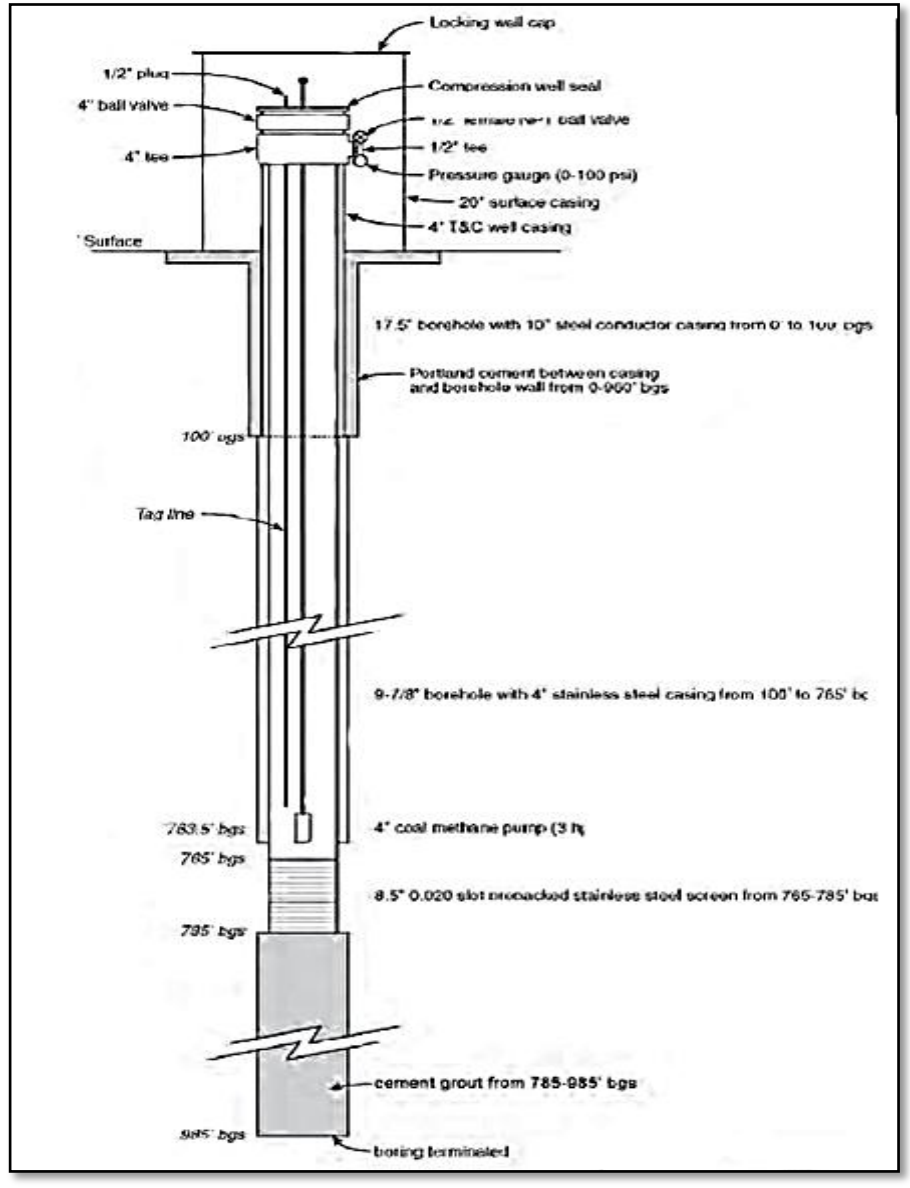
5) API supports the use of scientifically sound and unbiased studies. These studies are important in developing a better understanding of potential issues. EPA should ensure that qualified contractors and staff are utilized in their ongoing studies to minimize the potential for the types of significant problems documented in this review related to improper field techniques and data evaluation from continuing to occur in other similar studies.

EPA WELL CONSTRUCTION DETAILS
MW-01

Corrected Well Construction Diagram Posted On EPA's Pavillion Website: 11/8/12

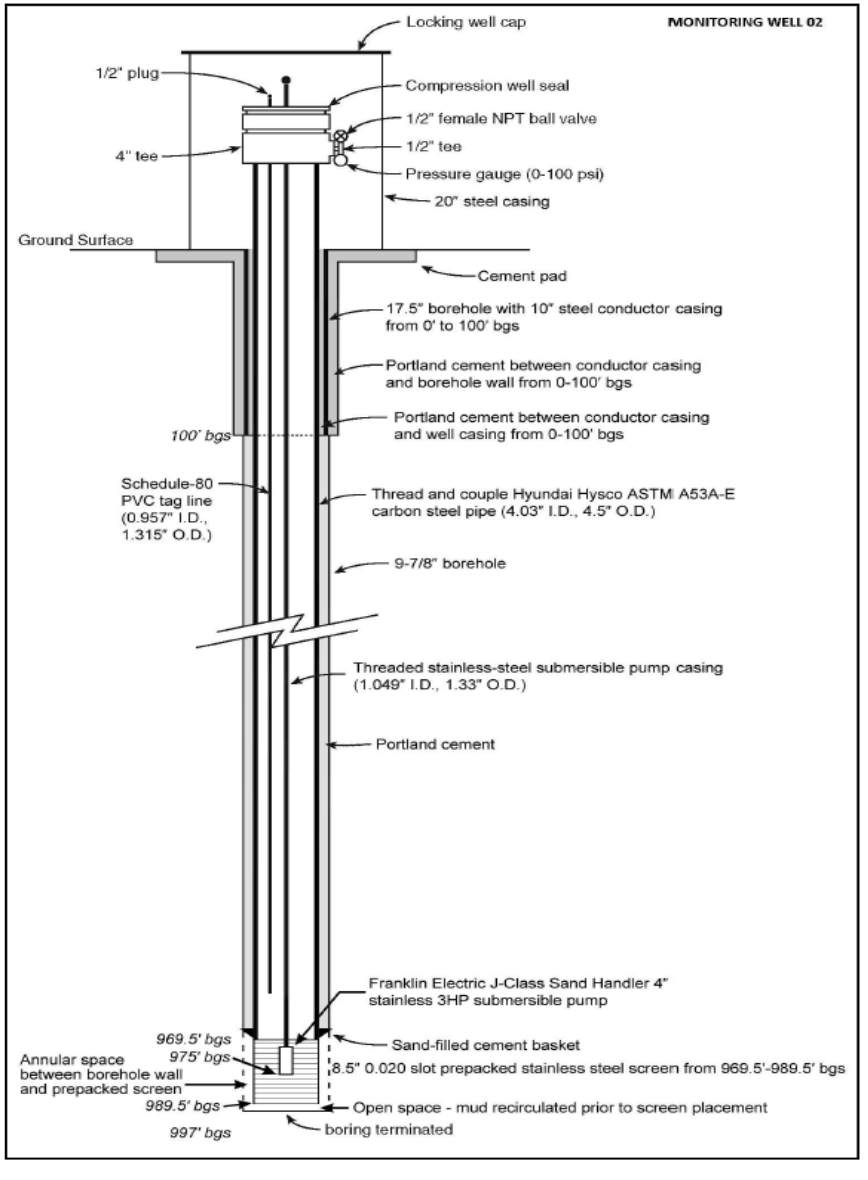


Initial Well Construction Diagram Provided in December 2011 EPA Draft Report



EPA WELL CONSTRUCTION DETAILS
MW-02

Corrected Well Construction Diagram Posted On EPA's Pavillion Website: 11/8/12



Initial Well Construction Diagram Provided in December 2011 EPA Draft Report