Comments on the Second Draft Battlement Mesa Health Impact Assessment

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1 Executive Summary

ENVIRON was asked to review and provide comments on the current draft[1] of the Battlement Mesa Health Impact Assessment (HIA) prepared by the Colorado School of Public Health (CSPH). The HIA addresses the potential impacts of a natural gas development project proposed by Antero Resources Corporation (Antero) on the health of Battlement Mesa residents. Based on our review of the current draft of the HIA and the associated Human Health Risk Assessment (HHRA) prepared by CSPH, we do not believe that either document was prepared using scientifically sound methodology. Neither document presents a realistic assessment of likely impacts or risks from the project. The documents should not be used as a basis for decision-making by Antero or regulatory authorities.

According to the Executive Summary of the HIA (p. ES-I), the HIA sets out to achieve the following objectives:

(1) Identify areas of concern (Scoping, as described in Appendix AA);
(2) Use existing data sources to conduct quantitative and qualitative analyses to describe baseline conditions in Battlement Mesa and to assess project impacts on the areas of concern (Assessment, as described in Appendix AA); and
(3) Develop a priority list of recommendations to minimize the potential health impacts of the proposed project (Recommendations, as described in Appendix AA).

While the HIA provides a high-level summary of potential impacts of the project, its usefulness as a guide to mitigating those potential impacts is limited by the lack of site-specific and project-specific analysis. The HIA generally carries out its first objective, but fails to achieve the second and third objectives. As part of the first objective, the HIA identifies eight broad areas of concern, but does not provide sufficient analysis to establish whether specific concerns rise to a level of significance that would require action. As a result, the HIA does not achieve the second objective. In addition, most of the assessments specific to areas of concern are qualitative and do not reflect consideration of project-specific details. Many of the HIA concerns apply widely to the natural gas industry or construction projects in general, and insufficient evaluation was performed to determine if these concerns apply to the proposed Antero project. Instead of evaluating the significance of the potential project-specific impacts for each concern, the HIA assumes that many of the concerns are significant (i.e., that action is warranted) without further investigation or detailed analysis.

Developing a priority list of recommendations, the third objective, is expected to logically follow the results of the assessment (second objective), but that is seldom the case in the HIA. Over 70 recommendations were included in the HIA. Many of them are very specific as to the types

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of technologies and work practices that Antero should be required to adopt (e.g., use of permitted tanks instead of a pond at the centralized storage facility, use of vapor recovery technology rather than combustion). However, the assessments conducted in the HIA are not sufficiently project-specific to demonstrate the rationale behind these particular recommendations or how effective they would be in mitigating potential risks from the proposed project. The specific recommendations do not appear to be linked logically to the characterization and prioritization of stressors. This disconnect is particularly troubling because it is counter to the expectation that the HIA's recommendations are based on a careful evaluation of stakeholder concerns and the application of professional judgment and analysis.[2] Recommendations are provided regardless of whether a stressor is assigned a low or high priority. Even though the authors refer to a "priority list of recommendations" (p. ES-I), no effort was made to prioritize recommendations or specify which ones may have the greatest potential health impacts. The prescriptive nature of some of the recommendations may prevent consideration of alternative technologies or work practices that may be equally or more protective and/or cost-effective. Many of the recommendations are already part of existing state or local regulations or are part of Antero's plans. Some of the recommendations added since the previous version (Draft 1) of the HIA appear to be driven by concerns brought up in the first round of comments (as provided in Appendix E). However, no additional analysis was completed to ascertain whether they rise to the level of significance warranting additional recommendations. The HIA should limit recommendations to only those that are fully supported by assessment.

Air quality is the only area of concern for which an ostensibly quantitative analysis was performed in the HHRA. To a lesser extent, the HHRA attempts to address the soil and water quality concerns, but this assessment is limited to surface water exposure. We have significant concerns with the HHRA as summarized in Table 1 below. We believe that the screening-level HHRA provides only a very general indication of the potential levels of risk that may be associated with the project. The risk estimates presented in the HHRA are not reliable indicators of relative risk or excessive risk. Because the elements of the proposed project that may cause or contribute to elevated or excessive risks to human health are not reliably identified, the HHRA does not provide a sound basis for decision-making or adequate support for many of the specific recommendations provided in the HIA.

Many of the assumptions that underlie the risk estimates calculated in the HHRA – exposure point concentrations (EPCs), exposure duration, and toxicity factors – are flawed, reflecting a departure from standard or reasonable risk assessment procedures. The exclusive reliance on disparate air monitoring datasets without any predictive modeling analysis is a major

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[2] For example, the HIA recommends extensive air, soil, surface water, and groundwater sampling that do not appear to be prompted by any real health risk given local use patterns and likelihood or magnitude of exposure by residents in the area.

shortcoming of the HHRA. Air monitoring, unless conducted over extensive periods of time, only provides a snapshot of conditions existing at the location and time sampled and has to be supplemented with further modeling analysis to accurately predict exposures at other locations and times. The use of “mixed” data sets from different locations, times, and operations and the choice of inappropriate toxicity values invalidates the authors’ assertion that potential health impacts will occur as a result of increased air emissions. The exposure scenarios evaluated in the HHRA fail to incorporate the realities of the proposed natural gas drilling operations.

Although the HHRA was conducted “in support of” the HIA, it does not appear that the air quality recommendations logically follow from the HHRA results. For example, the HHRA does not conduct any type of source characterization to determine the greatest contributors to pollutant concentrations, yet the recommendations stipulate source-specific emission controls and designs. Without any effort to identify the sources of Contaminants of Potential Concern (COPCs), mitigation strategies may not be appropriately targeted to effectively reduce emissions. A more detailed HHRA that accounts for site-specific details (such as local wind patterns) and project-specific details (such as the time spent in various phases of well pad development and the many mitigation measures Antero has proposed in public meetings) would provide a better basis for decision-making. In the “CSPH Response to Second Public Comment Extension Request” dated March 21, 2011, the HHRA authors noted that additional data or changes to assumptions in the HHRA are “not likely to substantively change the recommendations of the HIA.” This statement further confirms the disconnect between the recommendations in the HIA and the results of the HHRA. If the HHRA was not a key input in the development of recommendations, it raises questions as to its purpose.

In summary, the HIA serves as a general indicator of the types of concerns that stakeholders have about the potential health impacts of the proposed Antero project. It provides a system for prioritizing impacts, which serves as a starting point for further discussion and investigation. However, the HIA lacks substantive analysis to form the basis for the recommendations provided, and numerous deficiencies were noted in the one area, air quality, where substantive assessment was attempted. Our review of the current draft of the HIA indicates it cannot be used as a basis for drawing conclusions about the potential impacts and risks of the Antero project.

Table 1: Overall Concerns with the HHRA

Issue	Description
Risk Assessment Framework	The risk assessment has been developed for a “maximum exposure” scenario and a “reasonable maximum exposure” scenario (referred to in the HHRA as 95% UCL, or upper confidence limit). Both scenarios in concept are skewed toward the high end of the spectrum of potential exposures. In developing these scenarios, the HHRA applies compound worst case assumptions resulting in exposure and risk estimates that extend so far beyond reality that the HHRA loses its practical value for making informed decisions. Remedy: The HHRA should follow USEPA guidance as outlined in the Air Toxics Risk Assessment reference library for conducting community-scale risk assessments. As recommended in the guidance, the HHRA should focus on developing a “plausible worst case” and a “reasonable average” exposure scenario to provide risk estimates to which the community can relate.
Estimation of Cancer Risks	Figure 7-2 in the HHRA, “The Summary of Excess Lifetime Cancer Risks,” graphically (using histograms) presents a comparison of risks to residents prior to and following implementation of the Antero project that indicates risks are higher following implementation of the Antero project. The chart is misleading and cannot be supported. For example, calculations of project-related risks included compounds that were not analyzed in the baseline monitoring study, and outlier values were selected as exposure point concentrations. Remedy: As recognized in the conclusions section of the HHRA, the apparent increase in risks following implementation of the project is an artifact created because a key risk-driving chemical (1,4-dichlorobenzene) was not measured in the baseline scenario, but was measured in the comparison data sets. A fair comparison would show no significant difference in estimated cancer risks among the different scenarios. The chart should be rectified to provide an apples-to-apples comparison.
Estimation of Non-cancer Health Hazards	Due to a combination of calculation errors, inappropriate use of toxicity data, and improper use of measurement data, adverse acute and subchronic non-cancer health impacts are estimated that are contrary to the evidence. By way of illustration: (a) the highest hazard index estimated in the HHRA results from a child making contact with surface water. In reality, the chemical concentrations in surface water are so low that all but one chemical has concentrations less than the federal drinking water standard. The apparent discrepancy arises because of a 100-fold error in the exposure calculation; (b) inappropriate use of acute toxicity values has led to the paradoxical conclusion that benzene can be inhaled for 20-months without ill effect, yet acute exposure to benzene at the same concentration is estimated to produce potential adverse health effects (benzene accounts for virtually all of the estimated acute risk); and (c) values that are acknowledged outliers are arbitrarily assumed for missing measurement data, which produces subchronic risks that are incorrect. Remedy: A consistent framework should be established for incorporating data used in the assessment. The toxicity data selected should match as closely as possible the averaging time of the measured air concentration data to which it is being compared. Air concentration measurements can only be used at the location where the measurement occurred; air flow and source receptor relationships need to be honored in extrapolating data to other locations. The assessment has to be true to the underlying data.

2 Summary of Primary Comments

ENVIRON was asked to review and provide comments on the current draft[3] of the Battlement Mesa Health Impact Assessment (HIA) prepared by the Colorado School of Public Health (CSPH). The HIA addresses potential impacts on the health of Battlement Mesa residents of a natural gas development project proposed by Antero Resources Corporation (Antero). Eight areas of concern are identified and discussed in the HIA, and recommendations for mitigation of the potential impacts in each area are provided. Some (but not all) of these recommendations are related to the conclusions of a screening-level Human Health Risk Assessment (HHRA), which is included as an appendix to the HIA.

ENVIRON's primary comments on the HIA are presented below. More specific and detailed comments on the HIA follow this section.

2.1 Primary Comments on the HIA's Assessment of Stressors

2.1.1 Air Quality

The HIA's reliance on limited air monitoring datasets (as evidenced in the HHRA) and absence of air modeling to predict exposures to residents limits the ability of the HIA to evaluate air quality impacts. Air modeling would account for local topography and meteorological conditions, and project-specific parameters, such as the locations of well pad emission sources and residential receptors. Without source characterization to determine the key contributors to pollutant concentrations, it is impossible to determine where emission control efforts should be focused. The HIA fails to clearly distinguish between health effects associated with increased risk from exposure to airborne contaminants and health effects associated with unpleasant nuisance odors. Even if a more project-specific risk assessment found that elevated pollutant concentrations would not have demonstrable impact on human health, it is possible that transient odor problems could still be a concern to Battlement Mesa residents. At the same time, odor complaints should not be driving exposure characterization, such as the selection of the ½ mile distance as the definition of "near a well pad" in the HHRA.

2.1.2 Water and Soil Quality

The discussion in the HIA suggests a number of ways in which Antero's operations could potentially impact surface water, groundwater, or soils within the Battlement Mesa PUD. Some of these suggestions fail to account for the details of Antero's planned activities. The Antero project will be designed and implemented to prevent chemical releases to soil and water; the possibility of such releases occurring arises only as a result of accidents or malfunctions. A review of information collected at other gas fields indicates that water contamination exceeding

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regulatory limits was not associated with routine natural gas development and production activities (p. 42). These findings indicate that efforts to protect the public health from the effects of soil and water contamination should be directed toward preventing accidents and malfunctions. State regulations require spill reporting and monitoring of conditions in the vicinity of each well pad and the central water handling facility, so significant chemical releases will be addressed promptly. Therefore, potential exposures to contaminated soil or water associated with Antero's operations would be short-term and local (not community-wide) unless the public water supply was affected. Because there is no hydrologic connection between Antero's proposed activities and Battlement Mesa's primary water source (upstream on the Colorado River) and the potential hydrologic connections between Antero's proposed activities and the secondary public water sources (four groundwater wells) will be evaluated under state regulations before the project proceeds, exposure through the public water supply seems extremely unlikely.

2.1.3 Traffic and Transportation

The HIA fails to take into account Antero's traffic management plan, which identifies preferred haul routes. Many of the recommendations are already part of Antero's proposed plans. The primary traffic and transportation concerns are also related to accidents and malfunctions, air quality, and noise, vibration, and light, so it is important that the effects of any recommendations for these other areas of concern are considered from the traffic and transportation perspective . Even though Antero's traffic management plan (including haul routes), project-related vehicle trips per day, and construction schedule are available, as acknowledged in the HIA (p. 50), the HIA made no attempt to perform any traffic analysis or modeling to determine the extent to which congestion and accidents would increase or evaluate the significance of any increase.

2.1.4 Noise, Vibration, and Light

There is a lack of baseline or background data on noise levels and light intrusion, despite existing natural gas well development in Battlement Mesa and the rest of Garfield County. Further data collection would be necessary before determining how noise, vibration, and light conditions would change. Some recommendations, particularly Recommendation 1 which recommends reducing permissible noise levels by 25 dBA (p. 20), are more stringent than existing regulatory requirements, and would require a change in state regulations or an evaluation of why Antero's proposed project is sufficiently different from other state oil and gas projects to warrant more stringent noise regulations. According to the HIA, light intrusion is not a significant concern based on modeling performed by Antero (p. 56), but the authors provide no information on Antero's light abatement measures or modeling.

2.1.5 Community Wellness

Even though the HIA explicitly states that it is not likely that Antero's proposed project will create a boom or bust economy in Battlement Mesa (p. 69), it repeatedly compares the project to the Garfield County boom of 2003-2008. This comparison is inappropriate because it implies that the adverse impacts in crime, sexually transmitted diseases, property values, and education that reportedly occurred as part of the boom could somehow apply to the proposed project in

Battlement Mesa despite the significant differences in scale of the natural gas boom and Antero's proposed operations. By proposing to make measurements "related to lifestyle and social cohesion" (p. 22), the HIA is implicitly validating linkages between natural gas development and health endpoints that are inherently subjective and impossible to quantify, and which may not have a basis in science. Selecting such measures without evidence of scientific causality is misleading and uninformative. The recommendations of the HIA regarding community wellness include a provision to support baseline and ongoing studies to determine the impact of residential natural gas development on community health and individual health (p. 22). The studies would not have the means to characterize the contribution(s) of non-Antero activities to many of the health impact endpoints proposed for the baseline study. Antero's activities take place in a larger geographic area that already has existing natural gas development. Without information on the role and importance of non-Antero activities, there is a significant potential for any impacts to be misattributed and no means to mitigate such impacts if the actual origin of the problem is not known.

2.1.6 Accidents and Malfunctions

In its discussion of accidents and malfunctions, the HIA does not distinguish between minor incidents that may occur with some predictable regularity (e.g., traffic accidents) and major incidents that are unpredictable and potentially life-threatening (e.g., explosions). Incident rates based on past spills and other accidents are not appropriate measures of potential health impacts to residents near well pads because many of these incidents likely had little or no health impacts. The reporting of incident rates that combine minor and major incidents also implies that residents will be affected by accidents on a regular basis. Residents will likely be most concerned about incidents that may seriously threaten their health and/or property, but the HIA does not enumerate what the likelihood of such major incidents might be. It appears that accidents and malfunctions have risen to a high priority concern based on citizen comments about catastrophic events after the first draft of the HIA. However, the HIA does not evaluate the likelihood of catastrophic events or the extent to which required or proposed mitigation measures sufficiently minimize risk of such incidents. As such, the basis for escalating accidents and malfunctions to a high priority concern is driven solely by citizen concern and is not informed by additional analysis.

2.2 Primary Comments on the HHRA

As a preface to our comments on the HHRA, we note three significant changes to the previous draft of the HHRA that are reflected in the second draft: (1) the addition of data collected since the last draft of the risk assessment that enables a comparison of present risks compared to risks associated with the Antero project; (2) the addition of a subchronic risk assessment, in addition to the chronic and acute risks evaluated previously, with the modification of the exposed population from "adjacent" to the well pad to "near a well pad," which is defined in the HHRA as within ½ mile of a well pad; and (3) addition of a "maximum" case that relies on maximum concentrations of chemicals in air.

In general, the new Battlement Mesa data allow the HHRA to put the risks of the Antero project in perspective with existing risks, a component that was missing in the earlier draft. With respect to subchronic risks, as discussed further below, there are significant limitations with the underlying data that limit their usefulness in assessing subchronic risks. In particular, extrapolating the data from adjacent (generally less than 200 feet) to the well pad to further distances can be achieved only by transport modeling, particularly as the data have to be extended from a one-day measurement to a 20-month exposure duration. This extrapolation cannot be accomplished without consideration of the effects of changes in emissions and meteorological conditions within that time period on ambient air concentrations. Because the well pad data are applied without modeling, they are better suited for assessing acute risks to adjacent residents and should be used in lieu of odor measurements (the 2008 ASTDR Health Consultation report discusses the limitations of the odor measurements for risk assessment purposes, which resulted in several additional sampling campaigns to produce more appropriate data for risk assessment).

Finally, the use of a "maximum case" is inconsistent with USEPA community risk assessment guidance and should be eliminated. As cited in USEPA's Air Toxics Risk Assessment report (Volume I, Part I, Chapter 3): "**Derive Realistic Exposure Scenarios.** Risk management decisions should be based on realistic exposure scenarios, rather than on the hypothetical **maximum exposed individual** (MEI)" (emphasis original). As constructed, the "maximum case" has no practical value and serves to increase, rather than decrease uncertainty in the risk assessment process. In developing scenarios for evaluating the likelihood that exposure may cause an adverse health outcome, USEPA (Air Toxics Risk Assessment, Volume I, Part I, Chapter 3) recommends: "Per the Agency's *Policy for Risk Characterization,* this likelihood is evaluated both with regard to a "central tendency" of exposure estimates and "high end" estimates." The "95% UCL" in the HIA serves as the "high-end" estimate. The "central tendency" case is synonymous with "typical" or "average" and would provide a range of risks that can be used as a basis for decision-making. By providing the 95% UCL and maximum case side-by-side in the result tables and graphs, the HHRA suggests that both are valid risk estimates, even though the maximum case is unrealistic. A summary of our primary comments on the HHRA follows.

According to the Executive Summary of the HIA, the HHRA indicates that "residents living near a well pad (defined as within ½ mile) are more likely to experience health effects than residents living farther away from a well pad (defined as greater than ½ mile)"[4] (p. ES-II). Our review of

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[4] Although the area referred to in the HHRA as "near a well pad" is defined by a radius of ½ mile (2,640 feet), all of the data used to estimate long-term concentrations of chemicals in ambient air were collected at distances less than 500 feet from a well pad. As a practical matter, based on the conservative approach used in the HHRA, the risk estimates were actually determined by measurements made 200 feet from the well pad. Accordingly, "near a well pad" should be redefined to accurately reflect the underlying data used in the assessment. As the proposed setback for the project is 500 feet, there will be

the HHRA indicates this conclusion cannot be supported, as explained below. In forming its conclusions, the HIA also states that, "The key findings of our study are that health of the Battlement Mesa residents will most likely be affected by chemical exposures, accidents or emergencies resulting from industry operations and stress-related community changes" (p. ES-I). As discussed below, there is no foundation for this conclusion.

The risk estimates in the HHRA address three exposure periods (chronic, subchronic, and acute) for various subsets of the population of Battlement Mesa. Baseline risks and risks for all Battlement Mesa residents are provided for chronic exposure, but not for subchronic or acute exposures. Thus, direct comparison between the risks to residents living near a well pad and residents living farther away is possible only for the chronic exposure period.

2.2.1 Comparison of Estimates of Chronic Cancer Risks

The risks to Battlement Mesa residents were estimated using conventional risk assessment practices under a "baseline" condition (representing present conditions), "not near a well pad" and "near a well pad" (the latter two represent long term conditions during and subsequent to completion of the Antero project).[5] The baseline risk estimates were derived using air samples collected at Battlement Mesa over a three-month period (from September to November of 2010). The risk estimates for residents "not near a well pad" were calculated using an air monitoring data set collected in another area (Bell-Melton Ranch) from 2005 to 2010. Finally, the risk estimates for residents "near a well pad" were calculated using a combination of the Bell-Melton Ranch data and data collected within 500 feet of well pads during well completion activities in the summer of 2008 (CDPHE Air Toxics Study) and in 2010 (Antero Watson Ranch Pad sampling). The estimated lifetime excess cancer risks estimated for these three scenarios in the HHRA are as follows:

- Baseline – 55 cancers per one million people exposed;
- Not near a well pad – 61 cancers per one million people exposed; and
- Near a well pad – 74 cancers per one million people exposed.

While it was recognized in the HHRA that all of the estimated risks were within USEPA's acceptable range of 1 to 100 per million people, the projected future risks for residents of Battlement Mesa from implementation of the Antero project were identified as higher than baseline conditions.

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no residents within that distance. If desired, more realistic estimates of the risks to residents at distances greater than 500 feet could be derived from the available concentration data by air transport modeling.

[5] A fourth estimate was also provided near a well pad using "maximum" concentrations of chemicals detected in air. This estimate is not comparable to the estimates for other three scenarios that rely on the 95% Upper Confidence Limit (UCL) on the mean concentration for each chemical.

The risks listed above are compared on a chart (Figure 7-2 of HHRA) entitled "Summary of Excess Lifetime Cancer Risks." This is a departure from the previous draft of the HHRA, which states that "it is not appropriate to directly compare" cancer risks because the list of chemicals measured were not the same in the data sets used to derive the risk estimates (p. 37 of previous HHRA). Although not reflected in the tables and figures, the text of the current (second) draft HHRA points out that "two of the cancer risk drivers" (1,4-dichlorobenzene and methylene chloride) in the Bell-Melton data set were used to estimate future risks at Battlement Mesa, but were not measured in the baseline data set. If these risk drivers were removed to make the comparison fair, the estimated risks to residents "not near a well pad" would drop to 50 cancers per one million people exposed. While this acknowledgment is made in the text of the HHRA (Appendix D, pp. 43, 66), it is not reflected in the accompanying tables or in the figures used to compare baseline risks with future risks. Thus, a fair comparison with the same list of chemicals in both datasets demonstrates that the estimated risks to residents "not near a well pad" are lower than the baseline cancer risk. Furthermore, if the incremental risks associated with well completions as determined from the CDPHE Summer 2008 measurements made within 500 feet of well pads were added to these risks (no aldehydes measurements were made in 2008, which is a limitation in the use of the data), the estimates of cancer risks would increase by six cancers per one million people exposed for residents "near a well pad." Thus, even for residents "near a well pad," cancer risks are not demonstrably different from baseline conditions. The revised estimated lifetime excess cancer risks estimated for the three scenarios are:

- Baseline – 55 cancers per one million people exposed;
- Not near a well pad – 50 cancers per one million people exposed; and
- Near a well pad – 56 cancers per one million people exposed.

In conclusion, while it is recognized there are limitations in the data (the HHRA provides a detailed discussion of the limitations in the monitoring data and in the toxicity factors), application of the available data in the risk assessment indicates that future cancer risks following implementation of the Antero project are not meaningfully different from baseline risks existing today.

2.2.2 Comparison of Estimates of Chronic Non-Cancer Risks

The HHRA ignores USEPA's Air Toxics Risk Assessment (ATRA) guidance in conducting community-scale assessments, and in a departure from this guidance, develops a "maximum" case to illustrate the range of risks when evaluating the potential for chronic adverse health effects, in addition to the conventional high-end (referred to in the HHRA as 95% UCL) case that is intended to reflect reasonable maximum exposure. The maximum case relies on maximum concentrations of chemicals detected from multiple sampling events that are disconnected in time and space and bear no relationship to actual exposure at any given time or location. The pitfalls of this approach are illustrated using formaldehyde as an example, which is described below in Section 2.2.3. Using maximum concentrations in the manner applied in the latest version of the HHRA is inconsistent with USEPA guidance (USEPA ATRA Library 2004-2006).

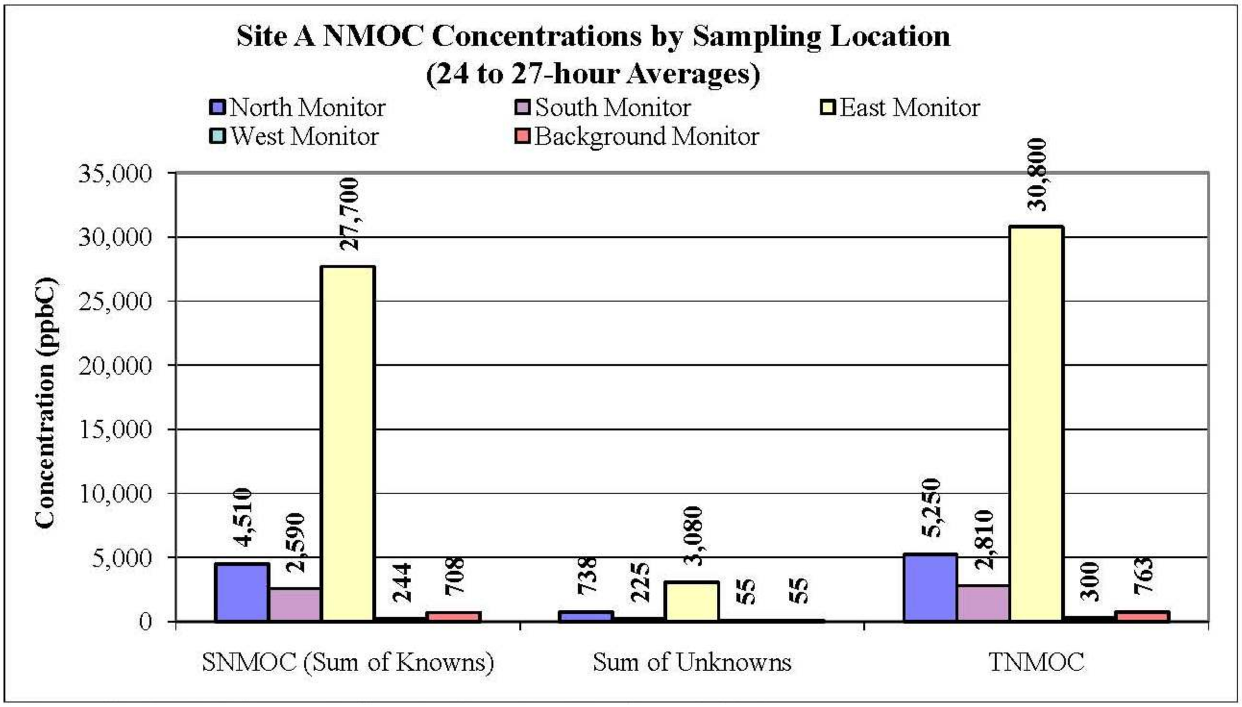
In lieu of the maximum case that applies to no real individual, it is recommended that the HHRA develop a central-tendency risk estimate that is more representative of community exposure, in addition to the high end case, and eliminate the "maximum" case that was introduced in the latest draft of the HHRA.

In evaluating the likelihood that adverse non-cancer effects may currently exist under baseline conditions or may occur in the future from development of the project, the HHRA uses a hazard index approach. An estimated hazard index greater than 1 indicates adverse health effects may occur. For all three chronic scenarios using the 95% UCL concentrations – baseline, "not near a well pad," and "near a well pad" - the hazard indices estimated in the HHRA are between 0.5 and 1.0 (Appendix D, Figure 7-1). Thus, no chronic non-cancer adverse health effects are anticipated from the project. Detailed comments provided in subsequent sections of the report do not alter this overall conclusion, but reduce risks further within the acceptable range.

2.2.3 Comments on Subchronic Risk Estimates for All Residents Near a Well Pad

As stated above, the HHRA evaluates only future subchronic and acute risks during implementation of the project, so there is no comparison with baseline conditions. USEPA has developed guidance more generally for conducting Air Toxics Risk Assessments, as well as for assessments to evaluate the potential for subchronic and acute health effects (USEPA ATRA Library 2004-2006, USEPA RAGS Part F 2009). In developing the high-end (95% UCL) case using reasonable maximum exposure assumptions, USEPA's ATRA guidance emphasizes the application of "upper-bound and mid-range exposure factors." Combination of upper-bound factors alone produces an unrealistic result that applies to no real individual; it is the combination of upper and mid-range values that produces a conservative, yet reasonable scenario. In developing the subchronic risk estimates, the HHRA uses the CDPHE Summer 2008 measurements made on four well pads during well completion activities and the 2010 measurements made by Antero at the Watson Ranch Pad. Air concentrations were measured in the four principal cardinal directions (east, west, north and south) at distances less than 500 feet from each well pad. In combining the data from all well pads, the risk assessment procedure adopted in the HHRA tends to gravitate towards the highest measurement for each chemical irrespective of location, which for some chemicals were measured when the wind was blowing north at a well pad, while for other chemicals were measured when the wind was blowing east at another well pad location. Clearly this is conservative and illustrates the application of upper-range assumptions. However, to compound this conservatism, these approximately 24-hour air concentration measurements were used to represent exposures over 20 months, which is unrealistic. As shown in Figure 1 (Non Methane Organic Chemicals (NMOC) measured at a well pad in 2008), which is from one of the Summer 2008 well completion sites, there is considerable variation in concentrations measured in the different cardinal directions (consistent with short term emissions and prevailing wind conditions). Assuming residents over 20 months are experiencing the highest 24-hour measured concentrations without accounting for emissions variation and changes in meteorological conditions over approximately two years is unreasonable.[6] Rather than use compound worst case assumptions, mid-range assumptions should have been applied to produce a more realistic estimate of likely risks.

Figure 1: NMOC Concentrations at Well Pad During 2008 Well Completion



Source: CDPHE 2009. "Analysis of Data Obtained from the Garfield County Air Toxics Study – Summer 2008."

Despite the conservatism applied in the assessment, the results of the HHRA analysis of subchronic health effects indicate the individual chemical hazard quotient exceeded 1.0 for only

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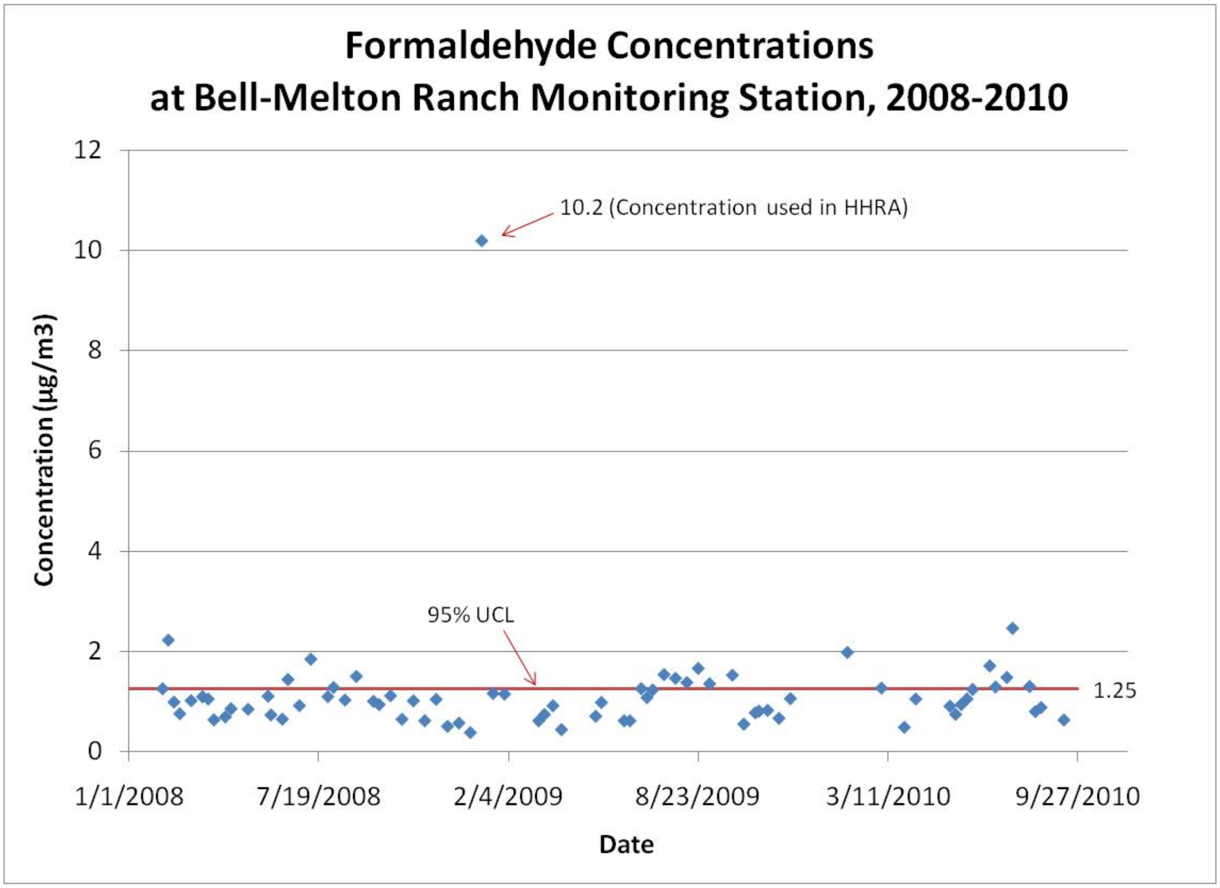
[6] It should be recognized that over a 20-month period, the wells will undergo different stages of development. The HHRA focuses on flowback operations during well completions performed in the summer of 2008, but contains no discussion of emissions during drilling operations. Flowback operations produce substantially higher emissions, but do not persist continuously over 20 months. If the intent is to capture a 20 month window, the HHRA should average emissions through the various phases of well development at the well pads.

a single chemical, formaldehyde.[7] However, formaldehyde was not actually measured by CDPHE during the Summer 2008 study. To supplement the data used in estimating risks associated with well completion activities, the HHRA relies on another dataset – monitoring conducted at Bell-Melton Ranch – and selects the maximum concentration ever detected at that location to assess subchronic risks. Figure 2 shows the measurements of formaldehyde historically conducted at Bell-Melton. The maximum for formaldehyde used in the HHRA was actually detected on January 7, 2009, and is obviously unrelated to the well pad sampling conducted in the summer of 2008 or Antero's sampling in 2010. Examination of the other chemicals present at Bell-Melton Ranch on that day indicate low levels of other aldehydes, such as crotonaldehyde (less than 0.1 $\mu g/m^3$), and other risk drivers, such as benzene (less than 5 $\mu g/m^3$). Thus, there is no obvious relationship between the maximum formaldehyde measurement at Bell-Melton and well pad completion activities, and the result is likely an anomaly. The application of maximum values at other stations for chemicals not measured during Summer 2008, as adopted in the HHRA, focuses on outliers (as evident in Figure 2) and is inconsistent with acceptable risk assessment practice.

[7] Other chemicals have hazard quotients less than 1. The HHRA incorrectly adds hazard quotients for all chemicals; it is appropriate to add hazard quotients only for chemicals with the same health endpoint.

Figure 2: Formaldehyde Concentrations at Bell-Melton Ranch



In the final step in the assessment of subchronic health effects, the air concentration measurements are compared with chemical-specific subchronic toxicity values to estimate the potential for adverse health effects. In risk assessment guidance intended for evaluating acute and subchronic risks, RAGS Part F (USEPA 2009) instructs that "risk assessors should consider the duration associated with their estimate of exposure (e.g., a 1-hour versus a 24-hour air sample)" and select toxicity values accordingly. Since the air samples are 24-hour samples, the toxicity values should be short term as well. USEPA further emphasizes, "Use of a toxicity value specified for a longer duration than that of the exposure estimate may overestimate hazard." Because the HHRA selects toxicity values intended for months to years of exposure, and the concentrations measured are not integrated over that period, the potential for subchronic adverse health effects estimated in the HHRA is overstated. If the HHRA had eliminated the values from unrelated datasets (formaldehyde is an example) and accounted for a better correspondence between duration of exposure and toxicity value, it would not predict adverse subchronic health effects for residents within 500 feet of well pads. The risks for the actual community would be even less.

2.2.4 Comments on Acute Risk Estimates

The HHRA provides acute non-cancer risk estimates for certain subgroups of Battlement Mesa residents living near a well pad. Risk estimates for child residents are presented separately for exposure to ambient air and surface water; the combination of risks associated with these two exposure pathways is also presented. The HHRA also presents acute risk estimates for adults and elderly residents living near a well pad. Risks are based primarily on exposure to ambient air. As noted above for the chronic and subchronic risk estimates for residents "near a well pad," a "maximum" case was calculated using the maximum observed concentration for each chemical and should be disregarded as unrealistic and inconsistent with standard risk assessment methods.

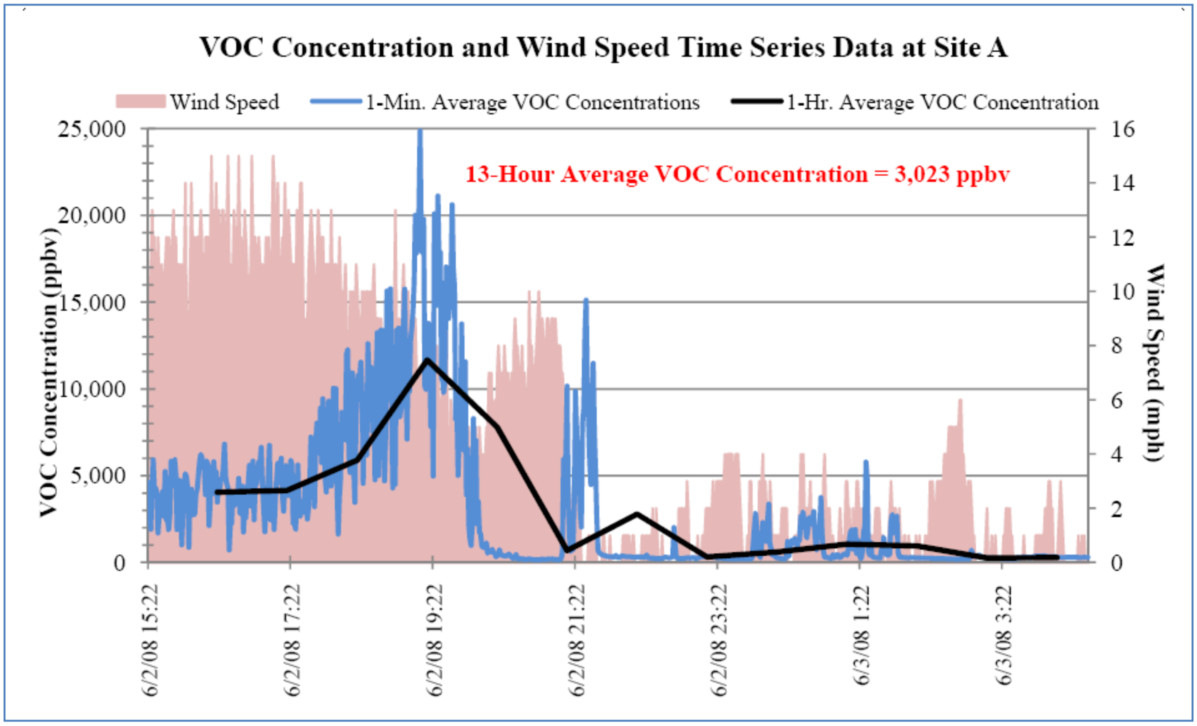
The exposure point concentrations (EPCs) used in the acute risk calculations are based on air concentration measurements collected from grab samples in 2005-2007. Grab samples were collected over a period of approximately 10 to 15 seconds by Garfield County staff, contractors, and residents in response to odor complaints. The 95% UCL on the mean concentrations from these grab samples were used in the HHRA to compare to toxicity criteria, which resulted in an HI of 2 for children, adults, and elderly residents living "near a well pad."

As discussed previously, CDPHE has conducted a detailed analysis of emissions during well completion operations in Summer 2008. As described in the study, there are periods during well completions when the pressure of the escaping gases is very high and difficult to control and "venting of non-salable gas occurs that has the highest potential for creating odors, and elevating the concentrations of volatile organic compounds (VOCs) and non-methane organic compounds (NMOCs)." In addition to the 24-hour/27-hour measurements made during the study, CDPHE monitored wind direction, wind speed and made real-time total VOC concentration measurements. As shown in Figure 3, VOC concentrations are not constant during well completions and occasional VOC spikes may be observed. If these spikes are high enough, prevailing wind conditions may cause odors to be observed at downwind locations. Depending on the magnitude of emissions and meteorological conditions, odors may be experienced intermittently, on the order of minutes to hours, potentially at various time periods during a 24-hour period.

As discussed above, USEPA guidance (RAGS Part F 2009) in conducting an assessment of acute exposures considers it important to match the exposure sample measurement time with the time period over which the toxicity value is developed. As shown in Figure 3, the maximum 1-minute average concentrations (blue lines) are substantially larger than the maximum 1-hour averages (black lines), which in turn are larger than the 13-hour average VOC concentration. If a 1-minute maximum was used to represent the 13-hour average, it would greatly exaggerate the longer term average concentration. Accordingly, it is inappropriate to use a 10-15 second sample collected during odor events to compare with toxicity values appropriate for exposures over significantly longer periods. Despite the short duration of the samples, the HHRA selects Agency for Toxic Substances and Disease Registry (ATSDR) Minimum Risk Levels (MRLs) as the toxicity values for benzene, chloroform, ethylbenzene, formaldehyde, m&p-xylenes, and toluene, which are intended for exposures spanning 1-14 days. USEPA defines acute exposures as being less than one day and has developed a compilation of acute toxicity values that would be more appropriate for this short exposure duration (USEPA ATRA Library 2004-2006). For example, USEPA lists 1,300 μg/m^3 as the California Office of Environmental Health Hazard Assessment (OEHHA) acute reference exposure level (REL) for benzene (benzene is the risk-driver for acute risks estimated in the HHRA). Comparing the REL with the benzene measurements made during odor events (see Figure 4), it is evident that adverse acute risks are unlikely to present a health concern at Battlement Mesa.[8] The guideline value applies to a six-hour exposure duration, which is an extremely conservative point of comparison for the grab samples. As discussed previously, these grab samples should not be used in the HHRA; data collected from subsequent sampling events are more appropriate for assessing acute risks.

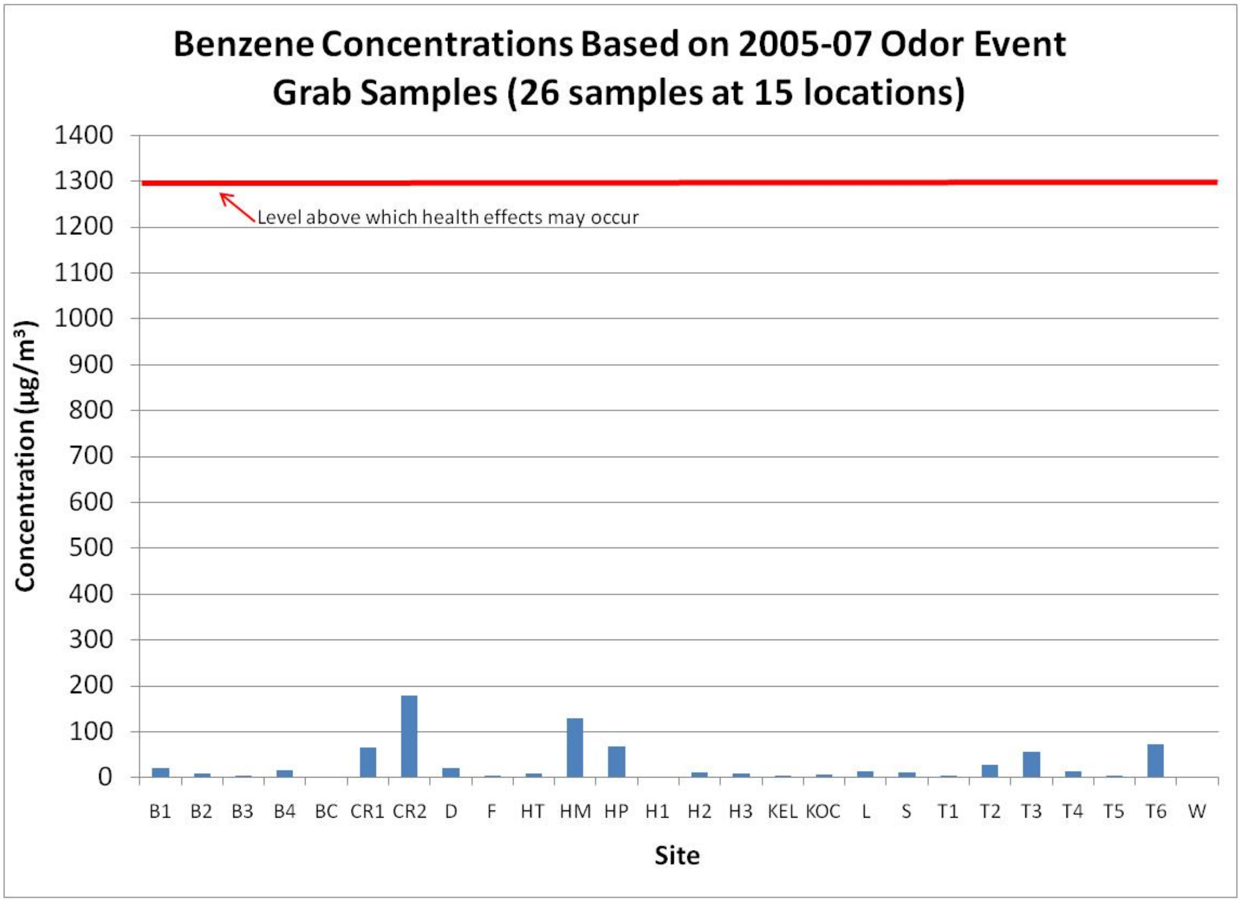
[8] The acute toxicity value used in the HHRA for benzene cannot be relied upon because the value is inconsistent with both the subchronic and chronic toxicity values (it is lower than both values, which is not possible). This discrepancy should be corrected, because otherwise it leads to the paradoxical conclusion that exposures to the level of benzene in the grab samples for 20 months will produce no adverse health effects, yet exposure to the same level for only seven days results in an estimate of adverse health effects (the 95% UCL is lower than the subchronic toxicity value for benzene).

Figure 3: VOC Concentrations and Wind Speed at Well Pad During 2008 Well Completion



Source: CDPHE 2009. “Analysis of Data Obtained from the Garfield County Air Toxics Study – Summer 2008.”

Figure 4: Benzene Concentrations Measured in Odor Event Grab Samples



The only risk estimate presented in the HHRA that is not based on exposure to ambient air is the acute risk estimate for a child living near a well pad due to exposure to surface water. The HHRA indicates that the concentration data used to calculate this estimate were collected from one snowmelt runoff sample collected at a well pad near Rulison, Colorado in 2008; that the exposure is expected to occur at puddles in the yards of homes adjacent to a well pad; and that the puddles, and the concentrations of volatile organic chemicals they contain, persist for seven days. This is not a realistic scenario, and more relevant and reliable risk estimates could be produced by additional analysis that accounts for the details of the proposed project (e.g., 500-foot setbacks from well pads that are constructed with perimeter berms to control runoff) and local soils and hydrologic conditions (which may not sustain puddles that contain well pad runoff for extended periods). Notwithstanding these observations, the hazard index of 15 calculated for this scenario is likely in error. The surface water concentrations of several of the chemicals are substantially below drinking water standards (e.g., toluene detected concentration 45 µg/L vs. drinking water MCL 1000 µg/L; ethylbenzene detected concentration 8.3 µg/L vs. MCL 700 µg/L), and it is very unlikely that occasional dermal contact will produce such high hazard quotients (Appendix D, Table 5-6). The calculations used in the HHRA to derive the hazard quotients for the surface water pathway could not be reproduced and are overstated by a factor of 100. The acute risks for all exposed populations from occasional contact with surface water are less than 0.2, and not 15. No adverse health effects from contact with surface water at Battlement Mesa can be expected.

3 Detailed Comments

Antero Resources Corporation (Antero) is proposing a natural gas development in the Battlement Mesa Planned Unit Development (PUD) in Garfield County, Colorado. Antero plans to install nine well pads (with a total of appropriately 200 wells), a water storage and management system, and natural gas pipelines within the PUD. In response to concerns of residents in the PUD, the Garfield County Board of County Commissioners (BOCC) requested that the Colorado School of Public Health (CSPH) conduct a Health Impact Assessment (HIA) to address citizen concerns by identifying potential health impacts of Antero's proposed project and making recommendations to mitigate those potential health impacts. As part of the HIA, a screening level human health risk assessment (HHRA) was conducted to estimate potential risks associated with exposures to pollutants in ambient air and surface water.

Prior to any drilling activities, Antero is required to submit an application for a Special Use Permit to the BOCC. Additionally, in order to streamline the well permitting process, Antero will also submit a Comprehensive Drilling Plan to the Colorado Oil and Gas Conservation Commission (COGCC). Antero has not yet filed any applications with the BOCC or COGCC. Many of the recommendations in the HIA propose that the BOCC require certain conditions on Antero's Special Use Permit.

The first draft of the HIA was released on September 20, 2010, followed by a public comment period. The HIA was revised based on public comments received and a second draft was issued February 28, 2011. ENVIRON was retained by Antero to review the findings and recommendations in the HIA and provide comments based on this review.

We have organized our comments such that we begin with our general comments on the HIA followed by more specific comments about several of the health impact assessments: air quality; water and soil quality; traffic and transportation; noise, vibration, and light; community wellness; and accidents and malfunctions. The final section includes detailed comments on the HHRA.

3.1 General Comments on the HIA

3.1.1 Characterization of Stressors

On p. 29, the text still refers to the “numerical ranking of impacts,” but the numerical system has been replaced by a qualitative ranking system, which categorizes stressors as low, medium, medium-high, and high priority. While this is an improvement over the previous numerical ranking system, the basis for selecting the priority rankings lacks transparency. The ranking does not appear to be based on the previous numerical system. For example, accidents and malfunctions previously received a numerical rank of -10. If compared to the first draft and current draft’s rankings of community wellness or noise, vibration, and light, accidents and malfunctions would be expected to be of low or medium priority, but is ranked as high priority in the current draft. Public comments to the first draft have expressed heightened concerns about catastrophic accidents, which may have resulted in greater emphasis on accidents and malfunctions. The priority ranking also does not clearly state whether it is based purely on an assessment of potential risks based on readily ascertainable information or also accounts for public perceptions of risk, which may be driven by concerns about unfamiliar or poorly understood risks. For example, residents may express more concern about a well-related explosion than a traffic accident, even though the likelihood of impacts from a traffic accident may be higher. The HIA does not provide sufficient explanation of how the impacts were prioritized, which makes it difficult to understand how changes in attributes (e.g., moderate to low magnitude of health effects, frequent to infrequent exposure) resulting from adopted mitigation strategies might change the rankings.

3.1.2 Lack of Baseline Data

The HIA repeatedly notes the lack of or limited nature of the available baseline data. For example, the authors report that there is no measurement of baseline noise levels in Battlement Mesa. While Battlement Mesa ambient air monitoring data were collected and analyzed between the first and second HIA drafts, the data were for a single location (Battlement Mesa Fire Station) and span September to November 2010 only, and do not capture spatial and seasonal variations. The HIA’s Executive Summary recommends the collection of baseline data (p. ES-V): “We recommend the collection of baseline and ongoing air, groundwater, surface water, and soil data around well pads and the centralized water storage facility.” In some cases, the HIA is specific about sampling design parameters (e.g., groundwater sampling locations and analytes in Water and Soil Quality Recommendation 9 on p. 16). However, the HIA does not provide sufficient basis for its recommended sampling plans or explain how the baseline data would be used to supplement the HIA or to conduct separate analysis. Many of the conclusions about the proposed project’s potential health impacts are made without an understanding of baseline conditions.[9] The extent to which the gathering of baseline data might alter the findings of the HIA is not discussed.

The HIA's baseline does not account for development, whether by the oil/gas industry or other sectors, in Battlement Mesa or neighboring jurisdictions that would occur in the absence of Antero's proposed project. If Antero's project proceeds, it is unclear how future monitoring and analysis would be able to differentiate potential health impacts from Antero's project and impacts from other development in the area. The HIA does not evaluate the extent to which existing requirements or best management strategies mitigate potential health impacts, or the extent to which additional requirements, as proposed in the recommendations, would provide added benefit.

3.1.3 Comments on HIA Recommendations

Many of the recommendations are already addressed under existing COGCC or Garfield County regulations, while others are already part of Antero's plans. Other recommendations may require changes to state or local regulations that appear to be beyond the scope of the project.[10] Given the large number of recommendations, it would aid future discussion to clearly distinguish those items that represent original recommendations proposed by the authors based on their assessment from those that are descriptions of existing requirements and plans.

[9] For example, despite the lack of baseline noise data in the vicinity of the proposed well pads, Noise, Vibration, and Light Recommendation 1 (p. 20) suggests improving sound mitigation to achieve noise levels that are well below existing COGCC required levels. Other noise-related recommendations (p. 20) propose mitigation measures without knowledge of what existing sound levels from non-project related sources might be. Likewise, the traffic and transportation recommendations contain provisions for industrial haul routes, speed control, and other safety measures (pp. 18-19), but the HIA did not evaluate existing traffic incident rates on roads in Battlement Mesa (p. 49 provides only crashes by county). Without this information, it is not possible to determine where the safety measures would have the most impact or how incident rates may change on specific roads or intersections.

[10] For example, Air Quality Recommendation 18 (p. 14) refers to adherence to Clean Fuel Fleet Program truck emission standards, which are required for areas in nonattainment of national ambient air quality ozone standards. Because Garfield County is in attainment with national ambient air quality standards for all criteria pollutants, the county is not subject to the emission standards in the Clean Fuel Fleet Program. If new requirements are to be imposed, the decision would need to be considered for the county or state as a whole, and not just for this specific project. The recommendations pertaining to the prevention of idling trucks on well pads and along roads (p. 14), reporting any spills of one or more barrels (p. 17), speed control on county roads (p. 19), achievement of noise levels below currently required levels (p. 20), best available noise reduction technology requirements (p. 20), and monitoring the provision of company health insurance (p. 24) would require changes to county or state regulations because these policies would not apply to Antero's project only.

However, the HIA recommendations are not organized in this way, and they are not prioritized to aid in decision-making.

The specificity of some of the recommendations may prevent consideration of alternatives that are more protective and/or cost effective.[11] The COGCC regulations generally include default requirements but some of these regulations include specific alternatives, and some allow the operator to propose and request approval for alternatives that are not specifically described. In essence, the regulations allow the COGCC and the operator to consider various alternatives and select alternatives that are mutually acceptable.[12] Some of the recommendations would eliminate this flexibility and effectively substitute the judgment of the HIA authors for the judgment of engineering professionals and state officials with experience in the oil and gas industry.

Specific recommendations that eliminate alternatives provided in the COGCC regulations should be supported by site-specific and project-specific analysis. In the absence of such analysis, it is not appropriate to describe these recommendations as "best" (see for example, Water and Soil Quality Recommendations 10 and 12 on pp. 16-17).

[11] Air Quality Recommendation 1 (p. 12) mandates the use of air monitoring to demonstrate that Antero's low emissions flowback technology is effective. However, other types of testing and/or analysis (e.g., combination of source testing and modeling) may be more effective and indicative of the range of ambient air concentrations than a single day of air monitoring. Air Quality Recommendation 9 (p. 13) specifies the use of vapor recovery technology rather than combustors, without any evaluation of whether vapor recovery technology is as effective at reducing vapor emissions. Air Quality Recommendation 6 (p. 13) and Water and Soil Quality Recommendation 6 (p. 16) advise the use of permitted tanks rather than Antero's proposal of a covered, centralized storage pond. However, these recommendations do not consider the cost or feasibility of using tanks, since 40 to 50 tanks containing 5000 barrels each (and approximately 30 feet high) would be needed to provide the same capacity as the pond.

[12] For example, COGCC Section 908 discusses site-specific monitoring wells in the vicinity of centralized exploration and production (E&P) waste management facilities: "Where applicable, the Director shall require ground water monitoring to ensure compliance with the concentration levels in Table 910-1 and WQCC standards and classifications by establishing points of compliance, unless an oil and gas operator demonstrates to the satisfaction of the Director that an alternative method offering equivalent protection of public health, safety, and welfare, including the environment and wildlife resources, can be employed…" The COGCC noise abatement rule (Section 802) states "the goal of this rule is to identify noise sources related to oil and gas operations that impact surrounding landowners and to implement cost-effective and technically-feasible mitigation measures to bring oil and gas facilities into compliance with the allowable noise levels identified in subsection c."

3.2 Air Quality

3.2.1 Comments on Air Quality Assessment

Air dispersion modeling is a useful and commonly used tool to provide ambient air concentrations of pollutants experienced by receptors (i.e., residents), which can be used to estimate inhalation risk. USEPA's Air Toxics Risk Assessment recommends that even for relatively simple, screening-level risk analysis, simple modeling can be performed to determine whether more detailed analysis is required (USEPA 2006). No air modeling was conducted as part of the HIA; the HHRA relies solely on limited sets of air monitoring data and recommends "comprehensive modeling approach" for future work (Appendix D, p. 68). On p. 36, the HIA reports: "At this time, there is insufficient measurement and modeling information to determine air pollutant movement from well pads and truck routes to people's homes." A 2008 study conducted by Coons and Walker included air dispersion modeling of five different emission scenarios, using representative emission rates for hypothetical natural gas development operations in Garfield County. Although not specific to Antero's proposed project, this study illustrates the use of modeling results in risk calculations. A reasonable amount of project-specific information is already available as inputs into an air dispersion model, including emission source locations (well pad and centralized water storage pond locations), receptors (existing residents and areas that may be developed into residences in the future), and local meteorological and topographic data (already used in previous studies). The existing monitoring data on well development activities could be used to validate and improve the model. The impact of mobile source emissions can also be included in the model from the information on increased traffic that Antero is submitting as part of its permit application.

Without air modeling, ambient air concentrations at residences 500 feet to ½ mile from the well pads are being estimated with 15-second grab samples collected in response to odor events and a few days of monitoring data collected less than 500 feet from well pads using emissions control technologies potentially different from those Antero is proposing. New regulations have taken effect since the historical measurements were made, including the COGCC Section 805 odor and dust regulations, governing venting, condensate tanks, glycol dehydrators, pneumatic devices, etc. Air modeling would allow for developing estimates of air concentrations beyond 500 feet, and the impact of adopting different control technologies on off-site concentrations could be tested with the model.

Given the variations in weather, topography, and local emission sources, relying on a limited amount of monitoring data to conduct a risk assessment, even a screening-level risk assessment, may misrepresent expected concentrations and risks. In addition to hampering the understanding of concentrations beyond 500 feet from the well pad, the lack of a site-specific air model makes it difficult to prioritize mitigation strategies or evaluate whether the proposed mitigation strategies, such as the recommendations in the HIA, would be effective. The HIA performs no source characterization. As a result, when elevated pollutant concentrations are observed in the monitoring data, it is unknown what the key contributors are – flowback operations, production tanks, well pad truck traffic, diesel-powered equipment, off-site road traffic, or non-project emissions. Without identifying emission sources and their contribution, it is impossible to determine the best strategy to control emissions.

In Section 5.1.3 (p. 35), the HIA blurs the distinction between health effects from elevated levels of airborne contaminants and health effects from nuisance odors. The HHRA in Appendix D specifically deals with air quality, but some of the air monitoring and many of the recommendations are driven by odor complaints (for example, Recommendations 3, 10, 13, 22, 23). Most prominently, the selection of the ½ mile distance as the definition of "near a well pad" is not driven by an expectation that health risks exist within ½ mile, but because odors were detected up to ½ mile of the Watson Ranch Pad in 2010. Unpleasant odors do not indicate that the chemicals responsible for the odors are at concentrations that would lead to serious long-term health effects.

The HIA goes on to note on p. 35 that the BTEX levels detected in the grab samples were higher than the USEPA regional screening levels for residential ambient air. USEPA regional screening levels are meant to be protective of the general population, including sensitive individuals over a 70-year lifetime, and it is inappropriate to compare 15-second grab sample results to these screening levels.

In Section 5.1.3 (p. 36-37), the HIA documents many items as "what we do not know" but does not provide concrete guidance as to the types of data collection and analysis that would eliminate or reduce these information gaps or uncertainties. The HIA has not clearly articulated which uncertainties could be resolved or minimized through further work specific to this project (e.g., source characterization), and what uncertainties remain (e.g., insufficient toxicity data from the broader scientific literature) and how they might affect the assessment.

3.2.2 Comments on Air Quality Recommendations

Several of the recommendations proposed by the HIA are quite specific but do not appear to be based on analysis using site and project-specific information.[13] The prescriptive nature of these recommendations does not leave any room for decision makers to weigh options that are equally or more effective in achieving the desired goals.

Section 3.1 (p. 12): Recommendation 1 suggests that Antero demonstrate the effectiveness of their low emissions flowback technology through the collection of twenty 24-hour ambient air samples at five distances in each cardinal direction from the source. As impacts near a well pad are influenced by numerous sources and weather conditions, it is difficult to see how ambient air

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[13] This includes the recommendations regarding the use of permitted tanks rather than a centralized water storage pond (pp. 13, 16), use of vapor recovery technology instead of combustion (p. 13), location of the centralized water storage facility (p. 16), and groundwater, soil, and surface water monitoring at each well pad (pp. 16-17),

monitoring can be used to demonstrate effectiveness. An alternative approach may be to apply an air model based on uncontrolled and controlled emission scenarios that can be used to estimate concentrations at the various distances. Air monitoring should only be used to validate model results, in the event existing data are not sufficient.

Section 3.1 (p. 13): Recommendation 9 and the related discussion on p. 34 articulates the preference of vapor recovery over venting or combustion because "combustion of fugitive VOC emissions generates carbon monoxide, carbon dioxide, and nitrogen oxides, whereas venting results in VOC emissions" assumes that vapor recovery is 100% effective, which is not the case. The HIA recommends that Antero use vapor recovery technology rather than combustion, but does not evaluate the estimated emissions from each scenario.

Section 3.1 (p. 13): Recommendation 11 discusses the implementation of an air monitoring program for all well completion activities within the PUD and at the centralized water storage facility, and specifies the collection of 24-hour and grab samples, real-time monitoring, and odor monitoring. The HIA does not clarify the objective of such a program – whether it is to gather inputs for further risk assessment, compare to acute exposure thresholds, verify the effectiveness of emissions control, provide data for a broader scale study of natural gas well development, or another purpose. The objective will drive the scope of the program and the type of data collected. For example, grab sample data would not be useful for further risk assessment where longer sample periods (e.g., eight-hour, 24-hour) are preferred.

3.3 Water and Soil Quality

3.3.1 Comments on Water and Soil Quality Assessment

Section 5.3 (pp. 40-41): The Antero project will be designed and implemented such that nearly all of the types of releases described in the opening paragraph of this section will potentially occur only as a result of accidents or malfunctions. Systems will be constructed and operated to prevent all of the releases named in this paragraph except for diesel exhaust. The likelihood that diesel exhaust will impact surface soil to levels constituting "contamination" (i.e., to levels that may impact public health) is extremely small. Detectable impacts to soil from diesel exhaust would most likely occur on the well pad (if at all), where perimeter berms and other stormwater management controls will prevent transport of impacted soils by surface water. Any impacted soils on the well pad will be remediated at or before the reclamation phase. These findings indicate that recommendations to protect the public health from the effects of soil and water contamination should be directed toward preventing accidents and malfunctions.

Section 5.3.1 (p. 41): This section refers to the HHRA (Appendix D) for information regarding specific health effects associated with several potential contaminants. The HHRA suggests that surface water runoff from well pads may cause elevated risks to nearby child residents. This scenario is further discussed in detailed comments on the HHRA.

Section 5.3.2 (pp. 41-43): This section reviews information collected at other gas fields and states that groundwater and surface water contamination at levels with the potential to impact water quality and exceed regulatory levels are associated with incidents described as accidents and malfunctions. The authors did not identify evidence of significant water contamination associated with routine natural gas development and production activities. These findings indicate that recommendations to protect the public health from the effects of soil and water contamination should be directed toward preventing accidents and malfunctions.

Section 5.3.3 (pp. 43-44): This section reviews the available information regarding current (baseline) levels of contaminants in soil and groundwater in the PUD. It is not clear from the text whether the authors of the HIA consulted government databases to identify previously-reported spills or releases within the PUD or potential sources other than the 10 listed USTs. The last paragraph of this section suggests that a hydrologic connection between the four Battlement Mesa backup wells and “the aquifer on Battlement Mesa” could allow contaminants from natural gas extraction activities to impact these wells. The uncertainty regarding the source of water to these wells will be resolved under state regulations before the project proceeds; but regardless of this connection, Antero’s activities will not impact the quality of water in these wells unless accidents or malfunctions occur.

Section 5.3.4 (pp. 45-47): This section suggests a number of ways in which Antero’s operations could potentially impact surface water, groundwater, or soils within the Battlement Mesa PUD. Some of these suggestions fail to account for the details of Antero’s planned activities. For example, the text on page 46 refers to “spills that may occur outside the berm perimeter”; this suggestion accounts for the containment berm around the storage tanks, but does not account for the berm around the perimeter of the well pad. The text also refers to “production water-hauling trucks”; Antero plans to use pipelines (not trucks) to transport produced waters to the central water handling facility. The Antero project will be designed and implemented to prevent routine releases that may impact soil and water; the possibility of such releases occurring arises only as a result of accidents or malfunctions.

Section 5.3.5 (p. 47): The text should note that almost all of the potential impacts to soil and water discussed in Section 5.3 will only occur as a result of accidents or malfunctions. The extent to which these impacts are addressed in Section 5.9 (Assessment of Accidents and Malfunctions Impacts on Health) should be stated in Section 5.3.5, and the same potential negative impacts should not be counted in evaluating both topics. The note regarding the numerical ranking system that appears under the table in Section 5.3.5 is apparently carried over from the previous draft and should be revised or deleted.

The table indicates that the extent of exposure to impacted soil and water is community wide, and the text suggests that this entry is based on exposure through the public water supply. Exposure through the public water supply seems extremely unlikely given the lack of any demonstrated connection between Antero’s proposed activities and the primary and secondary public water sources. As suggested in the text, other potential exposures to contaminated soil or water associated with Antero’s operations would most likely be local, not community-wide. The text related to the entry in the table for duration of exposure (“Long,” which indicates one year or more) suggests that water quality degradation could last through the life of the project. If this degradation caused exceedances of health-based standards in the public water supply, these exceedances would be detected and corrected long before the end of the project and most likely in less than one year.

3.3.2 Comments on Water and Soil Quality Recommendations

As noted in comments on Section 5.3, the Antero project will be designed and implemented to prevent chemical releases to soil and water. Because any releases, if they occur, will only occur as a result of accidents or malfunctions, recommendations to protect the public health from the effects of soil and water contamination should be directed toward preventing accidents and malfunctions. Many of the recommendations in Section 3.2 are directed toward preventing such incidents.

Some of the recommendations suggest that the authors of the HIA may not fully understand Antero's plans, which fully incorporate some of the recommendations (e.g., numbers 4, 16, and 17) and include some elements of many of the other recommendations. Recommendations related to compliance with Federal, state, and county regulations (such as Recommendations 1, 2, and 5) are not necessary; Antero intends to comply fully with all applicable regulations throughout the life of the project. Other responses to specific recommendations and elements that are not consistent with Antero's plans are provided below.

Recommendation 6 (p. 16) suggests using tanks instead of ponds at the central water handling facility. The HIA may not have considered the number and size of the tanks required to implement this recommendation; Antero expects to store approximately 200,000 barrels (more than 8 million gallons) of water at this facility. Also, the HIA appears to be unaware of Antero's plan to cover the ponds. Covering the ponds to reduce air emissions is also expected to prevent wildlife and pet exposures.

Recommendation 7 (p. 16) suggests locating the central water handling facility at least one mile from any residence or school. Because potential emissions from the ponds will be controlled by covers, adoption of this recommendation is not necessary to protect the public health. If such a recommendation is to be considered, the required distance should be determined by calculations that account for the relevant characteristics of the site and project; a distance of one mile seems arbitrary.

Recommendation 8 (p. 16) suggests that all volatile organic compounds (VOCs) used on the well pads should be included in the water monitoring program. The likelihood, extent, and possible health implications of contamination by VOCs are largely determined by the volume, mode of use, fate and transport characteristics, and toxicity of the individual chemicals. These factors should be considered in selecting chemicals for inclusion in any monitoring program.

Recommendations 9 and 10 (p. 16-17) suggest intensive groundwater monitoring at all well pads and at the central water handling facility for many chemical parameters and categories, including "any chemical identified in the full disclosure of chemicals of potential concern." This recommendation may be intended to provide early detection of groundwater impacts resulting from accidents or malfunctions, or it may be in response to the changes in groundwater noted in the Mamm Creek hydrologic study.[14] Antero plans to monitor the groundwater in the vicinity of the central water handling facility in compliance with the applicable COGCC regulations. Antero also plans to collect baseline samples from existing wells near each well pad, and then collect additional samples from these wells as the project develops. The chemicals and parameters these samples will be analyzed for will be selected to protect the health of those who use the local groundwater. The HIA has not determined that sampling from dedicated monitoring wells at each well pad and analyzing for a long list of chemicals that may never be released in meaningful quantities would be more protective.

Recommendation 11 (p. 17) suggests baseline soil and surface water testing at all well pads and at the central water handling facility. Antero plans to conduct surface water testing as required by applicable regulations, but does not believe that baseline soil sampling at each well pad is necessary to protect public health.

Recommendation 12 (p. 17) suggests monthly monitoring of local surface water bodies during well drilling and development activities, then annual monitoring for the life of the project. Antero plans to conduct a surface water testing program that complies fully with applicable regulations. The HIA has not explained why the frequencies specified in this recommendation are optimal, necessary, or appropriate for preventing exposures through impacts to surface water.

Recommendation 13 (p. 17) suggests soil testing at each well pad and the central water handling facility during reclamation activities and includes a list of conditions that would trigger remediation. Antero plans to conduct a reclamation program that complies fully with applicable regulations. The HIA has not explained why the remediation trigger conditions specified in this recommendation are optimal, necessary, or appropriate for preventing exposures through impacts to soil.

Recommendation 14 (p. 17) suggests that Antero be required to comply with regulations that may be applied to the project at the discretion of the Director of the COGCC. Antero plans to comply fully with all applicable regulations, including any that are imposed at the discretion of the Director.

Recommendation 15 (p. 17) suggests that Antero develop plans to prevent tracking of mud onto Battlement Mesa and Garfield County roads. Antero's plans for control of fugitive dust emissions include use of dust suppressants, graveled access roads, road brushing and road washing, and other measures that are expected to minimize the amount of mud deposited on public roads due to Antero truck traffic.

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[14] Section 5.3.2 of the HIA states that the Mamm Creek study showed that concentrations of chloride and methane increased over time as the number of gas wells increased, but did not exceed regulatory limits.

Recommendation 18 (p. 17) suggests monthly inspections of water and gas pipelines. Antero plans to conduct these inspections annually as required by regulations established by the COGCC unless the benefits of more frequent inspections are clear.

Recommendation 19 (p. 17) suggests that Antero be required to report any spill of one or more barrels to GCOG. Antero plans to report any spills as required by applicable regulations; the benefit of reporting to GCOG as well as COGCC is not explained in the HIA.

Recommendation 20 (p. 18) suggests covering all drill cuttings during storage on well pads. This specific recommendation is not practical, but Antero does have a plan to control emissions of fugitive dust from the well pads.

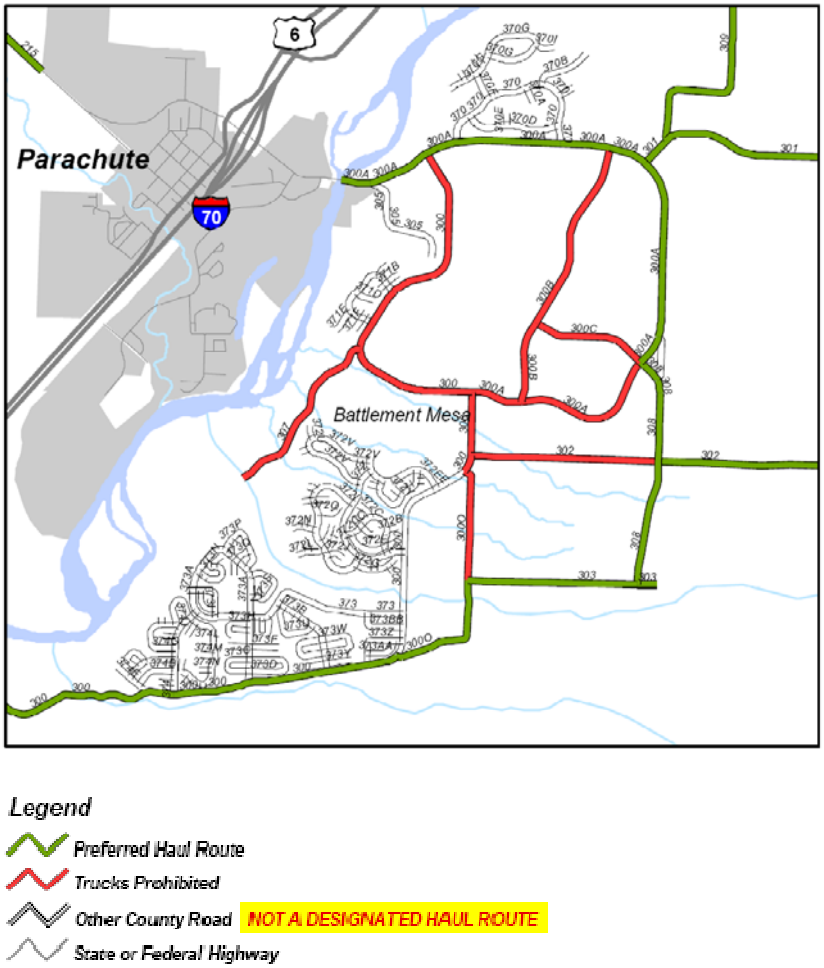
Recommendation 21 (p. 18) suggests assigning a Garfield County inspector to monitor Antero's compliance with the terms of the Special Use Permit. This decision will be made by county officials, not by Antero.

3.4 Traffic and Transportation Assessment

3.4.1 Comments on Traffic and Transportation Assessment

Section 5.4 (p. 52): The table on this page indicates that community-wide exposure to traffic associated with the project is expected. Section 4 notes that "community wide" means that effects occur over most or all of the Battlement Mesa PUD. This characterization is not consistent with Antero's traffic management plan (Figure 5), which identifies preferred haul routes and prohibits truck traffic through most of the PUD.

Figure 5: Antero Traffic Management Plan - Battlement Mesa Area Map



Source: Antero 2009. Traffic Management Plan.

Section 5.4.3 (p. 50) enumerates the estimated number of vehicle trips per day for the different phases of the project, but the HIA does not place those values in context with the existing traffic in the vicinity of the well pads and on the county haul routes. Despite available information on haul routes, vehicle trips, and construction schedule, the HIA does not perform any traffic analysis or modeling to determine whether there are any potential “hot spots” for congestion or accidents associated with the project. Even if sufficient data were not available at the time of the HIA, explaining how such an analysis could refine the recommendations and inform decision-making should be part of the HIA.

3.4.2 Comments on Traffic and Transportation Recommendations

Section 3.3 (p. 18-20): This section indicates that accidents, air pollution, and noise levels are the primary concerns associated with project-related traffic. These concerns overlap with some of the other topics addressed in the HIA (accidents and malfunctions; air quality; and noise, vibration and light). Thus, traffic may contribute to perceptions and assessments of other topics and effectively be counted twice unless care is taken to prevent this.

Antero's plans already include Recommendation 1 (installation of pipelines before well pad development). Antero's traffic management plan includes Recommendation 2 (develop industrial haul routes outside the PUD) to the extent possible. The lower speed limits suggested for trucks related to the Antero project in Recommendation 4 may increase the rate of accidents on public highways. Many of the other recommendations for this topic (3, 5, 6, 9, and 10) would require decisions or action by local officials as well as Antero.

3.5 Noise, Vibration, and Light

3.5.1 Comments on Noise, Vibration, and Light Assessment

(Section 5.5.1, p. 54) The references to studies suggesting that light at night may affect health by disrupting normal circadian rhythms do not directly apply to this project because the cited papers (Davis et al. 2009 and Stevens 2009) discuss the link between breast cancer rates and night shift work.

While the HIA summarizes data collection and modeling by Antero on noise impacts from the Watson Ranch Pad drilling operations, it does not specify whether any complaints about light intrusion to nearby residences were reported as a result of those activities. The HIA brings up light intrusion as a potential concern, but reports that modeling by Antero has demonstrated that its proposed light abatement measures will adequately reduce light intrusion to residents. Discussion of this modeling is limited to one sentence in the HIA and it would be helpful to explain these measures and the modeling more thoroughly.

3.5.2 Comments on Noise, Vibration, and Light Recommendations

The HIA repeatedly notes that noise levels meet permissible COGCC levels, but still be above levels that may impact health. Some of the recommendations include requirements that would be more stringent than existing COGCC regulations, such as Recommendation 1, which requires noise levels be below 55 dBA in the day and 50 dBA at night at 350 feet from the well pad noise source during all well development and production activities. Meanwhile, current COGCC regulations permit noise levels up to 80 dBA in the day and up to 75 dBA at night for those activities. If COGCC chose to lower permitted noise levels, the requirement would not just apply to Antero's proposed project. The HIA should specify which recommendations are broader than the scope of this project and would require a change in state regulations.

3.6 Community Wellness

3.6.1 Comments on Community Wellness Assessment

The HIA frequently brings up the natural gas industry during the boom of 2003-2008. However it never discusses how that boom of 2003-2008 is related to Antero's proposed project. From data provided in the Garfield County Socio-Economic Impact Study (2007, Section II, Page 7)[15], as of mid-2006, there were approximately 4000 people employed in the natural gas industry in the county; approximately 70 drilling rigs were operating, and about 1000 new gas wells were being installed per year. When contrasted to Antero's proposed operations of two rigs, staffed by 120-150 workers, and a total of 200 wells to be drilled over a five-year period, it is clear that there are substantial differences in the geographic area impacted and the number of rigs and workers that the HIA explicitly or implicitly links to community wellness. These differences are significant and quantifiable; inclusion of these statistics in the HIA would have provided a more realistic background for the discussion of potential impacts on community wellness by Antero's proposed operations. Without them, the HIA analysis of community wellness is misleading.

In the Executive Summary (p. ES-III), the HIA states "Community impacts of the natural gas industry during the boom of 2003-2008 and decline of 2009 included increased crime and sexually transmitted diseases, declining property values and impacts on the education environment," and in Section 5 (p. 59) the HIA states "Social problems of mental health, criminal activity, divorce, suicide and alcoholism are said to occur at disproportionate rates in boomtown natural gas economies." Why is this relevant, given that the HIA itself acknowledges that "It is not likely that the two rig operation will create a boom or bust economy in Battlement Mesa" (p. 69)?

The HIA states (p. 20) that "Battlement Mesa saw increases in crime, sexually transmitted disease [STD] and school population and a decline in educational environment during the years of the natural gas boom in Garfield County." This statement exemplifies three basic – but unsupported - premises of the HIA with respect to Community Wellness, which are that (1) changes that occurred in crime, STDs, school population, and education during the natural gas boom (2003-2008) are most likely due to that boom; (2) that changes in measures of Community Wellness such as education, crime, and STD represent changes or trends unique to – and thus linked to – activities in the local area; and (3) real or apparent impacts of the county-wide natural gas boom (2003-2008) can be qualitatively extrapolated to the proposed operations of Antero.

The natural gas boom that reportedly occurred in Garfield County, and whose inferred impacts are central to many of the concerns expressed in the HIA, is not characterized by the HIA in any way that would support an understanding of what the boom was, and why it might or might not

[15] http://www.garfield-county.com/oil-gas/documents/garfield_socio-economic_impact_study__1-25_.pdf

have had an impact on measures of Community Wellness. For example, no data are provided on the number of drilling rigs that were operating in Garfield County; the number of workers employed by the industry; whether these workers enrolled their students in local schools, and if so, how this enrollment compared to enrollment changes due to other factors; what the racial/ethnic characteristics of these workers were, and whether or not the racial/ethnic composition of the workers was reflected in the local schools (racial/ethnic changes in the student population was one of the data sets evaluated by the HIA). Importantly, did academic achievement decline during this period? Without data such as these, it is not possible to understand the fundamental characteristics of the boom on the very measures of the community (e.g., education) that are cited as likely impacted.

Closely related to the above comments is the assumption that changes in local statistics represent changes or trends unique to – and thus linked to – activities in the local area. Such changes may actually be occurring at larger scales, such as regional, state, or national levels, and thus may not be attributable to local circumstances; without consideration of such data, there is no true reference with which to understand the data presented in the HIA. For example, with respect to the crime statistics presented in the HIA, there is no discussion or comparison made to crime statistics for the nation and/or for demographically-comparable areas over the time period in question. Because the types and incidence of crime can fluctuate substantially based on such factors as changes in laws, technology, law enforcement practices, and other variables, the absence of comparable reference statistics limits the linkages drawn by the HIA between increased crime and the natural gas boom to inferences of questionable significance. Another example is provided by an examination of the educational data evaluated in the HIA. The HIA states that there was a decline in educational environment during the natural gas boom. The data supporting this statement are that (1) enrollment increased during the period 2005-2008 and (2) that there was a change in the racial and ethnic profile of students between the years 2000 to 2009 (Appendix C). Neither one of these measures of the educational environment equate to a 'decline'. Further, as noted with respect to the crime statistics, without a comparison to data from national, statewide, or demographically-similar areas, there is no way to assess whether the enrollment and racial/ethnic changes reflect local changes potentially linked to a natural gas boom or other local phenomenon, or are consistent with trends occurring across other areas of the state and/or US for the same time period.

Even given that the HIA itself says the project will not create a boom or bust economy, when discussing community wellness the HIA presents two sections on boomtown effects: Section 5.6.2 (Natural Gas Industry and Community Wellness) and Section 5.6.3 (Garfield County and Battlement Mesa during the Garfield County 2003-08 Boom).

Section 5.6.2 (Natural Gas Industry and Community Wellness) starts with "Boomtowns Changes: There are a small number of case studies available relating community impacts to boomtown effects of the natural gas industry" (p. 59). According to the HIA, some of the studies provide evidence that exposure to natural gas development and production can have negative psychosocial health implications, some find positive effects and some find no association.

Crime (p. 60): This section starts with the following statement “Several research studies have correlated increased crime rates with communities involved in natural gas development and production, including crimes such as domestic violence, rape, prostitution, assault, child abuse, and homicide” (citing references 66, 67, 68, and 69). But curiously, neither reference 66 (which focuses on land use in urban San Francisco) nor 67 (which focuses on the health benefits of a sustainable community) has anything to do with natural gas development production or its relationship with crime. Reference 68 uses the HIA for the oil development on Alaska’s North Slope as one of two case studies. There is no independent research in this paper; it merely summarizes the “key findings” of the cited studies. Reference 69, which looks at proposed oil and gas development in remote Alaskan Inupait Villages, lists substance abuse and domestic violence as potential health outcomes but does not provide data to support this.

Substance Abuse (p. 60): This section starts with the following statement “Several studies have reported an increased burden of substance abuse behaviors in communities involved in natural gas development and production, with primary emphasis being that substance abuse is prevalent among workers in the oil natural gas development and production” (citing references 65, 69, and 72). Reference 65, which discusses framing perceptions of oil development, did not report an increased burden of substance abuse. This study obtained interview data from long-time residents in the coastal region of Louisiana and concluded that the subject of the study perceived far less in the way of disorganizing effects of oil development, and for the most part suggested the impacts to be either benign or positive. Reference 69, as noted above, lists substance abuse as a potential health outcome but does not provide data to support this. Reference 72 also does not support the above statement. Reference 72, which looks at Alaskan native elderly suicide, concluded that during the Alaska “oil boom” suicide rates more than tripled for the general populations but decreased to zero for Alaska Native elders. Although the study mentions that most of the Native Alaskan suicides during that time were young men that were more likely to have had a history of alcohol abuse than age-matched controls, there was no mention as to whether these young men actually worked in oil/natural gas development and production.

Mental Health (p. 60): As noted by the HIA, “Studies of the community impacts of boomtown industries do not offer clear evidence for direct impacts to mental health.”

Sexually Transmitted Infection (p. 60): In this section, the HIA states that “Increases in the community burden of sexually transmitted infection have been identified as a health effect of extraction industries in many low- and middle-income countries (citing references 76-77). Although literature regarding STI and the extraction industries in North America does not exist, this is an area which should be monitored.” Interesting enough, the two references cited in the first sentence, are from North America, in particular Canada. Similar to other boom town studies, these studies evaluated the rapid in-migration of young, primarily male workers in response to the “boom” in the oil/gas industries. In the case of reference 76, the authors studied Fort Saint John, BC where there was an 8.4% increase in population since the 2001 boom and the workers were housed for long periods in remote oil/gas camps far from town. Additional workers for the proposed project (150-200) would comprise approximately 3-4% of the population of Battlement Mesa/Parachute (given as 5,041 in the HIA, Appendix BB Page 3) and 0.3-0.5% of the population of Garfield County (given as 43,791 in the HIA, Appendix BB Page 3), with Battlement Mesa located approximately 50 miles from Grand Junction, a city of approximately 58,000 in 2009 (http://www.city-data.com/city/Grand-Junction-Colorado.html).

In Section 5.6.3 (Garfield County and Battlement Mesa during the Garfield County 2003-08 Boom), the HIA states that the concerns of the Battlement Mesa residents are similar to those reported in the 2008 Saccomanno Study (several social and community concerns, including increase in spouse and child abuse, child neglect and stressed family relationships; increase in alcohol abuse and drug abuse, high suicide rates, increase in sexually transmitted infection, access to health care and mental health services, availability of housing, cultural clash between longtime residents and industry workers, and traffic and public safety) and reflects the county's earlier experience with the natural gas industry during the 2003-2008 boom. The HIA fails to state that the authors of the 2008 Saccomanno Study, concluded: "Based on the data available to us from state, hospital association, and healthcare provider sources, the health of people in Garfield County is not different from the health of residents of other Western Slope counties. However, citizen perception, as evidenced by focus group and interview data and the household survey, indicates that at least some individuals in impacted areas of Garfield County believe otherwise" (p. 226).

3.6.2 Comments on Community Wellness Recommendations

As discussed above, the proposed Antero project is not representative of boomtown conditions. Although the HIA uses boomtown data to evaluate potential community wellness issues, it acknowledges that there are limited studies for these conditions and the results range from positive, to negative, to in between. Nevertheless, the HIA proposes the following recommendations to reduce impact to community wellness (p. 21-22):

For Antero, Battlement Mesa Citizens, and Garfield County:

- Establish a Community Advisory Board.

For Garfield County:

- Review sexually transmitted infection clinic access, outreach and education.
- Identify operators and subcontractors that have implemented drug and alcohol free work-place programs and encourage Antero to do so and subcontract to companies that also do so.

For Garfield County and Antero:

- Support baseline and ongoing studies. These studies should include measurements related to lifestyle and social cohesion, education, crime, sexually transmitted infection, mental health and suicides, and substance abuse.
- Ensure recommendations to mitigate other concerns (air quality, traffic, and noise) are implemented.

We note that Garfield County already has an Energy Advisory Board (EAB) whose specific mission is to provide "… a forum for the oil and gas industry, the public, impacted landowners and local government to prevent or minimize conflict associated with oil and gas development through positive and proactive communication and actions that encourage responsible and balanced development of these resources within Garfield County." We believe that the existing EAB can address the primary purpose of the Community Advisory Board proposed by the HIA, which is to facilitate communication between community members and Antero Resources. The structure of the EAB supports this purpose, in that it includes community representatives as well as representatives from local government, organizations, school districts, and the energy sector.

Perhaps our single greatest concern regarding the recommendations is that the studies envisioned by the HIA (Recommendation 4 on p. 22) would have no means to characterize the contribution(s) of non-Antero activities (e.g., emission sources) to many (if not all) of the health impact endpoints proposed for study. This is because Antero's activities will take place within a larger geographic area that already supports natural gas exploration and other industrial activities. In the absence of information on the role and importance of these non-Antero activities to each health endpoint, there is a significant potential for any impacts to be misattributed, and no means to mitigate such impacts if the origin of the problem is not accurately known.

For example, mental health status (one of the endpoints of interest) is affected by a number of social and biological factors, including socioeconomic status and past and present access to health care. In a state and county with dynamic growth in both population and in energy-sector jobs, it would be difficult – and potentially impossible – to separate out any impacts of Antero's relatively small operations on mental health status from impacts due to other sources.

Further, we are concerned that by proposing to make measurements "related to lifestyle and social cohesion," the HIA is implicitly validating linkages between natural gas development and health endpoints that are inherently subjective in nature, impossible to quantify or accurately assess, and which may not have a basis in science. Selecting such measures for evaluation in the absence of evidence of scientific causality can be misleading and potentially futile.

To properly design and conduct and evaluate scientific studies of the type proposed here is both a long-term and complex process that is not likely to provide the direct feedback noted in the recommendation and deemed desirable by the HIA. To assess any impacts of Antero's operations on community and/or individual health will require, for each endpoint, the determination of a measurement metric, establishment of a true and accurate baseline, the identification of measurement methods, an assessment strategy, and identification of both geographic and temporal domains. Considering a change in education outcomes as an example of a community wellness metric, the study designers would need to determine what specific education outcome to measure (e.g., performance of high school students on the SAT Reasoning Test, or eight-grade grade point average), what school to measure it in, what year to measure baseline conditions, what year(s) to measure non-baseline conditions to compare against baseline, and where to obtain the necessary data. Acquisition of baseline data will require consideration of the frequency with which the data are (or can be) updated, the geographic domain of the data, how to address inconsistencies between the domain of the data and the domain of potential impact, how and when to measure for a potential change in a baseline indicator, and how an incremental change from baseline can be accurately interpreted. While such challenges are not insurmountable, they require considerable time and resources if they are to yield scientifically meaningful results.

Importantly, and as discussed in our comments above, we have significant questions as to whether such studies are even warranted, in that the perceived need for such studies is based on several flawed premises. Given these concerns, we believe that the community might receive the greatest and most immediate benefit if Antero's monetary donation to Battlement Mesa be allocated to establishing community programs or other activities selected by the community to best address their specific concerns. Allocation of Antero's donated funds in this manner is also consistent with Community Wellness Recommendation 7 (p. 22).

3.7 Accidents and Malfunctions

3.7.1 Comments on Accidents and Malfunctions Assessment

According to the HIA, accidents and malfunctions are rated as high because of the severe consequences if a catastrophic event were to occur. However, the HIA is not internally consistent with its characterization of accidents and malfunctions. On p. 29, it notes "we have prioritized accidents and malfunctions as high but note that incidents of this nature are difficult to predict." Meanwhile, on p. 76, in the Assessment section, the HIA notes "because incidents of this nature [accidents and spills] happen with low, but predictable, regularity, an assessment of potential health impacts is warranted." The discrepancy in these statements should be clarified; it seems that incidents, particularly catastrophic events, would be difficult to predict. The availability of historical statistics on spills, fires, loss of well control, and explosions in the state and Garfield County does not mean that it is appropriate to calculate future incident rates based on past incident rates, as was done in the HIA on p. 78.

Section 5.9 (p. 76): The assessment does not distinguish between accidents and malfunctions with little or no health impacts (e.g., minor spills that contained within secondary containment or are appropriately contained and cleaned up) and those with potentially significant health impacts (e.g., large fire or explosion). The HIA discusses Garfield County spills reported to the COGCC but implies that spills of any size or chemical may have potential health impact. The HIA does not focus its discussion on the past incidents that had potentially significant health impacts on residents near well pads, which would be of greatest relevance to residents. Statements like "local newspapers and COGCC databases have recorded numerous incidents of well fires, blowouts, tanker spills, condensate tank emissions and pit discharges in Garfield County" do not guide understanding of the incidents' root causes or potential health impacts.

It is also not clear whether the authors of the HIA considered spill reporting records or requirements established by government agencies other than the COGCC. Regulations promulgated by the USEPA establish reporting requirements for oil and a large number of hazardous substances, some of which are commonly used in many industrial and commercial activities. Records of spills reported under these regulations are available in government files and databases. Future vehicle accident rates due to the proposed project can be calculated with predictive models that estimate increased accident rates based on the additional vehicle miles of travel. It appears that the traffic analysis conducted by SGM (referenced on p. 50) has already projected average and management trips per day.

Section 5.9: As noted in comments on earlier sections of the HIA, care should be taken to prevent potential double-counting of the negative aspects of the proposed Antero project. For instance, most of the concerns about water and soil contamination addressed in sections 3.2 and 5.3 will not occur except as a result of accidents or malfunctions.

3.7.2 Comments on Accidents and Malfunctions Recommendations

Section 3.8 (pp. 24-26): Many of the recommendations related to mitigating impacts from accidents and malfunctions are already required by existing regulations or part of Antero's best management practices. Other recommendations, like the one regarding the relocation of pads to prevent well pad fires from spreading appear to stem from the Battlement Mesa Concerned Citizens (BMCC) concern that well pad locations at the base of steep slopes with dry vegetation could increase the risk of a well pad fire spreading up the slopes. This concern appears to have been transferred from a comment directly to a recommendation without further analysis by the authors to determine if the concern was warranted. In general, the authors do not identify the basis of the recommendations, whether they are from existing regulations, Antero's plans, citizen comments, or the authors' own assessment.

3.8 Human Health Risk Assessment - Appendix D

The HHRA concludes that residents living "near a well pad" (defined as within ½ mile) are more likely to experience health effects than residents living farther away (defined as greater than ½ mile). Our review of the HHRA indicates that this conclusion cannot be supported. We identified serious concerns about the appropriateness of the data sets and assumptions used to derive the risk estimates, which are explained below.

The lack of site-specific and project-specific analysis prevents us from evaluating the trade-offs between various alternatives. For example, it may be helpful to compare the risks between two different Antero scheduling alternatives (e.g., one that involves a shorter but more intensive drilling period using two rigs, perhaps limited to a single season, compared to a longer less intensive drilling period using one rig). Some trade-offs may be qualitatively compared, such as a shorter period of greater noise and traffic, etc., but the effects on human exposures cannot be properly evaluated using the information in the current HHRA.

3.8.1 Chronic Exposure Scenario

Based on a review of the air monitoring data and calculations behind the chronic cancer and non-cancer risks, as summarized in Tables 5-1, 5-3, and 5-4, we have serious concerns about how the underlying data were used to arrive at the estimated cancer risks and non-cancer hazard indices.

Measurements at the Battlement Mesa Monitoring Station were used as the basis for the baseline scenario, while measurements at the Bell-Melton Ranch Monitoring Station were the basis for the “all Battlement Mesa chronic exposure scenario.” The Bell-Melton Ranch Monitoring Station was selected to represent chronic residential exposures in Battlement Mesa if Antero proceeded with the natural gas development project. The authors point out several uncertainties regarding whether Bell-Melton Ranch is representative of Battlement Mesa’s chronic exposure scenario, including differences in the type of natural gas produced, population density, and well emission controls. Additionally, although both locations may be considered rural rather than urban, Battlement Mesa is a predominantly residential community while the Bell-Melton Ranch Monitoring Station, as its name implies, is located in the vicinity of a ranch, and other sources of air toxics, such as combustion byproducts from trucks or ranch equipment, may be present. The HHRA does not address these land use differences as another source of uncertainty. The HHRA recognizes that the Battlement Mesa data, collected for a three-month period (September to November 2010), does not adequately capture possible seasonal trends. This data gap casts further doubt on how the Bell-Melton Ranch data, which was collected year-round between 2005 and 2010, can be compared to baseline data. Bell-Melton Ranch data are used specifically to represent concentrations that would be experienced by residents not near a well pad, but the HHRA does not explain where Bell-Melton Ranch is located relative to existing well pads or whether any well completions occurred during the sampling period.

The differences in the compounds measured at these two monitoring stations complicate the risk and hazard index calculations. Three of the compounds measured at Bell-Melton Ranch and identified as contaminants of potential concern (COPCs) - 1,4-dichlorobenzene, methylene chloride, and 2-hexanone - were never measured in the samples collected at the Battlement Mesa station, but they are included in the cancer risk calculations for the chronic exposure scenario. As a result, the chronic exposure scenario, in which 1,4-dichlorobenzene and methylene chloride are cancer risk drivers, has a higher cancer risk (61 in a million) than the baseline cancer risk (55 in a million). If these two compounds are not included, the chronic exposure scenario cancer risk drops to 50 in a million, lower than the baseline scenario. The authors acknowledge this discrepancy (Appendix D p. 66). However, the impact of excluding these two compounds, which essentially eliminates any real difference in the risk between the baseline and chronic exposure scenarios, is not noted in accompanying tables or Figure 7-2, “Summary of Excess Lifetime Cancer Risk.” Similarly, 1,4-dichlorobenzene, methylene chloride, and 2-hexanone are included in the calculation of the hazard index for non-cancer risks, even though they were not measured for the baseline scenario. If these three compounds are not included, the hazard index drops from 0.5 to 0.4, which is below the baseline scenario HI of 0.5.

To calculate the subchronic risk contribution to chronic risks to residents living near a well pad (defined in the HIA as within ½ mile of a well pad), the authors used air monitoring data from well completions conducted in 2008 and 2010 in Garfield County. The maximum and 95% UCL concentrations were used in conjunction with the chronic EPCs from the Bell-Melton Ranch data to calculate a time-weighted average (TWA) maximum and 95% UCL cancer risk, respectively (Table 3-2). If a compound was not measured in these well completion studies, maximum concentrations from the Bell-Melton Ranch Monitoring Station were used as a substitute for both the maximum and 95% UCL concentrations. Use of the maximum concentration instead of the 95% UCL is a departure from standard USEPA guidance on risk assessment. The authors do not provide an explanation for this substitution, and relying on the maximum concentrations has substantially exaggerated the likely cancer risk. For example, for formaldehyde, the 95% UCL on the mean concentration for the Bell-Melton Ranch data is 1.25 $\mu g/m^3$, while the maximum concentration is 10.2 $\mu g/m^3$. Figure 6 shows all the formaldehyde measurements at the Bell-Melton Ranch Monitoring Station, and the 10.2 $\mu g/m^3$ value is clearly an outlier, approximately an order of magnitude higher than the other 75 results, but it is the maximum value that the HHRA selects for the cancer risk calculations. The authors make the same substitution for the other carbonyls, acetaldehyde and crotonaldehyde. If the cancer risk is calculated from 95% UCL concentrations only and compounds not measured for the baseline scenario (1,4-dichlorobenzene and methylene chloride) are excluded for a fair comparison, the excess cancer risk is 56 in a million, which is not significantly different from the baseline risk (55 in a million) or chronic exposure risk to residents not near a well pad (50 in a million), as illustrated in Figure 7. In conclusion, while it is recognized there are limitations in the data (the HHRA provides a detailed discussion of the limitations in the monitoring data and in the toxicity factors), application of the available data in the risk assessment indicates that future cancer risks following implementation of the Antero project are not meaningfully different from baseline risks existing today.

Figure 6: Formaldehyde Concentrations at Bell-Melton Ranch

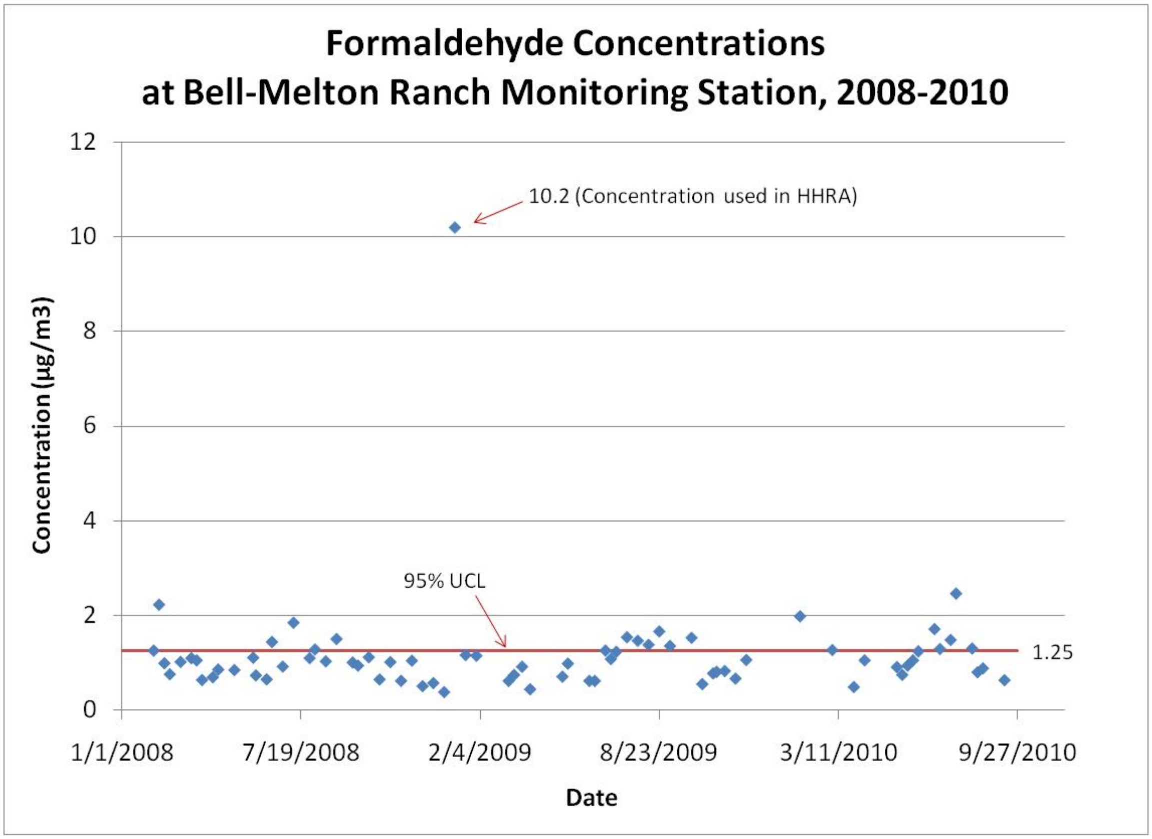
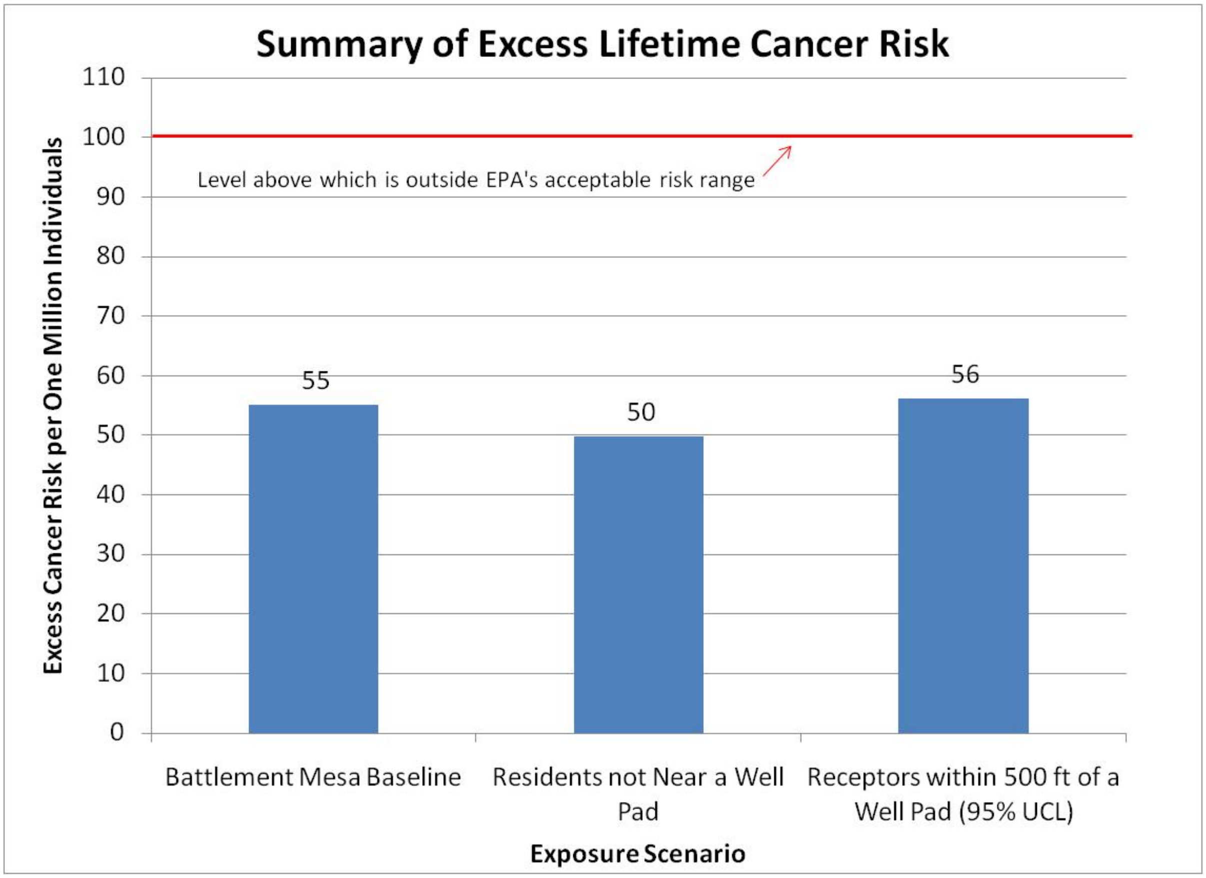


Figure 7: Summary of Excess Lifetime Cancer Risk



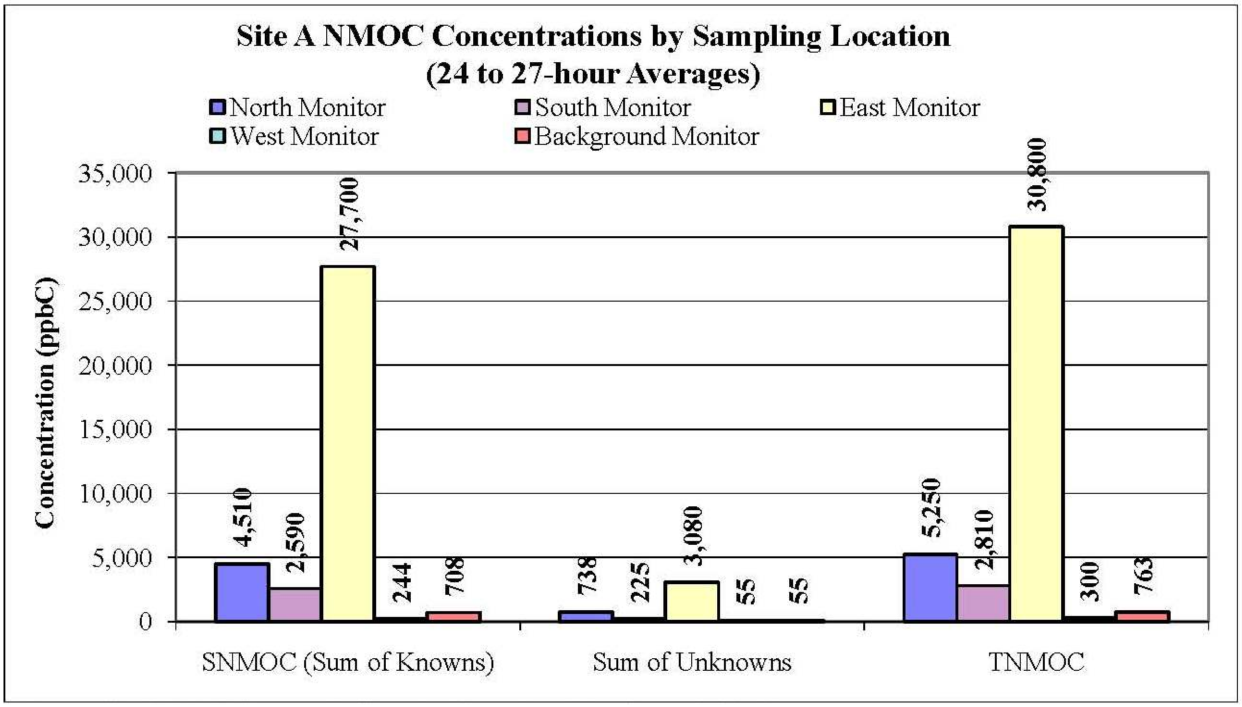
In evaluating the likelihood that adverse non-cancer effects may currently exist under baseline conditions or may occur in the future from development of the project, the HHRA uses a hazard index approach. An estimated hazard index greater than 1 indicates adverse health effects may occur. For all three scenarios using the 95% UCL concentrations – baseline, "not near a well pad," and "near a well pad" - the hazard indices estimated in the HHRA are between 0.5 and 1.0. Thus, no non-cancer adverse health effects are anticipated from the project.

3.8.2 Subchronic Exposure Scenario

In estimating future subchronic risks to residents "near a well pad," the HHRA compounds worst-case assumptions in its use of monitoring data from locations where no residents would be present, unrealistic well development timelines, and maximum measured concentrations substituted from other datasets. The HHRA estimates the subchronic risk based on air monitoring results during well completion activities from the 2008 Air Toxics Study and Antero's August 2010 sampling at the Watson Ranch Pad. These monitoring results are used to calculate subchronic non-cancer risk as well as the contribution to chronic cancer risk of living near a well pad for a 20-month time period, which was discussed earlier. However, a review of these sampling campaigns indicates that they are not representative of residential exposures. In the 2008 Air Toxics Study, samples were collected 130 to 430 feet from the well pad center, and in Antero's 2010 sampling, samples were collected 350 to 500 feet from the well pad center. In reality, residents would be further from the well pad than these locations, because Antero plans to use a 500-foot setback from its proposed well pads in Battlement Mesa. However, the HIA still uses the concentrations measured 130 to 500 feet from a well pad to estimate risks for residents 500 feet to ½ mile from the well pad. The study authors note this discrepancy (Appendix D, p. 55): "most samples were collected at distances nearer the well head than the 500 foot setback proposed by Antero." They attempt to justify this inappropriate use of data by pointing to higher COPC concentrations detected in samples at 500 feet than 350 feet as evidence that "the transport and fate of COPCs is not well understood." The laws of physics do not change for COPCs associated with natural gas wells. The HIA itself notes in the Executive Summary (p. ES-III): "pollutant concentrations generally decrease with increasing distance from an emission source."

The authors do not attempt to conduct air dispersion modeling, investigate the relationship between local meteorology and concentrations, evaluate the potential for other local emission sources, or otherwise address the potential changes in concentration in distances further from the wellhead. As illustrated in Figure 8, which shows non-methane organic chemical (NMOC) concentrations measured at one of the well pads monitored in 2008, there is considerable variation in concentrations measured in different cardinal directions, consistent with short-term emissions and wind variations. The HHRA does not account for changes in emissions and meteorological conditions over the 20-month subchronic exposure period. Instead, the HHRA combines data from all well pads, and gravitates toward the highest measurement for each chemical irrespective of location.

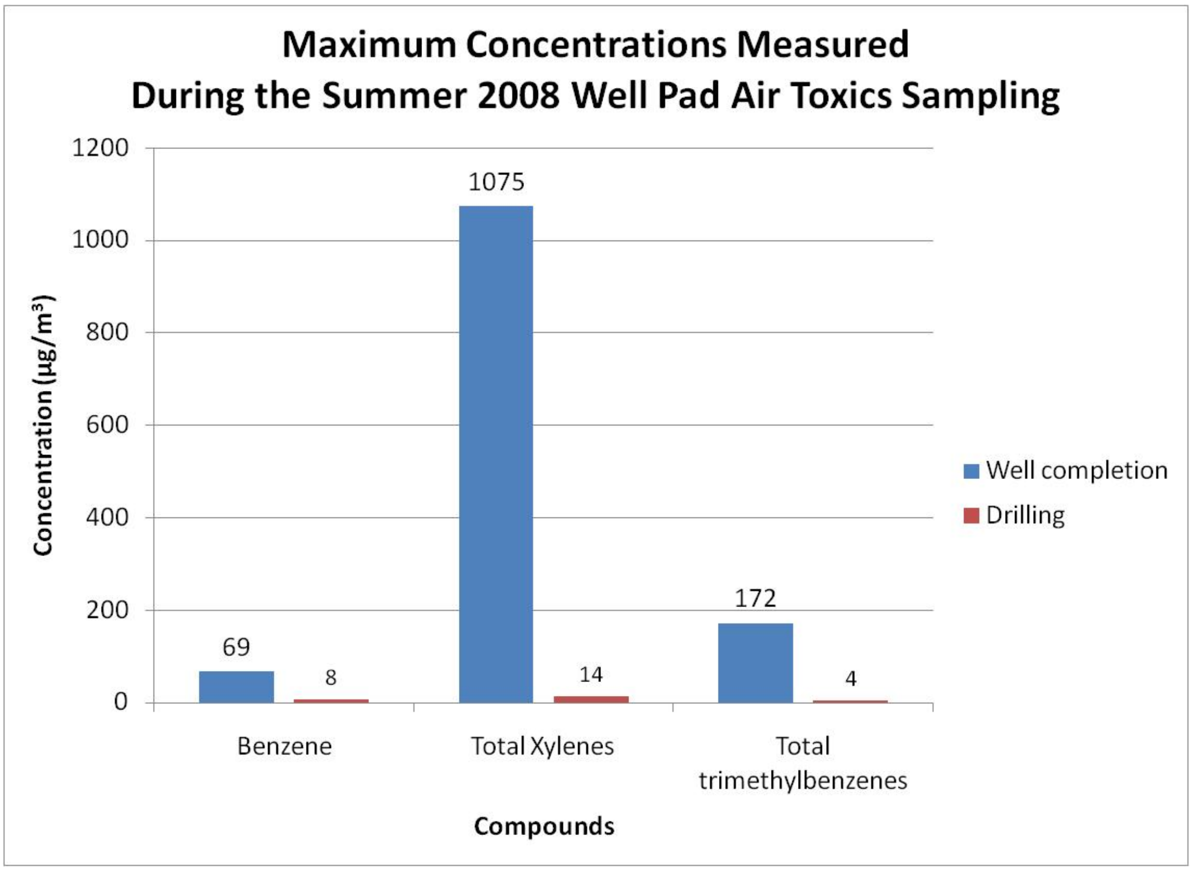
Figure 8: NMOC Concentrations at Well Pad During 2008 Well Completion



Source: CDPHE 2009. "Analysis of Data Obtained from the Garfield County Air Toxics Study – Summer 2008."

The subchronic exposure period for well completion activities per well pad was assumed to be 10 months. A 20-month subchronic exposure duration was used because some residents live within ½ mile of more than one well pad. However, this estimated duration does not reflect the realities of the well development process or the well pad sequencing that Antero has proposed. Antero's proposed plans suggest that well completion can take 5-10 days per well, and wells are developed in batches. In Antero's response to the first HIA draft, the Company noted that for a four-well completion scenario, the frac/flowback period is four weeks, so a 20-well pad would have a five-month frac/flowback timeline (Appendix E, Comment A154). In response to the comment, the HHRA authors appeared to generally agree that based on the prior experience with the Watson Ranch Pad, the well completion activities occur over a 5-6 month-period per pad. Nevertheless, the authors selected a time period twice as long (10 months) and doubled it to 20 months to account for residents near more than one pad. The 2008 Air Toxics Study and the 2010 Antero sampling took measurements during both drilling and well completion (specifically flowback) activities, but the HHRA uses only measurements collected during the well completion, when the flowback from the well was sent to open top tanks that vented directly to the air. Flowback is considered to be the process with the highest potential emissions. A comparison between the maximum concentrations of benzene, trimethylbenzenes, and xylenes in the 2008 Air Toxics Study is shown in Figure 9. Figure 9 shows that the maximum concentrations measured during well completion are 1-2 orders of magnitude higher than during the drilling stage. An alternative and more accurate approach of evaluating subchronic risk would be to obtain a better understanding of the different stages of the well development process, and apply both the drilling and well completion monitoring results over representative time periods to develop a time-weighted exposure point concentration (EPC). Also, if the exposure periods are actually intermittent during the subchronic exposure period, USEPA guidance recommends estimating a separate exposure concentration for each exposure period (USEPA RAGS 2009). Given the 24-hour sampling duration, the exposures should be treated as acute rather than subchronic exposures. Additionally, the HIA does not consider how Antero's timing of the different phases affects the exposure period. For example, the HIA notes that homes in Stone Ridge Village and Monument Village are within ½ mile of pads A, B, and D (Part 1, p. 35). These three pads are all part of Antero's Phase 2 development plan, but the HHRA has not evaluated how the clustering of these pads into one phase would affect the estimated subchronic exposure duration.

Figure 9: Maximum Concentrations in 2008 Well Pad Air Toxics Sampling



Several of the compounds – 1,4-dichlorobenzene, 2-hexanone, methylene chloride, acetaldehyde, and formaldehyde - were not measured as part of the 2008 Air Toxics Study or the 2010 Antero sampling, so the HIA authors substituted the maximum detected concentration from the Bell-Melton Ranch Monitoring Station as the subchronic EPC (Appendix D, p. 11). Although the authors had already calculated the 95% UCL (Table 2-9 in the HHRA) on the mean concentrations for these data, the maximum detected concentration, not the 95% UCL, was used to calculate the 95% UCL subchronic intake. However, for the other compounds, where data were available from the 2008 Air Toxics Study and 2010 Antero sampling, the HIA authors used the 95% UCL for the 95% UCL subchronic intake. The maximum concentration for formaldehyde used in the HHRA was actually detected on January 7, 2009, and is obviously unrelated to the well pad sampling conducted in the summer of 2008 or Antero's sampling in 2010. Examination of the other chemicals present at Bell-Melton Ranch on that day indicate low levels of other aldehydes, such as crotonaldehyde (less than 0.1 µg/m^3), and other risk drivers, such as benzene (less than 5 µg/m^3). Thus, there is no obvious relationship between the maximum formaldehyde measurement at Bell-Melton and well pad completion activities, and the result is likely an anomaly. The authors do not explain their rationale for this "mixed" use of concentrations. Substituting concentrations from an unrelated data set is not acceptable risk assessment practice.

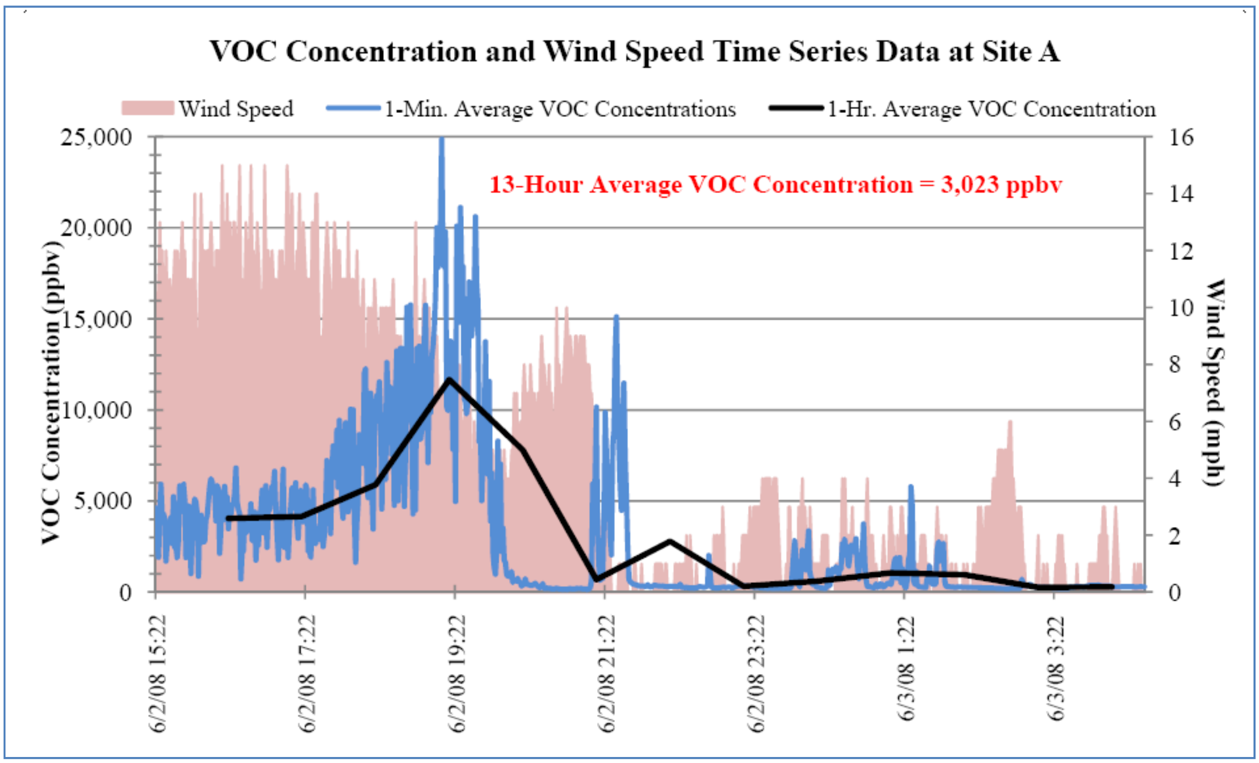
Based on a review of Table 5-5 in the HHRA, which summarizes the subchronic risk characterization, formaldehyde stands out the largest risk driver in the hazard index calculated based on the 95% UCL subchronic intake. (Note: The last column is incorrectly labeled as "HQ (Maximum)," and should be labeled as "HQ (95% UCL).") As mentioned earlier in Section 3.8.1, upon closer inspection of the underlying Bell-Melton Monitoring Station formaldehyde data, the maximum concentration of 10.2 µg/m^3 is approximately an order of magnitude higher than the other 75 formaldehyde results analyzed between 2008 and 2010. Figure 6 shows how much of an outlier this value is compared to the other formaldehyde concentrations and the 95% UCL of 1.25 µg/m^3. However, the authors select this outlier value as the basis for the maximum and 95% UCL subchronic intake. If the 95% UCL had been used instead, the hazard index for the 95% UCL would have been 2, not 3. This focus on outliers is not consistent with acceptable risk management practice.

3.8.3 Acute Exposure Scenario

The HHRA estimated risks to two subgroups of residents living near a well pad: (1) adult and elderly residents for exposure to ambient air, and (2) child residents for exposure to ambient air and surface water. The acute exposure scenario for ambient air exposures assumes that a resident would be exposed to the same concentration for a continuous seven-day exposure period. The selected EPCs for VOCs were based on 10-15 second grab samples collected during odor events in 2005-2007 by residents. While use of such grab samples to guide further sampling is understandable, use of the grab samples for risk assessment is inappropriate. If odor is used as a surrogate for exposure, it represents the high end of exposures. It therefore represents measurements of the upper level of exposure, and should not be expected to represent "acute" exposures, which are based on hours, not seconds (USEPA RAGS Part F 2009). USEPA has developed Acute Exposure Level Guidelines (AEGLs), which apply to short-term exposure durations between 10 minutes and eight hours, and would be more appropriate for comparison to grab samples. They are specifically intended to protect most individuals in the general population, including susceptible individuals such as children and the elderly.

The HHRA unreasonably assumed that the concentrations associated with odor measurements would stay the same for seven days. The grab samples were collected by Garfield County staff, contractors, and residents in response to odor complaints, and there is no evidence that the odor events lasted for days. The CDPHE Summer 2008 Air Toxics Study noted that there are periods during well completions when the pressure of the escaping gases is very high and difficult to control and "venting of non-salable gas occurs that has the highest potential for creating odors, and elevating the concentrations of volatile organic compounds (VOCs) and non-methane organic compounds (NMOCs)." As shown in Figure 10, taken from the Summer 2008 Air Toxics Study, there is considerable minute-by-minute variation in real-time total VOC concentrations during flowback operations. The 1-hour and 13-hour average VOC concentrations are substantially lower than the 1-minute measurements. Without collecting sufficient data to calculate 1-hour or 24-hour averages, the grab samples taken in 2005-2007 likely reflect spikes in concentrations (when odors are noticeable).

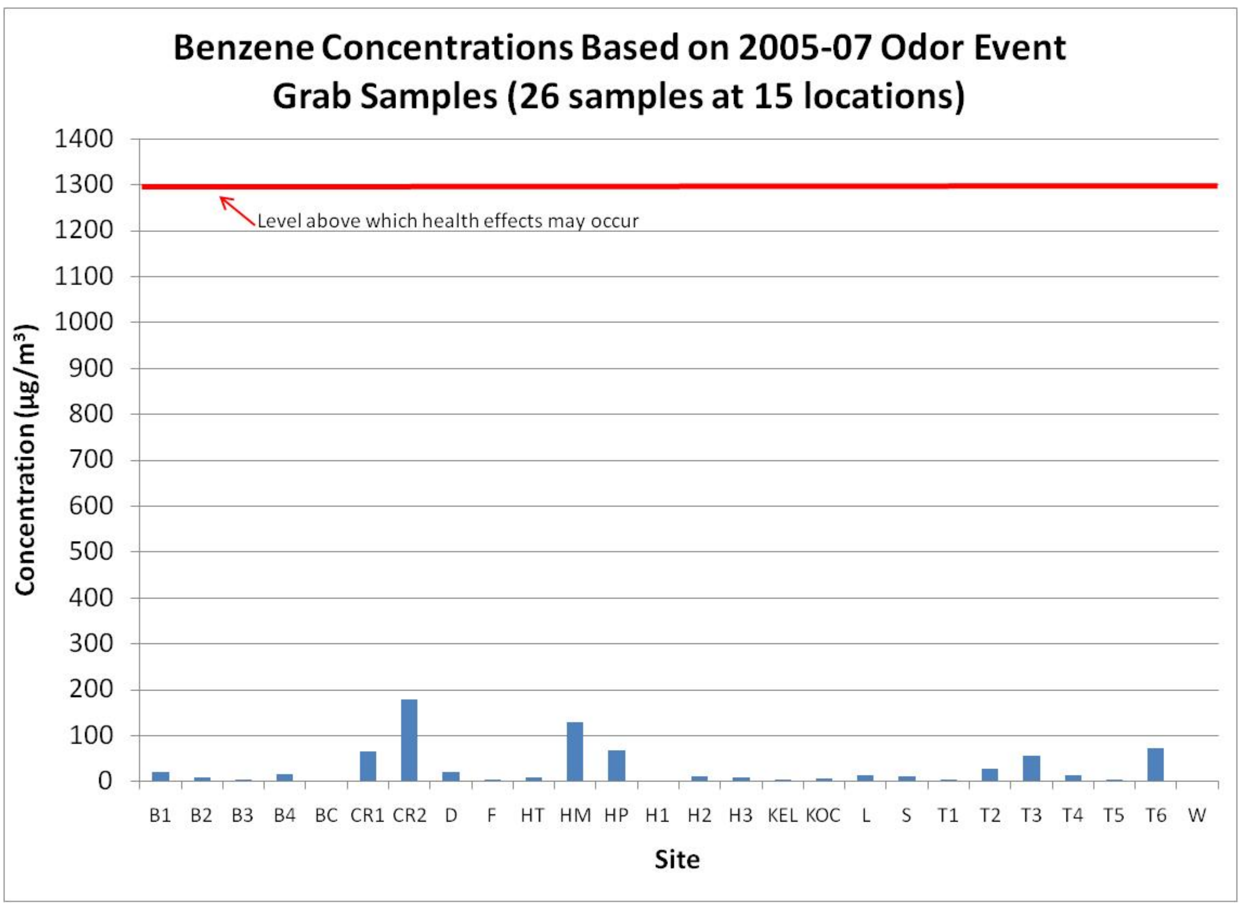
Figure 10: VOC Concentrations and Wind Speed at Well Pad During 2008 Well Completion



Source: CDPHE 2009. "Analysis of Data Obtained from the Garfield County Air Toxics Study – Summer 2008."

USEPA guidance in assessing acute exposures considers it important to match the sample measurement duration with the time period over which the toxicity value is developed. The HHRA authors use toxicity values, primarily ATSDR minimum risk levels (MRLs) for exposures spanning 1-14 days. However, it is inappropriate to use a 10-15 second grab sample to compare with toxicity values appropriate for significantly longer exposure periods. For example, the HHRA selected an acute toxicity value (reference concentration, or RfC based on the ATSDR MRL) for benzene of 29 µg/m^3, and derived a hazard quotient of 2. USEPA defines acute exposures as those lasting 24 hours or less, and provides a compilation of acute toxicity values that would be more appropriate for this scenario. For two of the compounds, acetaldehyde and o-xylene, for which there are no MRLs, the HHRA selected the California OEHHA acute RELs as RfCs, which are typically based on a 1-hour exposure duration and are more appropriate for comparison than the MRLs. The USEPA lists 1,300 µg/m^3 as the California OEHHA acute REL for benzene, which applies to a six-hour exposure duration. As shown in Figure 11, the benzene measurements made during the odor events are well below this value. It should be noted that there is a discrepancy in acute and subchronic toxicity values for benzene that needs to be resolved. The subchronic toxicity value of 80 µg/m^3 used in the assessment is USEPA approved. Under these circumstances, consistent with the procedures used in the HHRA, if it is assumed that the grab samples represent concentrations over 20 months, no adverse effects would be predicted under the 95% UCL scenario, where the 95% UCL is 62 µg/m^3. The toxicity value for acute risks for benzene deserves further scrutiny.

Figure 11: Benzene Concentrations Measured in Odor Event Grab Samples



The highest benzene concentration detected in the odor event grab samples was 180 µg/m^3, and was collected from a location known as CR 326, which does not appear to be located at a residence, but appears to be located within 500 feet southeast of a well pad that was installed in 2005. Another grab sample was collected at a well pad (Hooker Pad), and had the highest xylene concentrations of all the grab samples. The authors did not exclude these grab samples from the assessment, although they would not be representative of residential exposures for Antero's proposed project. In their response to comments (A151), the authors assumed that samples were collected from residences at least 150 feet from the well pad. However, they did not evaluate whether grab samples were actually collected at residences (clearly some were not) or collected 500 feet or further from a well pad.

Because carbonyls were not analyzed in the 2005-2007 Air Toxics Study, the EPCs for carbonyls were based on just two 15-minute grab samples collected in 2010 by Antero during well completion activities at the Watson Ranch Pad. This is not an adequate number of samples for risk characterization. Moreover, the authors note that the carbonyl concentrations may actually be associated with diesel emissions associated with truck traffic, and not well completion activities (Appendix D, p. 56). [Note: Toluene is absent from Tables 2-11 and 3-2 even though it was analyzed in the well completion samples.]

For the acute exposure scenario for a child resident living near a well pad, a 3-6 year old is assumed to play in a water puddle two hours per day for seven days during which time its arms, hands, legs, and feet are all immersed, and a dermal permeability constant is used to calculate absorbed dose. The exposure assumptions in the HHRA are not realistic for several reasons.

- The water sample was collected from snow-melt run-off collected from a well pad near Rulinson, Colorado, and no residents, including children, would be present within 500 feet from a well pad.
- Given the arid conditions of Battlement Mesa and the warm conditions under which a child would want to play in a puddle, it is unlikely a surface water puddle would persist for seven days without evaporation, or that it remain deep enough for a child to immerse most of its body in the puddle for two hours per day, every day for a week.
- The compounds measured in the surface water sample (benzene, ethylbenzene, toluene, and xylenes) would quickly volatilize in warm weather conditions, such that concentrations would decrease over the one-week exposure period.
- The use of a dermal permeability constant implies continual complete immersion in the water (not just getting hands and feet wet, which might be more realistic, but for which the permeability constant procedure would not be appropriate). The present draft of the HHRA perhaps inadvertently does not report the values of the permeability constants used. Based on the equations provided in the HHRA and a review of the permeability constants in the 1992 EPA Dermal Exposure Assessment document cited in Table 3-3, it appears that the dermal intake estimates are overstated by a factor of 100. The surface water concentrations of several of the chemicals are substantially below drinking water standards (e.g., toluene

detected concentration 45 µg/L, drinking water MCL 1000 µg/L; ethylbenzene detected concentration 8.3 µg/L, MCL 700 µg/L), so dermal risks are unlikely to be a health concern.

In conclusion, the surface water scenario does not appear to be realistic, and more relevant and reliable risk estimates could be produced by additional analysis that accounts for the details of the proposed project (e.g., 500-foot setbacks from well pads that are constructed with perimeter berms to control runoff) and local soils and hydrologic conditions (which may not sustain puddles that contain well pad runoff for extended periods). Nevertheless, the estimated non-cancer hazard indices are likely to be 0.2 and no adverse non-cancer health effects would be expected.

3.8.4 Broader Methodological Issues

The HHRA emphasizes that there are many sources of uncertainty in the risk assessment related to the lack of appropriate baseline and representative site data. The authors frequently acknowledge that more data collection would reduce these uncertainties. However, they proceed with attempting to estimate risks, often with minimal or inappropriate data. Their mixing of multiple data sets and sample types, selection of maximum concentrations among mostly non-detect concentrations, choice of maximum concentrations when 95% UCL concentrations are available, and use of very small sample sizes led to an assessment that cannot reliably be used to estimate risks from Antero's proposed well development project.

In assigning exposure point concentrations (EPCs), the HHRA authors routinely select the maximum detected concentration when the vast majority of samples are below the detection limit. They claim that the practice of assigning the maximum detected concentration as the EPC for COPCs with less than 10 detections is standard USEPA practice (Appendix D, p. 16). However, USEPA guidance specifically cautions against calculating statistics based upon only a few detected values (USEPA ProUCL Technical Guide 2010). Instead, USEPA suggests that when most (e.g., >95%) of the observations are below the detection limit, the sample median or the sample mode be used as an estimate of the EPC. As a result, the EPC would be reported as a non-detect value, such as half the detection limit. USEPA recognizes that the estimation of the EPC is ultimately the decision of the project team and decision makers, but in this case, the HHRA authors do not provide an explanation for selecting the maximum. The selection of the maximum concentration when most concentrations are below detection has a major impact on the risk calculations. For example, in the chronic exposure scenario for non-cancer risks, 2-hexanone has the highest hazard quotient of all the COPCs (Table 5-3). However, in the 29 samples collected from the Bell-Melton Ranch Monitoring Station, 2-hexanone was detected in only one sample and the compound should be omitted as a COPC. The other 28 samples had 2-hexanone concentrations below the detection limit, which was typically around 2.0 µg/m^3, but the single detectable result, at 4.4 µg/m^3, was selected for the EPC.

When the sample size for a compound is small (e.g., less than 5), as in the case of the two carbonyl grab samples mentioned earlier, the authors select the maximum detected concentration. For calculating the acute surface water exposure scenario for a child, the authors rely on a single sample. Standard risk assessment practice is not to use data from such small sample sizes. In the resulting risk characterization tables in the HHRA, the authors do not acknowledge this data quality issue, and risks calculated based on 20+ sample results are presented alongside risks calculated based on two sample results. The inclusion of chloroform as a COPC is based on its detection in one of 28 odor event grab samples. Moreover, the authors note that a “potential source associated with natural gas development and production is not clear” (Appendix D, p. 33).

The COPCs were selected without any attempt to identify the source(s) of those COPCs and whether they are associated with natural gas development activities or another local source. Many of the COPCs in the HIA are commonly found in ambient air as a result of fossil fuel combustion from road traffic or energy generation facilities. A particular COPC, like benzene, may be associated with multiple well pad activities (e.g., employee trucks, natural gas production, generators) but the lack of information on how each activity contributes to benzene levels in the air limits the ability to make decisions about emission control strategies. Also, the use or production of certain compounds in natural gas development operations does not necessarily mean they are used or produced in sufficient quantities to be detectable in the air 500 feet or more from a well pad.

The List of Figures in the HHRA includes Figure 3-3 (Locations of Baseline and Bell-Melton Ranch Monitoring Stations), which illustrates the locations of the monitoring stations described in the study, but was not included in the second draft of the HIA.

3.8.5 Indoor Air Concentration Assumption

Studies examining the relationship between outdoor VOC sources and indoor concentrations of the pollutants of outdoor origin have shown that factors such as the air exchange rate, volume of the home, and home construction material influence the intake factor of VOCs. Of these, air exchange rate is the dominant factor. Most studies looking at indoor exposures to VOCs conclude that indoor sources are the dominant exposure (see for example Adgate et al. 2004). This is because many home-related products, such as consumer products and construction material (particularly relevant in newer homes), as well as environmental tobacco smoke are dominant sources of indoor VOC pollution. Home-related factors such as attached garages are also important sources of these pollutants. In examining the relationship between VOCs of outdoor origin to indoor exposures, only a fraction of the chemicals from outdoor sources permeates the home. This is referred to as the infiltration factor. Once indoors, pollutants still need to reach the residents (intake fraction). For example, a study in 5 European cities found that the mean individual intake fractions ranged from 1.5×10^{-3} in Athens to 4.5×10^{-3} in Helsinki (Ilacqua et al. 2007). While the authors of the HIA may assume the windows are always open, or that fans and swamp coolers are in use, and attempt to support a 1.0 infiltration factor, this is not likely to be true 24 hours a day, every day, over a 20-month period (let alone over a 30-year period) and is certainly not supported by the exposure science literature. For example, a recent analysis of air exchange rates in residential homes and the median air exchange rate in detached homes in Denver, Colorado (a surrogate for Battlement Mesa) is 0.5 (Perily et al. 2010).

3.8.6 Toxicity Values

As indicated in risk assessment guidance intended for evaluating acute and subchronic risks, USEPA (2009) recommends in selecting toxicity values that, “risk assessors should consider the duration associated with their estimate of exposure (e.g., a 1-hour versus a 24-hour air sample).” USEPA further emphasizes, “Use of a toxicity value specified for a longer duration than that of the exposure estimate may overestimate hazard.” To estimate subchronic risks, the HHRA selects toxicity values intended for months to years of exposure, but selects concentrations based on a single day of sampling at a well pad site. When estimating acute risks, the HHRA selects toxicity values intended for 1-14 days of exposure, but uses concentrations from 10 to 15 second grab samples.

Contrary to the statement in the report (Appendix D page 34) that crotonaldehyde is a “possible human carcinogen,” what IARC actually says is: “There is inadequate evidence in humans for the carcinogenicity of crotonaldehyde. There is inadequate evidence in experimental animals for the carcinogenicity of crotonaldehyde.” IARC’s overall evaluation is that “Crotonaldehyde is not classifiable as to its carcinogenicity to humans (Group 3).” The HIA’s use of an inhalation cancer potency value that is based on a limited bioassay in which rats received crotonaldehyde in drinking water is inappropriate, and contrary to accepted USEPA procedures. Similarly, the cancer slope factor used for 1,4-dichlorobenzene is based on an oral gavage study and is inappropriate, and contrary to the USEPA accepted procedures for assessing risk from inhalation exposure.

USEPA provides the following guidance: “Performing simple route-to-route extrapolation without the assistance of STSC [Superfund Health Risk Technical Support Center] is generally not appropriate because hazard may be misrepresented when data from one route are substituted for another without any consideration of the pharmacokinetic differences between the routes (USEPA 1998). The following circumstances, outlined in the Inhalation Dosimetry Methodology (page 4-6), are specific examples of situations when route-to-route extrapolation from oral toxicity values might not be appropriate, even for use during screening:

- When groups of chemicals are expected to have different toxicity by the two routes − for example, metals, irritants, and sensitizers;
- When a first-pass effect by the respiratory tract is expected;
- When a first-pass effect by the liver is expected;
- When a respiratory tract effect is established, but dosimetry comparison cannot be clearly established between the two routes;
- When the respiratory tract was not adequately studied in the oral studies; and
- When short-term inhalation studies, dermal irritation, in vitro studies, or characteristics of the chemical indicate the potential for portal-of-entry effects at the respiratory tract, but studies themselves are not adequate for inhalation toxicity value development.

The Cancer Guidelines (USEPA, 2005a) includes the following statement regarding route-to-route extrapolation: ‘When a qualitative extrapolation can be supported, quantitative extrapolation may still be problematic due to the absence of adequate data. The differences in biological processes among routes of exposure (oral, inhalation, dermal) can be great because of, for example, first-pass effects and different results from different exposure patterns. There is no generally applicable method for accounting for these differences in uptake processes in a quantitative route-to-route extrapolation of dose-response data in the absence of good data on the agent of interest. Therefore, route-to-route extrapolation of dose data relies on a case-by-case analysis of available data" (page 3-10)'" (USEPA RAGS Part F 2009).

The largest non-cancer estimate of risk, a hazard index of 15 for "acute hazard to a child from the surface water pathway," is highly questionable. As noted earlier, the assumptions used in performing this assessment are unrealistic (i.e., a 3-6 year old is assumed to play in a water puddle two hours/day for seven days during which time its arms, hands, legs, and feet are all continuously immersed). The greatest contribution to this HI comes from benzene. However the "acute RfD" used in this assessment is completely inappropriate for this purpose. Based on the description in the source document, (USEPA Provisional Peer-Reviewed Toxicity Values for Benzene (CASRN 71-43-2) - Derivation of a Subchronic Oral Provisional-RfD and a Subchronic Inhalation Provisional-RfC), the value used is a subchronic RfD, not an acute RfD, and is based on an occupational study (Rothman et al. 1996) in which workers were exposed for an average of 6.3 years to benzene, not seven days, as is assumed for the HIA. There is absolutely no scientific basis for assuming that the exposures assumed for Battlement Mesa child residents could cause any adverse effect from a seven-day exposure, particularly when the unrealistic nature of the exposure assumptions are considered.

The basis for the acute toxicity value for the second major contributor (toluene) to the elevated HI for this scenario is also questionable. It is based on a study of visual evoked potential in rats administered doses of toluene in corn oil of 0, 250, 500, and 1,000 mg/kg/day by gavage. There was a reduction of the amplitude of the evoked potentials in these animals, but the effect was not dose-related. Hence, this is a particularly weak basis for an RfD. Further, in the case of ethylbenzene, the toxicity value used was an "Intermediate MRL" derived by ATSDR from a 13-week rat gavage study in which an increase in centrilobular hepatocyte hypertrophy was seen at 250 and 750 mg/kg/day, but no increase was seen at 75 mg/kg/day (the incidence at that dose was identical to that in the control group). Despite seeing no effect at 75 mg/kg/day, ATSDR performed benchmark dose modeling and derived a benchmark dose level (BMDL)value of 48.2 mg/kg/day, to which they applied an uncertainty factor of 100-fold to derive an intermediate duration MRL. Because of the compounded conservatism in this procedure, this value is entirely inappropriate for assessing putative acute health risks to Battlement Mesa residents.

The HHRA is inconsistent in its selection of acute toxicity values for xylenes. Table 4-1 lists acute RfCs of 8.7 mg/m^3 for m- and p-xylenes and 22 mg/m^3 for o-xylene, citing ASTDR Minimum Risk Levels (MRLs) and California OEHHA RELs, respectively. However, based on the USEPA's compilation, "Acute Dose-Response Values for Screening Risk Assessments," dated April 2010, both the ATSDR MRL and California REL apply to mixed xylenes, and there is no specific value for o-xylenes.

In assessing risks of mixtures, USEPA recommends assuming additivity for chemicals with similar mode of action and dose-response curves (USEPA 2000). This "common mode of action" assumption can be met by using a surrogate of the same target organ. A hazard quotient is based on the ratio of exposure concentrations to a toxicity value, often a Reference Concentration (RfC) from USEPA's Integrative Risk Information System (IRIS). The value itself is based on results from an individual study, looking at a specific "sensitive endpoint," with supporting information from other studies. While it is an acceptable approach to sum hazard quotients that refer to the same target organ, it is not acceptable to sum these values over different organs or systems. The HHRA lists all endpoints that may be affected by the various chemicals of potential concern, but does not indicate the specific endpoint that the toxicity value was based on. Table 2 lists the target organs or systems on which the selected acute toxicity values were based, and illustrates the variation in the different target organs or systems affected. The hazard quotients were calculated based on these acute RfCs, and then summed for a single hazard index , which is not acceptable practice.

Table 2: Summary of Acute Toxicity Values Used in the HHRA

Chemical	Acute RfC Used in HHRA	Target organs or systems
Acetaldehyde	470 µg/m^3 (California acute 1-hour REL)	Sensory irritation; bronchi, eyes, nose, throat
Benzene	29 µg/m^3 (ATSDR MRL)	Immunological
Chloroform	490 µg/m^3 (ATSDR MRL)	Hepatic (liver)
Ethylbenzene	43,000 µg/m^3 (ATSDR MRL)	Neurological
Formaldehyde	49 µg/m^3 (ATSDR MRL)	Respiratory
m&p-Xylene	8700 µg/m^3 (ATSDR MRL)	Neurological
o-Xylene	22,000 µg/m^3 (California acute 1-hour REL)	Neurological and respiratory systems, eyes
Toluene	3800 µg/m^3 (ATSDR MRL)	Neurological

Sources: ATSDR, MRLs for Hazardous Substances, http://www.atsdr.cdc.gov/mrls/mrllist.asp; California OEHHA RELs, http://oehha.ca.gov/air/allrels.html

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