Delaware River Basin Commission (DRBC) Consolidated Administrative Hearing on Grandfathered Exploration Wells

Report to:

Delaware Riverkeeper Network

And

Damascus Citizens for Sustainability

Prepared by:

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As a toxicologist and physician specializing in environmental medicine and public health, I have been asked by the Delaware Riverkeeper Network and Damascus Citizens for Sustainability to provide my professional opinion on the potential toxicological effects that may result from exposure to chemicals and substances that may be released from natural gas wells, including certain "grandfathered" exploratory wells, that have been or may be drilled in the drainage area of the Special Protection Waters of the Delaware River Basin.

In my professional opinion, due to the multiple known risks to human health from exposure to such chemicals and substances, such exploratory well drilling should not be done until the consequences of such exposure are thoroughly examined in a comprehensive health effects study for the Delaware River Basin. The necessity for such a study, before drilling begins, has been established in our research and in that of others in the western United States, especially in the Battlement Mesa area of Garfield County, Colorado. In Garfield County we found in 2008 that there was a total lack of research into the health effects from gas development activities. As a result of this study, a comprehensive Health Impacts Assessment was commissioned by Garfield County and completed in September, 2010. It is imperative that a similar study be performed for the Delaware River Basin before any gas development – including the grandfathered wells – is allowed to proceed.

One of the most glaring omissions of the gas drilling process has been the exclusion of consideration of human health impacts. Only through anecdotal reports can impacts to human health in the Delaware River Basin be presumed as no epidemiological or environmental health studies have been done in the Basin. This is necessary before drilling proceeds in the Basin in part because the Delaware River supplies water to more than 15 million people. In addition to the potential toxicological effects from exposure to water contaminated by pollutants released from gas drilling activities, there are significant air pollution issues which also may become water pollution issues due to downwash. We have studied these potential water and air pollution issues in certain areas in the western United States, but such studies have not been done in the significantly more densely populated northeastern United States.

In preparation for our September 2010 Health Impact Assessment (HIA) report on Battlement Mesa in Garfield County, Colorado (http://www.garfield-county.com/index.aspx?page=1408 and copy attached), in 2008 my colleagues and I reviewed previously completed studies from the general area of Garfield County and concluded that there were major gaps in public health information. At the request of the Garfield County Board of Commissioners, the Colorado School of Public Health (working in conjunction with the Garfield County Health Department) undertook a public health impacts assessment of the gas development activities underway or planned for this area. We conducted a qualitative and quantitative analysis of existing environmental, exposure, health and safety data for the Battlement Mesa community. We offered specific recommendations and produced a Health Impact Assessment (HIA) which involved several defined steps. The HIA looked at health stressors specific to gas development and rated them. Our results are in the HIA report, a copy of which is being submitted with this report.

The health effects on the Battlement Mesa residents were based on a careful study of the area population and the locations of gas development activity. The general conclusions of this HIA can be extrapolated from the study of the Battlement Mesa area to other areas with similar gas development activity across the county, including the northeastern United States. However, it is necessary to additionally look at the unique characteristics of any particular area, such as the Delaware River Basin including its geology and subsurface faulting and jointing, radioactivity of the underlying layers, water resources in proximity and downstream or down gradient from gas development areas and, of course, the unique population of that area. Therefore a study similar to the HIA should be done for the Delaware River Basin before exploratory drilling and gas development occurs and in preparation for any issuance of regulations. This study must precede permits, not the other way around, including any "test" or "exploratory" wells. These wells will include all the stressors we found, and perhaps additional ones, to a greater or lesser degree, depending on the unique population and geology of the potentially affected areas of the Delaware River Basin. Therefore it is imperative to study these issues before allowing gas drilling and development to proceed.

As part of the 2008 preliminary review that led to the 2010 HIA, my colleagues and I undertook an extensive review of the professional literature on the toxicology of the types of chemicals being used by the gas development industry and the substances being brought to the surface by gas drilling activities. As part of this report and my professional opinion in this matter, I am incorporating that 2008 literature review, entitled "Potential Exposure-Related Human Health Effects of Oil and Gas Development: A Literature Review (2003-2008)," into this report. The toxicology assessment in this literature review is just as relevant for the Delaware River Basin as it is for western Colorado. The same sorts of chemicals and substances are involved in gas drilling and development activities in the Delaware River Basin as are involved in such activities in western Colorado. Moreover, the toxicological effects of exposure to these various chemicals and substances do not change based on the location where the exposure occurs. For this same reason, references throughout the Literature Review to natural gas "exploration," "extraction," or "production" are essentially interchangeable as related to toxicity of chemicals and substances that may be released into the environment anywhere during these activities. The one exception to the applicability of the Literature Review to this hearing is that the portion of that Review related to chemicals used exclusively in fracking operations would not be relevant to this hearing related only to the drilling of exploratory wells. Everything else in the Literature Review is relevant to the issues involved in this hearing.

I have attached as appendices the 2008 White Paper and Literature Review Appendices listing all of the professional publications that were included in the literature review. I have also attached for completeness the 2010 report entitled, "Health Impact Assessment for Battlement Mesa, Garfield County Colorado."

The opinions provided in this report are stated to a reasonable degree of scientific and professional certainty.

/s/ Daniel Thau Teitelbaum

Daniel Thau Teitelbaum, M.D., P.C.

Attachments:

Potential Exposure-Related Human Health Effects of Oil and Gas Development: A Literature Review (2003 – 2008)

Potential Exposure-Related Human Health Effects of Oil and Gas Development: A Literature Review Appendices

Potential Exposure-Related Human Health Effects of Oil and Gas Development: A White Paper

Health Impact Assessment for Battlement Mesa, Garfield County, Colorado

Potential Exposure-Related Human Health Effects of Oil and Gas Development:

A Literature Review (2003-2008)

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Introduction and Background

The purpose of the literature review is to:

1. Review the known contaminants associated with oil and gas exploration, drilling, extraction and production.
2. Review the available medical literature regarding the health effects associated with oil and gas extraction and the health effects of the hazardous substances associated with oil and gas extraction and production.
3. Review the community and occupational injury rates associated with oil and gas extraction and production.
4. Review the literature regarding the potential social and psychological risks of increased oil and gas drilling on a community.

The United States and global energy needs have driven up prices for fossil fuels, with no relief in sight. In addition, political instability in major energy producing countries around the world has driven a US energy policy to increase domestic production of all types of energy, in particular fossil fuels. The combination of skyrocketing demand, interest in domestic supplies and new technology has made fuels previously unattainable or too costly now worthy of recovery. The American West has large reserves of extractable oil and gas. The West has therefore seen a dramatic increase in drilling for oil, gas, coal, and coal bed methane.

As pressures for increased fossil fuel production rises, areas that had previously been considered too sensitive for drilling are now being drilled. These previously sensitive sites have included an increasing number of oil and gas drills that are in close proximity to native and local populations. Human residence and activity close to oil and gas production sites increases the likelihood that people will be exposed to the hazardous chemicals, emissions and pollutants associated with these activities.

Hazardous chemicals are known to be used and produced by oil and gas extraction processes. Subsurface land formations are "fractured" (known as "fracking or frac'ing) by injection of fluids and/or solids into the ground under high pressure. Some of the chemicals used in this process are brought to the surface, potentially contaminating soil, air and water, while some of the chemicals are left underground, potentially contaminating subsurface aquifers. Other chemicals may also be used in the drilling fluids. These fluids may be fresh or salt water based muds, oil based muds or synthetic materials that contain esters, olefins, paraffins, ethers and alkulbenzenes, among others. The drilling fluids may also contain additives such as metals, acrylic polymers, organic polymers, surfactants, and biocides.(Occupational Safety and Health Administration)

Drilling sludge brought to the surface can contain fracking fluid, drilling mud, radioactive material from the subsurface land formation, hydrocarbons, metals, volatile organic compounds. When left to dry on the surface in waste pits, sludge can potentially contaminate air, water and soil. Sludge may also be removed to waste disposal sites (but usually not hazardous wastes sites) or sludge may be tilled into the soil in "land farms". These practices potentially contaminate soil, air and surface water.

Produced water can be brought to the surface during the extraction process. This water is usually contaminated with salts, hydrocarbons, radioactive material, metals, drilling fluids and muds. The produced water is often left on the surface to evaporate, or it may be re-injected into the ground or released into surface waters. All of these disposal methods threaten air, water and soil quality. Additionally, spills of oil and gas wastes and/ or chemicals used in production can pollute ground and surface water and soil.

Air surrounding oil and gas production areas is particularly vulnerable to toxic emissions. Fugitive natural gas emissions may contain many contaminants. Some of these such as methane and other hydrocarbons (ethane, propane, butane) and water vapor are of relatively low human toxicity. Others such as hydrogen sulfide (H2S) are of more significant toxicity. Some natural gas wells produce a condensate which can contain complex hydrocarbons and aromatic hydrocarbons such as benzene, toluene, ethyl benzene and xylene (BTEX). These substances are important human toxics with multiple non-cancer and cancer endpoints. Natural gas flaring can produce many hazardous chemicals including polycyclic aromatic hydrocarbons (PAHs, including naphthalene), benzene, toluene, xylenes, ethyl benzene, formaldehyde, acrolein, propylene, acetaldehydehexane. Glycol dehydrators, used to remove water from natural gas can produce BTEX leaks into the air.

Most of the hazardous chemicals associated with oil and gas production are well documented to produce adverse health effects in individuals. Some literature exists that demonstrates adverse health effects on populations exposed to these chemicals in other industrial or in urban settings. However, little research exists regarding the effects of these exposures on local populations as a whole in the setting of oil and gas extraction. Our review is an attempt to summarize what is known about these hazardous chemicals' effects on populations and to identify gaps medical and public health knowledge. A list of contaminants derived from the Oil and Gas Accountability Project website is listed in the next section. (Oil and Gas Accountability Project 2006) Our review may not include chemicals used in drilling muds and fracking fluids as these compounds are often considered proprietary and not available to the public.

Oil and gas drilling is associated with an influx of workers and resources to often rural or isolated communities. These changes can bring about stresses to the local people and may be reflected in changes in crime, social diseases, and psychological outcomes. We reviewed available literature regarding the psychosocial effects of oil and gas drilling on local communities. We also identified significant gaps in knowledge regarding the demographics and the psychosocial effects of oil and gas drilling on local populations.

Oil and Gas Contaminants

Contaminant Inventory	
Particulates	PM10 (diameter </= 10 microns) PM2.5 (diameter </= 2.5 microns) Ultrafine particles (diameter </= 1 micron)
Nitrous oxides (NOx)	
Sulfuric oxides (SOx)	
Ozone	
Hydrogen Sulfide (H2S)	
Volatile Organic Compounds (VOC)	BTEX (Benzene, Toluene, Ethyl benzene, Xylene) Methylene Chloride Tetrachloroethene Trichloroethene 1,4-dichlorbenzene m,p-xylenes 2-hexanone
Diesel fuel/exhaust	
Metals	Arsenic Barium Cadmium Chromium Lead Mercury Selenium Zinc
Polyaromic hydrocarbons (PAH)	
Produced water	
Fracturing chemicals (Fracking, Frac'ing chemicals)	
Radiation	Radon Radium Uranium
Noise pollution	
Light pollution	

Methodology

Literature Search

The literature search was performed by Paul Blomquist at the University of Colorado Denver Health Sciences Library after discussion with the work group to define the scope and extent of the searches. The bibliographic retrieval on May 13, 2008 included four different searches related to oil and gas drilling as follows: search 1 covered adverse reactions to various chemicals and events; search 2 retrieved impacts of fracking and fracturing; search 3 covered implications of produced water; and finally search 4 retrieved injuries related to oil and gas drilling. All searching in Ovid Medline excluded the pre-indexed component of Medline.

The first search covering adverse reactions to various chemicals and events related to oil and gas drilling was limited to the years 2003 through 2008 and for humans only. In this search, an initial set, limited by the subheading for adverse effects, was created for MeSH (Medical Subject Headings) terms that included "air pollution" and the subjacent MeSH term "air pollution, radioactive", the exploded term "Particulate matter," and the exploded term "environmental pollution." Also, "Waste products" included all subjacent MeSH terms other than "medical waste." Other exploded MeSH terms with adverse effects subheading included "water pollution," "noise," and "light." Finally three subheadings--adverse effects, poisoning, and toxicity--were applied to MeSH terms for both "vehicle emissions" and the exploded "Environmental Pollutants". From this initial aggregated set, citations were eliminated for the exploded MeSH terms of "household articles," "household products," "pest control," "swimming pools," "seasons," "weather," "smoking," "tobacco," and "tobacco smoke pollution." Also citations were eliminated with truncated free text terms for "offshore$" and "cigarette$."

The final aggregated retrieval for the first search strategy was parsed into 28 sets by concepts for adverse events or chemicals related to oil and gas drilling that included truncated full text terms, acronyms, and exploded MeSH terms supplemented with chemical registry numbers where appropriate. The MeSH terms used for parsing did not limit with subheadings except for the concept of diesel fuel in which the subheadings for toxicity, poisoning and adverse effects were applied to MeSH terms "vehicle emissions" and "gasoline." It is suggested that alternate searching could be formulated that applies subheadings for poisoning, toxicity, or adverse effect to the MeSH terms for the chemicals that comprised a large portion of the 28 concepts.

In the second search on the impact of fracking and fracturing in oil and gas drilling, an initial set was created of full text terms for "fracturing" or the truncated "frack$." This retrieval was narrowed to citations with exploded MeSH terms for either "environmental pollution" or "water supply." This set was further narrowed to citations pertaining to oil and gas drilling with a combination of fulltext terms and MeSH terms as follows: restriction to citations that contain exploded MeSH terms for both "extraction and processing industry" or "petroleum"; or restriction to citations containing fulltext terms for either "oil" or "gas" adjacent to any of the three truncated terms "drill$" or "indust$" or "explor$." Citations with truncated fulltext term "offshore$" was excluded from the final set of this retrieval.

For the third search on the implications of produced water in oil and gas drilling, an initial retrieval of citations included exploded MeSH terms for either "water supply," or "environmental pollution." Added to this set were citations that had both exploded MeSH terms for "extraction and processing industry" and "petroleum." A final aggregation included citations with fulltext terms of either "oil" or "gas" adjacent to any of three truncated terms: "drill$" or "indust$" or "explor$." This final set was narrowed to only citations containing the fulltext term "produced water," and citations containing the truncated term "offshore$" were eliminated.

In the fourth search on injuries related to gas and oil drilling, an initial set of retrieved citations of exploded MeSH terms for "extraction and processing industry" combined with "petroleum." To this set was added citations with full text terms of "oil" or "gas" adjacent to any of three truncated terms: "drill$" or "industry$" or "explore$." The aggregated set was narrowed to citations that had exploded MeSH terms for either "wounds and injuries" or "accidents." Finally, citations containing the truncated term "offshore$" were eliminated.

Summary of databases searched:

U.S. National Library of Medicine: Ovid Medline (R) 1950 to present.
Social/Psychological Databases: Psychological: PyschInfo, Web of Science
Medical: ScienceDirect, PubMed, MEDLINE OCLC, CINAHL
Public Health: American Journal of Public Health, Annual Reviews
Educational: EBSCO Academic Search Premier, ERIC, OCLC

Refining the Literature Review

After identifying potentially relevant literature, each paper was reviewed at the abstract or full text level for relevance. We reviewed English language, human studies published between 2003 and the present. Papers were excluded from further review based on the following criteria: foreign language literature; animal research; publication prior to 2003; laboratory based, experimental research studies; off shore drilling and exploration studies; reviews other than meta analyses; case reports; commentaries, editorials, letters to the editor and other opinion pieces. Exceptions to these rules are specifically noted in each subsection.

Having refined the list of potentially relevant literature, papers were reviewed and summarized according to exposure category. These reviews are a summary of relevant literature, taking into account the strength of evidence and study design. No attempt was made to rate individual articles.

Table 1. Overview of search results and literature reviewed

Category	Initial number of references identified by Search	Number of references Excluded (see criteria above)	Total number of references Reviewed	Appendix
VOC	247	147	100	1
Diesel Exhaust	197	144	53	2
Nitrogen oxides (NOx)	243	192	51	3
Sulfuric oxides (SOx)	118	85	33	3
Ozone	217	125	94	3
Particulate matter	510	183	327	3
PAH	276	245	31	4
Metals	299	224	75	5
H2S	85	65	20	6
Fossil Fuels	305	279	26	7
Fracking	234	234	0	-
Noise	881	857	24	8
Light	297	291	6	9
Occupational Injuries	40	31	9	10
Social/Psychological	1114	1093	21	11
Total	5063	4239	831	

Limitations

This literature review has a number of possible limitations:

- It relied on single reviewers for each section.
- It only considered literature published within the past 5 years, possibly missing important, relevant literature published prior to 2003.
- It may have excluded meritorious research published in foreign languages.
- Studies were considered without reference to their funding sources or their potential conflicts of interest.
- Use of additional search terms may have generated different results.
- Use of additional databases may have yielded different results.
- It did not use formal criteria to assess each individual paper for strength of evidence and study design.
- It relied on the major, known exposures of potential concern. There may be other exposures that should have been considered.
- Additional chemicals, used in proprietary formulas, may not have been included.
- In many cases papers focused on single exposures. This may fail to take into account potential health effects of these exposures when they are part of a complex mixture.

Contaminants and Health

Volatile Organic Compounds (VOCs)

Volatile organic hydrocarbon exposures as a result of emissions from production in the oil and gas industries are complex. These are composed of materials used in the production activities, and emissions from the produced material. Both point source releases at the well pads, and transportation activities to and from the drilling sites contribute volatile hydrocarbon loads to the resident and transient populations in the drilling regions. Because there is limited information on the distribution of population in the affected regions, it is not possible to define the distances of interest from the well heads and traffic patterns of concern. This makes it difficult to search the literature for exposure concentrations by source distance. Since dose and dose rate are important in assessing the relevance of the literature of VOCs to human information, the absence of this demographic information limits the interpretation of the found literature.

Terms utilized in the search are summarized above. A total of 247 studies were recovered. One-hundred and forty-seven studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.). Because reviews and comments were excluded for this study, known and theoretical issues of diseases suspected or proved to be causally associated with the materials of interest in past studies are not included in this paper. The search for VOC literature included the BTEX chemicals (benzene, toluene, and xylenes) and also included low molecular weight halogenated hydrocarbons. A total of 62 studies were selected for review dealing with benzene. Four relevant studies were reviewed for xylene. Studies relating to toluene were subsumed under the benzene and xylene rubric. No meaningful studies that dealt with dichlorobenzene were found. Two studies that met the search criteria were reviewed for dichloromethane [methylene chloride]. Ten relevant studies were reviewed for perchloroethylene. Twenty-two relevant studies were reviewed for trichloroethylene. These citations are collected in Appendix 1.

Chronic, low level exposure

The literature on the impact of volatile organic compounds including the BTEX group, and the low molecular weight halogenated hydrocarbons were reviewed for cancer and non-cancer endpoints in humans. Although there is an extensive occupational toxicology literature on these substances, little meaningful information on chronic, low level, exposure in the general environment has been developed.

High Concentration Exposure

It is well known that all of the chemicals in this group are neurotoxins. They impact the central and peripheral nervous system. They have significant cognitive and behavioral effects in occupationally exposed groups. They are known hepatotoxins. Most have been identified as reproductive toxins both in males and females. They are recognized as fetotoxins, and have been associated with teratogenesis and fetal wastage following large or critically timed occupational or accidental exposures. All are dermatotoxins. These effects have primarily been identified in persons who had exposures at levels or dose rates that are not found in the general environment, although widespread general environmental exposure to these chemicals occurs, few studies have been conducted at environmental exposure concentrations.

Occupational Exposures

Although much of the toxicological information on benzene in particular has been developed in the downstream petrochemical industries such as shipping, processing and refining, and distribution of the finished products, no studies on the impact of the BTEX group or the low molecular weight halogenated hydrocarbons in the upstream petrochemical industries were found. No data on exposure to these substances to occupational groups in the process of exploration or production were recovered. No studies of exposures to adjacent populations were found. This is a major data gap. All relevant studies selected for review and relevance then are removed from the oil and gas production activities and must be used as analogous to these activities.

A number of very low level occupational exposure studies that demonstrate positive outcomes are likely relevant to the exposures to resident local populations in the oil and gas exploration and extraction areas. For example, a statistically significant incidence of acute myeloid leukemia at doses and dose rates as low as 0.8ppm and 2ppm/years was demonstrated in the case control study portion of the Australian Health Watch Study. This important finding suggests that benzene may have adverse health effects at lower dose rates than previously thought and current exposure limits may not be protective.

It is necessary to extrapolate the occupational information which has been developed in healthy, midlife, mostly male workers to the broader universe of humans, including women, children, and the infirm. Because the body of literature recovered in the searches is not informative on these populations, it is immediately apparent that a major data gap exists in any attempt to characterize risk beyond the workplace. Broad general assumptions must be made about adjustments to dose response curves for use in risk assessment in non-occupational populations such as the target groups of concern in this review. Physical and psychological stressors that may influence the impact of exposure and outcome are unaddressed.

Biomarkers

A growing literature on the identification and quantification of biomarkers of exposure to volatile organics, and sub-clinical effect of these exposures was developed in this review. This literature offers some hope that biomarkers may provide meaningful data on exposure at very low levels to non-occupational populations. Papers recovered that deal with genetic diversity and metabolic variations in the handling of these chemicals in large groups of humans may indicate that in the future such measurable parameters will give early clues to adverse effects. Because there is a peer reviewed body of information that indicates that children are at increased risk for adverse toxicological outcomes following exposure to many synthetic organic chemicals, including the volatile organics, the absence of environmental toxicology data on childhood environmental exposure and outcome is particularly troubling.

Molecular epidemiologic investigation of biomarkers that have been identified in the occupational and para-occupational groups as a result of exposure to the BTEX and low molecular weight halogenated hydrocarbons should be done in the environmentally exposed persons based upon the material recovered in this review. Molecular epidemiologic studies may prove to be of great value. Such investigation may yield exposure information not currently available for these environmentally exposed persons. If registries of these findings are developed, maintained and properly analyzed, and linked to long term outcome follow up studies, they may prove to be characteristic and predictive of adverse health outcomes.

Epidemiology

Extensive epidemiologic, basic science, and mechanistic information has been collected and peer reviewed about each of the materials of concern in this part of the review. More of this information supports the classification of benzene as a known human carcinogen, trichloroethylene as a probable human carcinogen, and dichloromethane as a probable human carcinogen, than addresses the non-cancer endpoints that have been identified following occupational exposure to this group of chemicals. In the material recovered in this review, some of the well-known cancer endpoints and some of the lesser known toxic endpoints have been demonstrated in low level exposures in occupational or para-occupational populations. A few studies of exposure at low, general environmental exposure have also shown increased occurrence of the non-cancer endpoints, particularly in the neurological system.

Most of the studies that are relevant to the issues at hand in this review identify serious cancer and non-cancer endpoints in low level, long term occupational or para-occupational studies. For example, benzene or benzene and other volatile organic compound exposure in traffic police and the outcomes in these persons have been analyzed. Some studies have identified biomarker variants in these exposures that might also be found in persons who reside close to a point source of analogous VOC emissions. The biomarkers and outcomes in para-occupational groups provide insight into research findings that may predict outcomes in the environmentally exposed groups.

Summary

Based upon the material reviewed in this study, some conclusions are appropriate:

1. Benzene is a human leukemogen at airborne exposures lower than have been reported in past times. This may imply that persons residing close to sources of benzene from oil and gas production are at risk of leukemia from those exposures. Some evidence for the occurrence of a broad spectrum of hematological disorders exists. The scope of these diseases should be the subject of study. In addition, the low molecular weight halogenated hydrocarbons are noted to cause liver, kidney and neurological disease, and

likely increase renal and other cancers. Persons exposed to these materials in the oil patch should be evaluated for adverse effects.
2. Biomarkers that may be clinically relevant have been identified in numerous studies of human exposure to most of the chemical compounds in this review. An evaluation of the relevance and predictive value of these biomarkers should be undertaken. Selection and examination of the most useful biomarkers in this population and a registry of the findings should be developed for this population. The biomarkers may be indicative of exposure to the materials of interest and therefore may be predictive of increased risk of adverse outcome in the exposed population.
3. Evidence of cognitive and behavioral abnormalities, alterations in special sense function such as impairment of color vision and perception have been reported in occupationally exposed workers from these materials. Screening for cognitive function impairment, behavioral disorders and disorders of the special senses is appropriate in the population exposed to oil and gas activities.
4. Very limited evidence that children are at increased risk of adverse outcomes and that fetal and neonatal impact of these chemicals was found. Screening for such effect in early childhood and registry of birth outcomes in the exposed population is advised.

Diesel exhaust

As discussed above, diesel exhaust exposures from both stationary and mobile sources are among the categories of exposures of concern. Diesel exhaust is a complex mixture of diesel exhaust particulate matter (see section on particulate matter), metals, thousands of organic compounds especially solvents, and other chemicals. As such, we have examined the medical literature to identify published research on the human health impact of diesel exhaust a) specifically in relation to oil and gas exploration activities and b) generally in relation to people with environmental exposure to diesel exhaust. Much of this literature comes from studies of occupationally exposed individuals as well as studies of those exposed environmentally because of their proximity to major roads and diesel exhaust sources.

Key search terms are summarized in the methods section above. A total of 197 studies were recovered. One-hundred and forty-four studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.) A total of 53 papers were reviewed. See the list of these citations in Appendix 2.

As elsewhere in this literature review, this section will focus on those published studies that directly examine the human health impact of oil and gas exploration – generated diesel exhaust. Much of this exposure is anticipated to be related to increased vehicular traffic. In addition, we provide an overview of the body of evidence regarding diesel exhaust-related health effects in the general population. The section will include a set of conclusions based on this literature review.

Among the 53 reviewed papers published between 2003 and 2008, we identified no research studies that directly examined the human health impact of diesel exhaust emissions associated with oil and gas exploration activities. However, a number of studies are noteworthy because they reflect the health impact on communities when diesel vehicular traffic rises.

Notably, numerous epidemiologic and experimental studies have shown generally consistent relationships between diesel exhaust exposure and adverse human health outcomes. Health effects may vary some by the source of diesel exhaust as well as the chemical composition of the diesel fuel, metal content, and chemical composition. Diesel particulate matter has a center core of carbon and a variety of adsorbed organic compounds that include some known human carcinogens such as polycyclic aromatic hydrocarbons (PAH) and nitro-PAHs, as well as nitrate, sulfate, trace elements, and metals. Diesel particulate matter is composed of small particles including a high percentage of ultrafine particles (</= 1 micron diameter) which are of particular concern. These particles easily enter deep into the respiratory tract and have a large surface area where organic compounds can easily attach. Both stationary (e.g. industrial sources) as well as mobile sources (e.g. diesel fuel combustion emissions from vehicles and traffic density) contribute to risk. In some circumstances, increased risk may be due to a combined effect of diesel exhaust and the myriad of other pollutants that may also be in the air. Exposure to diesel exhaust can cause irritant symptoms, neurological, respiratory, and asthma-like symptoms, and can both increase the risk for developing allergic disorders and worsen allergenic responses to known environmental allergens. Lung cancer risk (independent of smoking status) is elevated among those with occupations where diesel engines have been used.

The majority of the studies reviewed are relevant in considering how increases in diesel exhaust from oil and gas exploration activities may affect health outcomes. The data are generally consistent. They show that many of the health risks that are associated with various forms of diesel exhaust disproportionately affect susceptible populations including those with lung disease, those with allergic disorders, and the elderly. As a major contributor to ambient particulate air pollution, the section in this document that refers to particulate matter is generally applicable to diesel exhaust as well.

Several references in the literature are particularly noteworthy. In 2002, the U.S. EPA released a health assessment document regarding diesel engine exhaust, based on data from the 1990s. This assessment concluded that long-term exposure to inhaled diesel exhaust is a lung cancer hazard in humans, based on epidemiologic and animal research. In addition, non-cancer chronic human health risks identified included lung inflammation, irritation, allergies, and asthma.

Although not specific to diesel exhaust emissions from oil and gas exploration and extraction, a paper by Gabrovska and Friedman (2004) is relevant to the concept of how increased diesel exhaust due to traffic around an industrial site affects health. In that study, community respiratory complaints were assessed during the closure of a community dump, in relation to dust exposure and measured or estimated diesel emissions. People living nearest to and downwind of the site were at increased risk of having respiratory symptoms. After the site closed, one-third of residents reported improvement of symptoms. The authors linked the rates of respiratory symptoms to changes in diesel emission and ambient dust levels.

In a study published in the New England Journal of Medicine in 2007, McCreanor and Cullinan demonstrated the respiratory effects of exposure to diesel traffic in people with asthma. They observed that increased diesel traffic is associated with worse lung function and worse lung inflammation in asthmatics.

In addition to these reports, the body of literature reviewed is sufficient to conclude that as exposures to airborne diesel exhaust rise, human risks increase for the following:

- **Cardiovascular disease:** See section on “Particulate matter.”
- **Respiratory disease:** Including respiratory disease-related hospital admission, mortality due to respiratory disease, premature death from respiratory disease including lung cancer, worsening of illness in people with lung disorders (e.g. asthma, chronic obstructive pulmonary disease), asthma, bronchiolitis and respiratory infections, reduced lung function (especially in asthmatic children), allergic lung inflammation, allergies, symptoms (e.g. cough)
- **Allergic diseases**
- **Genotoxicity** Damage to chromosomes and DNA
- **Childhood illnesses:** Pediatric allergies and respiratory disorders, exacerbation of existing asthma

Conclusions

1. We identified no published studies in the past five years that directly examined the health impact of diesel exhaust in the population living and working in the vicinity of oil and gas exploration activities. This is a major gap and calls for additional research.
2. No data on the impact of diesel exhaust at environmental concentrations on special populations such as the elderly, pregnant women, healthy and asthmatic children and other special groups was found. This is a major gap and calls for additional research.
3. The absence of studies directly examining diesel’s effects in populations surrounding oil and gas exploration facilities does not mean an absence of risk. The independent and generally consistent body of scientific evidence on diesel exhaust that we reviewed provides strong support for the relationship to human disease.
4. Based on the available evidence, it is highly likely that as diesel exhaust exposures rise due to exploration sites and associate diesel vehicular traffic, the health of the surrounding community will be adversely affected.

Criteria Pollutants

Nitrogen oxides (NOx), sulfuric oxides (SOx), ozone, and particulate matter

Sources

Nitrogen oxides (NOx) are released into the air from oil and gas production during flaring, and in exhaust from diesel and gas compressor engines. NOx are also released in automobile exhaust and play a major role in the formation of photochemical smog.

Sulfuric oxides (SOx) are formed during the combustion of coal and oil. SOx may be released during flaring of natural gas, or when fossil fuels are burned to provide power to the pump jack or compressor engines at oil and gas sites.

Ozone is among the exposures of possible concern. A potent respiratory irritant, ozone results from sunlight-driven reactions involving the oxides of nitrogen and volatile organic compounds that are generated by stationary and mobile sources. It is the principal component of photochemical smog.

Particulate matter exposures from both stationary and mobile sources are among the categories of exposures of possible concern.

Review

Terms utilized in the search are summarized above in the methods section. A total of 243 studies were recovered for NOx. One-hundred and ninety-two papers were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.). A total of 51 studies were selected for review of NOx exposure. A total of 118 studies were recovered from SOx. Eight-five studies were eliminated from further review following our criteria for inclusion in this literature review. A total of 33 studies were selected for review dealing with SOx. A total of 217 ozone studies were recovered. One-hundred and twenty-five were eliminated from further review following our criteria for inclusion in this literature review. A total of 94 studies for ozone were reviewed. A total of 510 studies were recovered from particulate matter. One-hundred and eighty-three were eliminated from further review following our criteria for inclusion in this literature review. In total, we reviewed a total of 327 studies for particulate matter. These citations are collected in Appendix 3.

As discussed above, these pollutants are among the exposures of possible concern. As such, we have examined the medical literature to identify published research on the human health impact of these air pollutants a) specifically in relation to oil and gas exploration activities and b) generally in relation to people with environmental exposure to ambient particulate matter.

Among the reviewed papers published on NOx, SOx, ozone and particulate matter between 2003 and 2007, we identified no research studies that examined directly the human health impact of these pollutants produced during oil and gas exploration activities. However, in contrast to other parts of this review there is extensive data about general exposure to these substances in the environment outside the workplace, and its impacts on non-occupational populations.

Health Effects

NOx, SOx, and ozone:

Notably, numerous epidemiologic and experimental studies have shown generally consistent relationships between all of these pollutants and adverse human health outcomes. Both stationary (e.g. industrial sources) as well as mobile sources (e.g. fossil fuel combustion emissions from vehicles and traffic density) of ground-level pollutants contribute to risk. Risk may, in some circumstances, be due to a combined effect of these pollutants. In some instances, it has been difficult to separate the independent contribution of each of these pollutants to health risk.

There is clear evidence that nitrogen oxides, sulfur dioxide, and ozone exposures are significant contributors to respiratory disease. There is reasonably strong evidence for its contribution to cardiovascular illness as well. The majority of the studies reviewed are relevant in considering how increases in these pollutants along with other air pollutants from oil and gas exploration activities may affect health outcomes. Special consideration is needed for the young (especially those with asthma) and the elderly (especially those with chronic obstructive pulmonary disease and/or cardiac disease). The data are generally consistent in showing that many of the health risks that are associated with these pollutants disproportionately affect these susceptible populations. In particular, ozone has been clearly associated with increased mortality. (Gryparis 2004, Bell 2005, Bell 2008). The body of literature reviewed is sufficient to conclude that with even small increases in exposure to these pollutants, human risks increase for the following:

- **Respiratory disease**: Including respiratory disease-related hospital admission, mortality due to respiratory disease, worsening of illness in people with lung disorders (e.g. asthma, chronic obstructive pulmonary disease), asthma, bronchiolitis and respiratory infections, reduced lung function (especially in asthmatic children), allergic nasal and airways inflammation, allergies, symptoms (e.g. cough, wheeze, shortness of breath, eye irritation, headache). (Galan 2004, Simpson 2005, Ostro 2006, Quian 2007, Chen 2007, Lee 2007, Yang 2003, Yang 2007, Pacini 2003, Hoffman 2004, Sienra-Monge 2004, Vagaggini 2007, Sole 2007, Kim 2004, Chan 2005, Tager 2005, Qian 2005, Kim 2007, McDonnell 2007, Rojas-Martinez 2007, Alexeeff 2007, Henrotin 2007, Penard-Morand 2005)
- **Childhood Asthma**: Some of the most compelling evidence, reinforced by publications in the past five years, relates to ozone's impact on children with asthma. While there is evidence for some 'adaptation' to the effects of ozone as people age, and heterogeneity in peoples' responses to ozone (that may be related to genetics), the overall impact of ozone related to childhood asthma is noteworthy. It includes increases in pediatric emergency room visits and pediatric hospital admissions, asthma exacerbations of symptoms and use of rescue inhalers, impaired lung development, and airways inflammation in addition to asthma, including bronchiolitis. (Lin 2003, Gent 2003, Sanhueza 2003, Lewis 2005, Hwang 2005, Calderon-Garciduenas 2006)
- **Cardiovascular disease**: Including cardiovascular hospital admission, mortality due to cardiovascular disease, arrhythmias (heart rhythm disturbances, heart rate variability), blood pressure elevation. (Holguin 2003, Ruidavets 2005, Urch 2005, von Klot 2005, Rich 2006, Zhang 2006, Ballester 2006, Sarnat 2006, Larrieu 2007, Peel 2007, Park 2008)
- **Genotoxicity**: Damage to chromosomes and DNA. (Pacini 2003, Tovalin 2006)
- **Fetal and neonatal health**: Preterm birth, low birth weight, hospitalization of newborns, and respiratory illness in infants born to asthmatic mothers who were exposed to ozone during pregnancy. (Dales 2006, Hansen 2006, Triche 2006, Salam 2005)

Particulate matter:

Health effects may vary somewhat by the size of particles. Recent data demonstrates that while particles with diameters </= 10 microns (PM10) pose health risks, particles with diameters </= 2.5 microns (PM2.5) and particles with diameters </= 1 micron (ultrafine particles) contribute disproportionately to human health risks. Due to their small size and large surface area, these smaller particles are carried deeper into the lungs when inhaled, and are capable of carrying toxic pollutants to the lung and elsewhere in the body as they enter the bloodstream. Both stationary (e.g. industrial sources) as well as mobile sources (e.g. fossil fuel combustion emissions from vehicles and traffic density) of particulate matter contribute to risk. Traffic density has, in particular, been confirmed now in multiple studies to confer additional risk, especially for respiratory health consequences. Additional research is needed to better determine the components of particulate matter that induce inflammation and disease. The majority of the studies reviewed are relevant in considering how increases in particulate matter from oil and gas exploration activities may affect health outcomes. The data are generally consistent in showing that many of the health risks that are associated with various forms of particulate matter air pollution disproportionately affect susceptible populations including children, the elderly. The body of literature reviewed is sufficient to conclude that with even small increases in airborne particulate matter exposure, human risks increase for the following:

- **Cardiovascular disease**: Including cardiovascular hospital admission, mortality due to cardiovascular disease, premature death from heart disease, cardiac ischemia (reduce blood flow to the heart), arrhythmias (heart rhythm disturbances, heart rate variability), hypercoagulability, atherosclerosis, myocardial infarction (heart attack), blood pressure.
- **Respiratory disease**: Including respiratory disease-related hospital admission, mortality due to respiratory disease, premature death from respiratory disease including lung cancer, worsening of illness in people with lung disorders (e.g. asthma, chronic obstructive pulmonary disease), asthma, bronchiolitis and respiratory infections, reduced lung function (especially in asthmatic children), allergic lung inflammation, allergies, symptoms (e.g. cough).
- **Fetal and neonatal health**: Preterm birth, restricted fetal growth, lower infant term birth weight, and increased neonatal death especially when it is associated with respiratory illness.
- **Childhood illnesses**: Pediatric allergies, ear/nose/throat and respiratory infections early in life, pediatric emergency room visits and pediatric hospital admissions, impaired lung development in children that affects lung function in adulthood, asthma, bronchiolitis, exacerbation of existing asthma and exacerbation of cystic fibrosis.
- **Geriatric illnesses**: Including exacerbation of chronic obstructive pulmonary disease, congestive heart failure, heart conduction disorders, myocardial infarction and coronary artery disease, and diabetes in the elderly.

Summary

Based upon the material reviewed in this section, some conclusions are appropriate:

1. We identified no published studies in the past five years that directly examined the health impact of nitrogen dioxides, sulfur dioxide, particulate matter, or ozone, in the population living and working in the vicinity of oil and gas exploration activities. This is a major gap in the literature and calls for additional research.
2. The absence of studies directly examining the above air pollutants and effects in populations surrounding oil and gas exploration facilities does not mean an absence of risk. The independent and generally consistent body of scientific evidence on these air pollutants that we reviewed provides strong support for the relationship between sulfur dioxide, nitrous oxides, particulate matter, and ozone, and human disease.
3. Based on the available evidence, it is highly likely that as exposures rise, either alone or along with other air pollutants due to exploration sites and associate vehicular traffic, the respiratory health of the surrounding community will be adversely affected.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are a large group (>100) of organic chemicals, which usually exist as a mixture containing two or more compounds. Airborne PAHs are a result of combustion of fossil fuels, tobacco, and other organic materials Both point source releases and transportation activities to and from the drilling sites contribute PAH loads to the resident and transient populations in the drilling regions. PAHs of concern include: enz[a]anthracene, benzo[b]fluoranthene, benzo[j]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene.

Terms utilized in the search are summarized above. A total of 276 studies recovered. Two-hundred and forty-five studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.). A total of 31 published studies were selected for review dealing with PAHs. These citations are collected in Appendix 4.

Among the 31 reviewed papers published between 2003 and 2008, we identified no research studies that examined directly the human health impact of PAHs produced during oil and gas exploration activities; this does not mean however that PAH exposure is not a human health risk.

Environmental exposures

Environmental exposure studies have revealed associations of chronic exposures to PAHs at different levels and alterations of immune responses by causing suppression of T-lymphocyte proliferation and augmentation of NK cell activity. Environmental exposure studies have also revealed that c-PAHs can alter the ability of blood lymphocytes to repair DNA damage and, as a result could potentially lead to effects that are hazardous to human health. (Karakaya, 2004, Cebulska-Wasilewska, 2007). One study measured prenatal exposure to airborne PAHs (low concentration) and birth weight, birth length, and birth head circumference, in two different populations, Krakow, Poland and New York City. The study suggested adverse reproductive effects of relatively low PAH concentrations in both populations. (Choi, 2006)

Occupational Exposures

No data on exposure to PAHs and occupational groups or adjacent populations in the process of exploration or production of oil and gas were recovered. The majority of PAH occupational exposure and effects on human health involve coke oven workers, exposed to PAHs at high concentration and DNA damage in the lymphocytes. Studies suggesting an increased risk of cancer (lung, bladder, skin, and gastrointestinal) in working populations exposed to PAHs are limited due to multiple exposures to carcinogens at work sites. (Wang, 2007, Siwinska, 2007, Chen, 2007, Pavanello, 2007)

Summary

There is very little data available on disease outcomes in non-occupationally exposed human populations. There is a significant gap of research in this area. As findings from this literature review demonstrate, the research in the past five years has been limited. There is some evidence of immune and lymphocyte damage in workers exposed to PAH at high concentrations and very limited evidence of reproductive effects of prenatal exposure to low concentrations of airborne PAHs. Findings from this literature review make it clear that future research is necessary to clarify our understanding of environmental and occupational exposure to PAHs.

Metals

Human activity may release environmental metals, or cause exposure to new metal containing compounds and are thus of concern. Metal exposure can occur through the air, water or soil and can enter the body through the skin, lungs or GI tract. Metals may be essential to life such as Copper(Cu), Iron(I) or Zinc(Zn) or toxic, such as Lead(Pb), Cadmium(Cd) or Arsenic(As). Toxic metals may influence human health by interactions with essential elements. The elderly and children are at a higher risk from metal exposure than the average adult due to developmental and immune factors. We examined the medical literature to identify published research on the human health impact of metals exposure a) specifically in relation to oil and gas exploration activities and b) generally in relation to populations with environmental exposure to toxic metal compounds.

Terms utilized in the search are summarized above. A total of 299 studies were found, including 35 studies related to Arsenic (As), 4 related to Barium(Ba), 23 related to Cadmium (Cd), 67 related to Chromium (Cr), 75 related to lead (Pb), 39 related to Mercury (Hg), 19 related to Selenium (Se) and 37 related to Zinc (Zn). Seventy-five studies were eliminated due to their reporting multiple exposures and thus being identified more than once. One hundred and forty-nine studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.). Overall, a total of 75 papers were reviewed. The list of these citations appear in Appendix 5.

This section will initially examine those published studies that directly assess the human health impact of oil and gas exploration and the health risks associated with contact, inhaled or water based exposure to eight metals (As, Ba, Cd, Cr, Pb, Hg, Se and Zn) and those eight metals in combination with one another. It will also offer an overview of the body of evidence regarding health effects related to metal exposure in the general population. The section will include a set of conclusions based on this literature review.

Among the 75 reviewed papers published between 2003 and 2008, we identified no research studies that directly examined the human health impact of metals exposure related to oil and gas exploration activities.

Notably, numerous epidemiologic and experimental studies have shown generally consistent relationships between metals exposure, either individually or in groups and adverse human health outcomes with individual metals showing distinct human health effects for instance exposure to lead and cognitive function. Much of the work in metals exposure involves industrial exposure to workers but there is a large body of literature involving population exposure to remnant industrial waste, for instance mine tailings and drinking water contamination. Many industrial sources do not create unique exposures to individual metals, rather several metals in combination may be an integral part of the industrial process, for instance tin smelting and exposure to As, Cd, Pb, antimony and polonium-210. The human health risks due to exposure to combined metals exposure versus each individual metal are difficult to assess though exposure to the combination is not likely to be protective. In some cases there is evidence that exposure causes damage to DNA but that that damage is subject to repair. The combination of exposure to more than one metal that causes DNA damage or increases oxidative stress (and thus reduces the body's ability to repair itself) can overwhelm inherent repair mechanisms. In other cases increased levels of a metal, such as Se, are found to be protective when examined in the context of a toxic exposure. For instance, Se may mediate ototoxicity caused by Pb exposure. (Chuang, 2007)

The majority of the studies reviewed are relevant in considering how potential metal exposure associated with oil and gas exploration activities may affect health outcomes. There are some examples of disagreement between investigators when specific exposures overwhelm the body's ability to repair itself, as when exposued to Cr and DNA damage (Paustenbach, 2003), Pb and cancer risk or stunting (Cocco, 2007), (Mahram, 2007), Hg and neurobehavioral changes or increased oxidative stress (Bast-Pettersen, 2005, Belanger, 2006) or Se and sperm motility. (Wirth, 2007) But, the consistent theme of metals exposure is there are known effects at the cellular or DNA level and some of these effects are consistent with neurologic, metabolic, immunologic and reproductive effects in individuals with specific exposures. The disagreement tends to occur when translating these known cellular and individual effects into population effects where the exposures are far more difficult to measure and correlate with health outcomes. This body of literature is sufficient to conclude that environmental exposures to metals are associated with the following;

- **Autoimmune disease:** Including Wegener's granulomatosis.
  - **Cr** (Albert, 2005)
- **Cancer:** Including all cancers; lung, stomach, oral and pharyngeal cancers.
  - **Pb, As, Cd, Zn**; (Dynerowicz 2005), (Lee, 2005 Apr), **Cd;** (Wang, 2004), (Satarug, 2003) **As** (Jones, 2007), (Lee,2006), (Vitayavirasak,2005), **As, Cd** (Obiri, 2006), **Cr** (Beaumont, 2008), **Se** (Gromadzinska, 2003), **Hg** (Zadnik, 2007)

- **Cardiovascular disease:** Including increased risk of atherosclerosis, hypertension and lipid abnormalities.
    - **Pb**; (Li, 2006), (Skoczynska, 2007), (Ademuyiwa, 2005), **Cd** (Satarug, 2003), **Hg** (Cortes-Maramaba, 2006)
- **Cognitive function:** Including neurobehavioral and cognitive effects, decreased IQ, cerebral white matter changes.
    - **Pb;** (Carta 2003), (Pusapukdepob, 2007), (Schwartz, 2005), (Bleecker, 2007) **As;** (Rosado, 2007), **Hg** (Carta, 2003)
- **Dermatologic toxicity**: Including occupational contact dermatitis
    - **Cr** (Athavale, 2007)
- **Genotoxicity** Damage to chromosomes and DNA
    - **As, Pb:** (Yanez, 2003), **As** (Jasso-Pineda, 2007), (Paiva, 2006), (Palus 2005), **Cr** (Kuo, 2003)
- **Hematology:** Including humeral and cell mediated immunity, altered levels of immunoglobulins and neutrophilic inflammation.
    - **Pb;** (Di Lorenzo 2007), (Heo, 2004), (Mishra, 2003), **Se** (Huang, 2003)
- **Metabolism:** Including reduced antioxidant capacity, increased oxidative stress, altered bone resorption, pancreatic dysfunction and bone fracture
    - **Pb,As**; (Chlebda 2004), **Pb** (Kasperczyk (2004), (Li 2004), (Li, 2006), (Potula, 2005), **Cd** (Lei, 2007), (Satarug, 2003), ↓Zn (Li, 2004)
- **Neurotoxicity:** Including altered heart rate variability, nerodegenerative disorders (multiple, sclerosis, transmissible spongiform encephalopathies and amyotrophic lateral sclerosis), neuromotor impairment, ototoxicity and visual impairment.
    - **Pb** (Gajek, 2004), (Blond, 2007), (Chuang, 2007), (Schwartz, 2005) **Ba** (Purdey, 2004), **Hg** (Despres, 2005), (Rodrigues, 2007), (Saint-Amour, 2006)
- **Renal dysfunction:**
    - **As, Pb** (Weaver, 2003), **Cd** (Lei, 2007), (Nogue, 2004), (Satarug, 2007), **Cr** (Saraswathy, 2007), **Hg** (Hodgson, 2007)
- **Reproduction, fetal health and development:** Including, growth stunting, reproductive impairment, stillbirth, low birth-weight, childhood under-weight and abnormal sperm morphology.
    - **Pb** (Ignasiak 2007), (Naha, 2006), (Shiau, 2004), (Tang, 2003), **Cd;** (Wang, 2004) **As** (Kwok, 2006), (Kumar, 2005)
- **Respiratory disease:** Including mucosal irritation, interstitial pneumonia, asthma.
    - **Pb, Cd** (Coelho 2007), **Cr** (Hisatomi, 2006), (Onizuka, 2006)

Conclusions

1. We identified no published studies in the past five years that directly examined the health impact of exposure to toxic metals in the population living and working in the vicinity of oil and gas exploration activities. This is a major gap and calls for additional research.
2. The absence of studies directly examining oil and gas exploration related exposure to metals in exposed does not mean an absence of risk. The peer reviewed body of scientific literature related to exposure to specific metals and metals in groups in this review indicates strong associations between metals exposure and specific human diseases.

3. There is disagreement in the literature as to specific human outcomes due to specific exposures though much of that disagreement is likely related to difficulties in measuring individual exposure over long time periods. The preponderance of evidence gleaned from well-controlled studies using clear end-points and measuring exposure precisely indicates an increased risk for individuals exposed. This risk is hard to detect on a population basis for the above mentioned reasons.
4. Based on the available evidence, it is likely that continued exposure to bioavailable metals will increase risk of associated adverse outcomes. Whether through inhaled or water based exposure, each of these metals can cause increased risk of many human diseases.
5. Specific populations are at increased risk for specific toxicities. These populations include children, the elderly and anyone already at increased risk due to other health problems.

Hydrogen Sulfide

Hydrogen sulfide (H2S) gas release to the air occurs in oil and gas drilling and extraction and flaring as well as in many other settings such as industrial, sewage and water maintenance, and agriculture. H2S also enters the air as off-gas naturally in geothermal areas and when organic matter decays such as in swamps. The health effects of hydrogen sulfide gas exposure in relation to oil and gas drilling has been studied infrequently, despite the fact oil and gas drilling near inhabited areas is common through out the world and hydrogen sulfide gas is frequently produced and released in exploration activities.

Terms utilized in the search are summarized above. A total of 85 studies were recovered. Sixty-five studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.). A total of 20 studies were selected for review of hydrogen sulfide exposure, acute and chronic. These citations are collected in Appendix 6.

High Level Exposure

Hydrogen sulfide is known to be fatal at high exposure levels and can cause long term sequelae in those that survive acute high level exposure. Most fatal exposures to H2S are occupational and occur in a confined space area or when the worker is near the opening of a confined space. There are several case reports describing fatal accidents for workers exposed to H2S. Furthermore, fatalities in persons attempting to rescue downed workers have also been reported. Persons exposed to high levels of H2S that did lose consciousness and persons exposed that did not lose consciousness both demonstrated neurobehavioral impairments when compared to controls. (Kilburn 2003; Hendrickson, Chang et al. 2004; Kage, Ikeda et al. 2004; Nam, Kim et al. 2004; Nikkanen and Burns 2004; Smith and Cummins 2004; Couch, Martin et al. 2005; Knight and Presnell 2005; Christia-Lotter, Bartoli et al. 2007; Gangopadhyay and Das 2007; Gerasimon, Bennett et al. 2007; Policastro and Otten 2007; Fiedler, Kipen et al. 2008; Yalamanchili and Smith 2008)

Low Level Exposure

There are very few current studies exploring chronic, low level H2S exposure in individuals, although there are a few studies from earlier literature not addressed in this review. Current and earlier literature suggests neuropsychological effects in individuals with chronic low level H2S exposure.

- Depression and hematological changes were reported in people living close to areas polluted by oil and gas drilling in Khozestan province,Iran. (Saadat and Bahaoddini 2004; Saadat, Zendeh-Boodi et al. 2006)
- Oil and gas extraction workers in Canada demonstrated a higher risk of transportation accidents if exposed to H2S gas. (Lewis, Schnatter et al. 2003)
- Persons in Dakota City, Nebraska were exposed to chronic, low levels of H2S from waste water lagoons, a beef slaughter/leather tanning factory and other point sources. Individuals reported a variety of symptoms, including loss of memory and loss of grip strength. (Inserra, Phifer et al. 2004)

Communities exposed to chronic low levels of H2S may experience high hospital admittance for pulmonary disorders in both adults and children.

- Hospitals in Northeast Nebraska reported higher levels of admissions for pulmonary disease, COPD, asthma, pneumonia in both adults and children in days following high levels of Total Reduced Sulfur (TRS) and H2S air pollution. (Campagna, Kathman et al. 2004)
- The city of Rotorua, New Zealand, lies over a geothermal area. Parts of the city lie directly over vents that off gas H2S and parts of the City are downwind. Citizens living in these areas have a higher risk of being admitted to the hospital for pulmonary illness than those citizens not living in the high exposure areas of Rotorua. (Durand and Wilson 2006)

Summary

Studies of exposure to H2S in relation to oil and gas drilling have not been done. The dangers of acute, high level H2S exposure are well documented., Although there is a small body of literature suggesting adverse health effects due to chronic, low level exposure, significant gaps in this literature remain. Given the potential for increased exposure to H2S from oil and gas drilling in proximity to human populations across the world, studies examining the health effects of H2S due to drilling and extraction activities should be planned in the future.

Fossil Fuels

Oil and gas extraction is known to produce multiple toxic contaminants, which may be released to the air, soil or water. Workers involved in oil and gas drilling, extraction, as well as those involved in transportation and refining may be exposed to these chemicals at high levels. Persons living in close proximity to oil and gas extraction sites may also be exposed to toxic levels of chemicals and experience adverse health effects. Available literature regarding the health effects to persons living and working in close proximity to oil and gas extraction sites demonstrates exposure to the oil and gas extraction process is detrimental to people's health.

Terms utilized in the search are summarized above. A total of 305 studies were recovered. Two-hundred and seventy-nine studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.) A total of 26 studies were selected for review, including 3 studies prior to 2003. These citations are collected in Appendix 7.

Oil and Gas Extraction Exposures

- Residence near oil and gas extraction fields is associated with an increased risk of adult myeloid leukemia and all leukemias when compared to residence in a nearby county in Croatia. (Gazdek, Strnad et al. 2007)
- Residence near the Masjid-i-Sulaiman oilfields in southwest of Iran, where subsurface natural gas and hydrogen sulfide emissions are high is associated with abnormal blood cell indices, including increased red blood sells, and decreased white blood cells. (Saadat and Bahaoddini 2004)
- Residence near a Canadian oil sands community was associated with higher autoantibody titers when compared to residents in a distant community. (Schoenroth and Fritzler 2004)

Studies Prior to 2003

While our search was limited to publications of the last 5 years, some important studies done prior to this time and some studies not revealed by our search criteria deserve mention as they directly address the potential health effects of oil and gas extraction on local populations.

A series of studies reveal multiple elevated heath risks associated with residence proximity to oil and gas extraction in the Amazon rainforest of Ecuador. Children living at close proximity to oilfields are at higher risk of childhood leukemia. Adults are at an increased risk of many types of cancers including stomach, rectum skin, soft tissue, kidney, cervix and lymph nodes. Residence at close proximity to these oil fields is associated with pregnancy ending in spontaneous abortion.

(San Sebastian, Armstrong et al. 2001; Hurtig and San Sebastian 2002; San Sebastian, Armstrong et al. 2002; Hurtig and San Sebastian 2004; San Sebastian and Hurtig 2004)

Other Fossil Fuel Exposures

Literature regarding the health effects of exposures associated with oil and gas extraction is limited. Petro-chemical complexes and refineries, work at coke ovens, and exposure to coal burning can share many of the same toxic exposures with oil and gas extraction sites. These exposures may include, but may not be limited to, benzene and other solvents, polyaromatic hydrocarbons (PAH), particulate matter, noise, air born sulfur oxides, arsenic, and hydrogen sulfide.

Community Exposures

- Pregnant women in the Labin district, Croatia residing near a power plant burning high sulfur coal are at increased risk of poor birth outcomes. High sulfur dioxide emissions during the first two months of pregnancy are associated with preterm delivery and birth of babies with low birth weight. (Mohorovic 2004)
- Prenatal exposure to toxic chemicals is associated with increased risk of fatal childhood cancers and leukemia. Children born to mothers living within 1 km of areas with high levels of carbon monoxide, PM10 particles, VOCs, nitrogen oxides, benzene, dioxins, 1,3-butadiene, and benz(a)pyrene. (Knox 2005)
- Residence in areas with high levels of outdoor air pollution from coal burning sources is associated wit decreased height in children. This study controlled for socioeconomic factors, birth weight and respiratory illness. (Bobak, Richards et al. 2004)
- Incidence rates of wheezing in children living within 3 km of an iron, steel and coke factory in Calarasi, Romania, significantly decreased after the factory closed, from 41% to 24%. The list of known pollutants from the factory is long but contained several pollutants that are known to cause respiratory illness including SOX, NO2, ozone, and particulates. (Cara, Buntinx et al. 2007)
- Residence in areas near a coke oven factory in Cornigliano district, Italy was associated with lung cancer in females and in both males and females in a part of the district where a foundry was operational. (Parodi, Stagnaro et al. 2005)

Occupational Exposures

- Workers at an oil refining plant in Australia have an increased risk of developing nonlymphocytic leukemia and chronic lymphocytic leukemia, due to benzene exposures. These increased risks are in association with their exposure to benzene at levels lower than previously identified as being hazardous. (Glass, Gray et al. 2003; Glass, Gray et al. 2005)
- Workers at petrochemical complexes have been shown to have high exposure to solvents and excess noise. There is an increased prevalence of hearing loss and standard threshold shift in these settings. (De Barba, Jurkiewicz et al. 2005)
- Acute hydrogen sulfide poisoning has been reported in a field operator at a petroleum refinery. (Nam, Kim et al. 2004)
- Workers at a petro-chemical complex have significant risk of respiratory symptoms (cough, phlegm, wheezing and shortness of breath) when exposed to dusts, vapors, metals and organic solvents. (Park, Lee et al. 2006)

Our literature search revealed some studies that do not find association of oil and gas extraction exposures and health effects. (Lewis, Schnatter et al. 2003; Neuberger, Ward-Smith et al. 2003; Buffler, Kelsh et al. 2004; Neuberger, Lynch et al. 2004; Dubnov, Barchana et al. 2007; Sorahan 2007) These negative studies suggest that potentially hazardous exposures related to oil and gas extraction have no health consequence. On the other hand, these negative results may be due to problematic issues such as lack of statistical power, misclassification of exposure, or other study design issues such as limited disease endpoints. Negative studies should not be taken independently as proof of no ill effects to exposed populations but rather should be placed into context with all available literature regarding the particular chemical, exposure or the process and the health effects. Chemicals known to be toxic in other scenarios are likely to be toxic at similar exposure levels in different scenarios. When discrepancies exist in the literature, further study is warranted. Furthermore, the most conservative course of action with regard to pollution control measures should be undertaken to protect people's health.

Summary

Oil and gas extraction is increasing world wide. Oil and gas extraction is known to produce toxic contaminants. Oil and gas extraction sites are often near peoples' homes and children's schools, putting individuals and communities at risk of adverse health effects due to exposure to toxic contaminants. Studies documenting health effects of oil and gas extraction on individuals and communities are few and more studies should be done in the future.

Fracking Fluids

"Fracturing" "fracking" or frac'ing is a process used by the oil and gas industry to improve well production. Fracking involves the use of high-pressure injection of liquids and/ or solids into the ground, when a well is drilled and often again one or more times after a well is in production. Fracking fluids may be water or may be any combination of hazardous chemicals such as acids, diesel fuel, biocides, metals ethylene glycol, or other chemicals, but oil and gas companies are not required to reveal the chemical composition of fracking fluids. Fracturing of the subterranean land formations can introduce these unknown but possibly hazardous chemicals into underground drinking water sources, potentially exposing people to toxics and causing adverse health effects. Fracking fluids may also be left at the surface with drilling mud and toxics may dry out and be dispersed in the air or enter surface water via run off. Little is known about the potential and actual exposures local populations may have.

Since fracking chemicals are unknown, review of specific chemical literature could not be conducted. Terms utilized in the search are summarized above. A total of 243 studies were recovered. All studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.)

Our literature search (expanded to include all literature regardless of publication date) did not find any studies addressing the health effects of fracturing or fracturing fluids on people, revealing a substantial gap in the medical and public health literature. This gap is especially troubling given the amount of oil and gas extraction occurring world wide in close proximity to human populations. This gap should be addressed. Studies examining the effect of fracturing subterranean land formations on nearby human populations should be conducted. Public disclosure of fracking fluid chemicals would permit studies examining human health effects of these chemicals to be undertaken.

Noise Pollution

We have examined the medical literature to identify published research on the human health impact of noise pollution on the communities surrounding oil and gas development. Specifically in relation to oil and gas exploration activities: drilling, well pumps, compressors, and vehicle traffic.

Terms utilized in the search are summarized above in the methods section of this document. A total of 881 studies were recovered. Eight-hundred and fifty-seven studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.). A total of 24 studies were selected for review of noise pollution. These citations are collected in Appendix 8.

Our literature search, expanded to include all literature regardless of publication date, did not find any studies addressing the health effects of noise on communities surrounding oil and gas operations.

Low Frequency Noise

Low frequency noise, produced from oil and gas compressors, may be of concern in the surrounding communities. A small number of studies reported the following symptoms related to low frequency noise: annoyance, stress, irritation, unease, fatigue, headache, adverse visual functions and disturbed sleep. (Berglund, 1999, Pawlaczy-Luszcyniska, 2005)

Traffic related noise

Noise produced from oil and gas activity, also of concern to surrounding communities, has not been studied. Although many papers have been published in the last 5 years suggesting an association of cardiac health effects and noise related to traffic, these studies are restricted to urban settings. The majority of these studies reported annoyance and disturbance due to road traffic noise and associations with a higher incidence of myocardial infarctions, hypertension, ischemic heart disease, and sleep problems. (Babisch, 2003, 2005, Bluhm, 2004, 2007)

Occupational Related Health Effects

Research available on noise and health effects on oil and gas workers is limited. In the last 5 years, only one study has been published in the medical literature describing the health effects of noise among oil and gas workers. The study suggested an increased hearing threshold shift for high frequencies in workers who had chronic noise exposure from more than 15 years. (Chen, 2003) A small number of studies reported findings for workers exposed to noise and chemicals, such as toluene and other solvents (these studies were not specific to the oil and gas industry). Hearing loss was reported in 45.3% of workers from a petrochemical company, where workers had low exposure to solvents, and moderate exposure to noise. (De Barba, 2005) Another study found increased low frequency hearing loss in workers exposed to both noise and the chemical toluene. (Chang, 2006)

Summary

We identified no published studies in the past five years that directly examined the health impact of noise in the population living and working in the vicinity of oil and gas exploration activities. Noise produced from oil and gas operations and the health effects on the surrounding community as well as for workers calls for additional research.

Light Pollution

Light pollution is excess exposure to artificial light and occurs in occupational as well as community settings. Recent studies in the medical literature suggest that light pollution is an emerging public health issue indirectly linked to cancer incidence.

Terms utilized in the search are summarized above. A total of 297 studies were recovered. Two hundred and ninety-one studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.). A total of 6 studies were selected for review of light pollution. These citations are collected in appendix 9.

In the last 5 years, no studies have been published in the medial literature describing the health effects of light pollution or light exposure at night among oil and gas workers or the communities surrounding oil and gas extraction activities. However, several studies suggest an increased risk of cancer among shift workers and exposure to light at night:

- The disruption of circadian rhythms caused by exposure to light at night is associated with an increased risk of breast and colon cancer in shift workers
- Light pollution interferes with the pineal gland and production of melatonin as well as hormone production
- Reduced levels of melatonin caused by light pollution are linked to tumor growth
- Exposure to magnetic fields while sleeping leads to decreased levels of melatonin and increased levels of reproductive hormones in women

(Anisimov, 2006, Davis, 2006, Pauley, 2004, Schernhammer, 2004, Schernhammer, 2004, Schernhammer, 2004)

Summary

Further investigation is needed to determine the health impacts of light pollution generated by oil and gas activities in workers and the surrounding communities.

Worker Health

Terms utilized in the search are summarized above. A total of 40 studies were recovered. Thirty-one studies were eliminated from further review following our criteria for inclusion in this literature review (i.e. published within the past 5 years, English language, human; excluding basic mechanistic studies and excluding review articles unless they are meta-analyses.) A total of 9 studies were selected for review of occupational injuries. It is important to note that this final group of studies includes two articles published prior to 2003. These citations are collected in Appendix 10.

Occupational Fatalities

There are multiple safety and health risks associated with oil and gas extraction activities. In the U.S., fatal and nonfatal occupational injuries and illnesses among oil and gas workers are well documented through the Bureau of Labor Statistics (BLS) Census for Fatal Occupational Injuries (CFOI) and the BLS Survey of Occupational Injuries and Illnesses (SOII). However, only one study in the last 5 years has been published in the medical literature describing occupational fatalities among oil and gas workers in the U.S.: (CDC 2008)

- Oil and gas workers in the U.S. experience a disproportional rate of occupational fatalities compared to other high-risk industries and occupations.
- In the U.S., an increase in oil and gas extraction activities is significantly correlated with an increase in the rate of fatal occupational injuries among oil and gas extraction workers.
- The annual rate of fatal occupational injuries in the U.S. in the oil and gas industry from 2003 to 2006 was 30.5 per 100,000 workers.
- Fatal occupational injuries were attributable to transportation incidents and being stuck by equipment and heavy tools.

International Studies

Studies of international oil and gas workers in the last 5 years describe fatal and nonfatal injuries:

- In the Niger Delta, occupational fatalities in the oil and gas industry were attributable to falls, explosions and fires, transportation incidents, and falling objects. (Seleve-Fubara 2006)
- Venezuelan oil and gas workers were found to have chromosomal alterations due to continuous exposure to low levels of ionizing radiation. (Diaz-Valecillos 2004)

Studies Prior to 2003

We expanded our literature review to include studies conducted prior to 2003 providing evidence of fatal and nonfatal occupational injuries in oil and gas workers:

- About a third of minor injuries among oil and gas extraction workers in Venezuela were attributable to ‘not paying attention when walking on or around labor areas’. Common injuries included being struck by equipment and tools, and contusions and crushing of upper and lower arms and legs. (Fernandez 2001)
- In Canada, workers involved in oil and gas drilling and extraction activities are at high risk for occupational injuries. (Guidotti 1995)

- Work-related injuries among international oil workers were higher and more severe than all industries in the US. The most common non-fatal injuries were getting arms ‘caught in’, ‘back strained’, ‘legs struck’, and ‘legs injured while slipping’ (McNabb 1994)
- Types of work-related injuries among international workers in the oil industry include burns, sprains, and hand injuries. (Sarma 2001)
- Workers in the oil and gas industry in the U.S. experienced a high rate of death related to asphyxiation and poisoning. (Suruda 1989)

Conclusion

Further research is needed to determine the health effects of oil and gas operations on workers.

Social and Psychological Health Effects

While some research has explored the physical health effects related to oil and gas exploration activities, less research has focused on the social and psychological impact of oil and gas development on individuals working or living in industrial communities. As such, we have examined the available literature to identify published research about a) the social and psychological impact of oil and gas development in neighboring communities. b) the socal and psychological impact of industrial development in neighboring communities.

Terms utilized in the search are summarized above. An initial literature search recovered a total of 1,114 studies that were published within the last 5 years (between 2003 and 2008). Based on our established list of inclusion criteria, 1,093 studies were eliminated from further evaluation. Thus, only 21 studies were retained for this literature review. It is important to note that this final group of studies includes two articles published prior to 2003 and two relevant review articles. The full list of these references can be found in Appendix 11.

The body of literature reviewed provides some evidence that exposure to oil and gas activities can have serious negative social and psychological health implications. Conversely, there is some evidence that such industrial activities may be associated with positive social and psychological health outcomes.

Violence and Crime Rates

Communities near industrial development, including oil and gas development, often undergo swift changes in the existing social and cultural norms. These changes may be, at times, associated with high occurrences of violence and crime while at other times, industrial development has been credited with a perceived decrease in local crime. Additionally, when a new industry is brought into a community, there may be a high demand for new laborers. Often times, these workers are blamed for a rise in criminal deviance,. In response to oil development in Louisiana, some local individuals blamed the increase in ‘unskilled laborers’ for the increase in criminal activities. One local individual claimed that, “during the 70s/80s [oil] boom we had lots of low life…police characters…criminals coming in as labor…they had little work history…when the [oil] bust hit they hung around and caused trouble…”. (Forsyth et al., 2007, p.292) On the other hand, some individuals in these areas believe that oil and gas drilling has helped build and bring their communities closer together, which in turn, has led to a decline in criminal activity. This idea is supported by a resident in Louisiana who stated that "this [community] was all poor white trash until oil came…oil decreased crime…oil and the oil business have caused the cycle of crime to go down". Rapid sociocultural change in Alaska has been associated with increasing rates of social pathology in native populations. Some of these populations have arrest rates for violent crimes 8 to 15 times higher than the overall national rate. (Wernham, 2007)

Sexual Promiscuity and Associated Diseases

Communities involved in oil and as extraction activities have experienced high rates of sexually transmitted diseases. For example, oil and gas communities in British Columbia have witnessed a rise in the occurrence of Chlamydia, and several regions in Africa have had increasing rates of HIV/AIDS since the introduction of oil and gas drilling to their communities. (Frynas, 2004; Goldenberg et al., 2007; Jobin, 2003; Udoh et al., 2007) These effects can be mitigated to some degree through intensive environmental and health management planning on the part of the oil companies. In Chad and Cameroon, companies were able to achieve a reduction in the occurrence of some sexually transmitted diseases in their labor forces by requiring contractors to provide health care for workers.

Rates of Suicide

Communities involved in oil and gas exploration may also experience a rise in suicide rates. Whereas the U.S. general population has an average suicide rate of 11 out of every 100,000 individuals, communities on the northern slope in Alaska experience an average suicide rate of 45 out of every 100,000 individuals. This very high suicide rate is thought to be due to rapid sociocultural change in Inuit communities. High suicide rates are also found in communities associated with offshore oil drilling in Louisiana. (Kettl, 1998; Wernham, 2007; Seydlitz et al., 1993)

Mental Health Concerns

Individuals working or living in communities involved in oil and gas exploration often experience greater mental health concerns than individuals who live in areas not involved in these industrial activities. Some researchers report that individuals in these regions have a certain vulnerability to psychological or psychiatric problems. (Lester & Temple, 2006) For example, oil and gas development has been associated with high rates of mental and psychological stress. Furthermore, increasing mental health concerns such as anxiety and depression, have been linked to communities in Wales, India, and the Peruvian Amazon that are involved in oil and gas drilling activities. (Bhatia, 2007; Gallacher et al., 2007; Izquierdo, 2005; Lester & Temple, 2006; Murthy et al., 2005; Wernham, 2007)

Our literature search also revealed a few studies that did not find an association between oil and gas exploration and social and psychological health effects. In particular, two studies found no relationship between industrial activities and crime rates. (Luthra et al., 2007; Seydlitz et al., 1993) Some researchers believe that much of the research depicting a negative or positive relationship between oil and gas exploration and crime is speculative in nature. Because of methodological weaknesses in many studies in this research area, it seems necessary to conduct controlled, empirical research to verify whether a relationship between oil and gas exploration and social and psychological health does truly exist. Consequently, findings from existing research need to be interpreted with caution.

Summary

Overall, there is an apparent lack of research in this area. As findings from this literature review demonstrate, the research in the past five years has been inconsistent, making it difficult to draw definitive conclusions about the psychological and social implications of oil and gas exploration. However, based on the evidence provided, it is probable that oil and gas exploration activities can have serious effects on people’s social and psychological health. Despite this possibility, the oil and gas industries have failed to take reasonable steps to protect these families and communities.

Findings from this literature review make it clear that future research is necessary to clarify our understanding of the social and psychological impact of oil and gas drilling on individuals living in and near industrial communities. By better understanding this relationship, we will be able to more effectively intervene and mitigate these potentially severe social and mental health problems.

Conclusions

As discussed in the medical and public health literature review (attached), few studies have been published on the health effects of oil and gas exploration and extraction on communities living and working in the vicinity of these activities. A lack of specific evidence, however, does not negate the fact that oil and gas operations use and produce toxic contaminants that adversely affect human health. Available studies show that exposure to air pollutants, toxic chemicals, metals, radiation, noise and light pollution cause a range of diseases, illnesses, and health problems, including psychological and social disruption. Neighborhoods, schools, and workers in close proximity to oil and gas activities may be at increased risk for cancer, cardiovascular disease, asthma, and other disorders due to uncontrolled or high exposures. Further research is needed to assess the health impact of oil and gas operations on surrounding communities.

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Potential Exposure-Related Human Health Effects of Oil and Gas Development:

Literature Review Appendices

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Potential Exposure-Related Human Health Effects of Oil and Gas Development: Literature Review Appendices

Appendix 1

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Potential Exposure-Related Human Health Effects of Oil and Gas Development:

A White Paper

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Executive Summary

Based on the body of scientific evidence, human health risks and social impacts are associated with oil and gas development. This white paper supports the need for an Health Impact Assessment to be included as part of any Environmental Impact Statement or other planning and assessment process when considering oil and gas development, especially in populated areas.

As an illustration of the health issues that should be considered, this white paper focuses on Garfield County, Colorado which has experienced a 39% increase in oil and gas drilling between 2000-2007. A detailed review of the human health literature plus preliminary studies of health status and air and water quality in Garfield County indicate that local residents maybe at risk for adverse health effects and psychological and social impacts.

Data necessary to completely assess the health and social impacts of the oil and gas industry are missing in all areas, including: population demographics, health status, psychological status, social measures, worker health, and environmental exposure. Further monitoring of both the community and the environment of Garfield County is essential. Action to decrease current chemical exposures of concern and improve monitoring should not be delayed. A Health Impact Assessment is an appropriate framework for relating exposure assessment to community health data and for making recommendations to mitigate adverse human health effects.

While this white paper focuses on Garfield County, Colorado as an illustration of the potential exposure-related health impact of oil and gas development, the principles of exposure and the related health issues should be considered generally applicable wherever oil and gas development is occurring.

Introduction

The purpose of the white paper is to:

1. Describe the population of the Western Slope of Colorado potentially exposed to hazards that have been associated with oil and gas exploration and extraction.
2. Describe the baseline health and social parameters of the population that may be at risk.
3. Discuss the possible health, medical, and social issues that face this population in light of the increasing oil and gas drilling and production in close proximity to where they live, work and go to school, using Garfield County, Colorado as an illustration.
4. Provide guidance for future environmental and medical monitoring of the Western Slope population and other similarly affected communities.
5. Weigh the need for conducting a Health Impact Assessment as part of the Environmental Impact Statement (EIS) process and other planning processes for oil and gas development.

Background

United States and global energy needs have driven up prices for fossil fuels. In addition, political instability in major energy producing countries around the world has driven a US energy policy to increase domestic production of all types of energy, in particular fossil fuels. The combination of increasing demand, interest in domestic supplies and new technology has made fuels previously unattainable or too costly now worthy of recovery.

As pressures for increased fossil fuel production increase, areas that had previously been considered too sensitive for drilling are now being drilled. These sites have included an increasing number of oil and gas exploration and extraction facilities, some of which are in close proximity to native and local populations. Human proximity to oil and gas production sites may increase the likelihood that people will be exposed to the hazardous chemicals, emissions and pollutants associated with this activity. (Saadat and Bahaoddini 2004; San Sebastian and Hurtig 2004)

Garfield, Mesa, Rio Blanco and Moffat counties, all on the Western Slope of Colorado, have seen and likely will continue to see dramatic increases in oil and gas drilling. As such, this white paper will focus on Garfield County as a ‘case study’ for considering the potential health consequences of exposure. Others have reported on the assessment of exposure. (Teresa Coons and Walker 2008) The emphasis of this white paper will be on exposure-related health risks.

Oil and gas development starts with obtaining permits to begin exploration. Development next involves drilling into the land in search for fossil fuels. The drilling process very often involves fracturing subsurface land formations in order to release the fuels in question. If the desired product is found, then extraction processes remove the fuels. The extraction of the fuels in these active wells may take several decades. Occasionally, in an effort to increase production, wells are fractured again. Once the well has ceased production, the wells are capped

As described below, drilling and fracturing activities may use and produce hazardous materials which could threaten human health. In addition, active wells can continue to pose health hazards due to fugitive air emissions from the wells and from emissions from stationary and vehicular traffic. (Oil and Gas Accountability Project) Abandoned wells may continue to be a source of toxic contaminants if proper capping and maintenance procedures are not used. (URS Corporation 2006)

Hazardous chemicals are used and produced by oil and gas extraction processes. Subsurface land formations are "fractured" (known as "fracking or frac'ing) by injection of fluids and/or solids into the ground under high pressure. Some of the chemicals used in this process are brought to the surface, potentially contaminating soil, air and water, while some of the chemicals are left underground, potentially contaminating subsurface aquifers. Other chemicals may also be used in drilling fluids and other products used by industry. Drilling fluids may be fresh or salt water-based muds, oil-based muds, or synthetic materials that contain esters, olefins, paraffins, ethers and alkulbenzenes, among others. Drilling fluids may also contain additives such as metals, acrylic polymers, organic polymers, surfactants, and biocides. Chemicals used in drilling muds and fracking fluids are often considered proprietary and specific composition of these compounds are generally not available to the public. (Oil and Gas Accountability Project)

Drilling sludge brought to the surface can contain fracking fluid, drilling mud, radioactive material from the subsurface land formation, hydrocarbons, metals, and volatile organic compounds. Sludge is often left to dry on the surface in waste pits, potentially contaminating air, water and soil. Sludge may also be removed to waste disposal sites (but not always to hazardous waste sites) or sludge may be tilled into the soil in "land farms." These practices can potentially contaminate soil, air and surface water. So-called "produced water" is brought to the surface during the extraction process. This water may be contaminated with salts, hydrocarbons, radioactive material, metals, drilling fluids and muds. The produced water is often left on the surface to evaporate, or it may be reinjected into the ground or released into surface waters. All of these disposal methods may threaten air, water and soil quality. (Oil and Gas Accountability Project)

Spills of oil and gas wastes and/or chemicals used in production can pollute ground and surface water and soil. The Colorado Oil and Gas Conservation Commission (COGCC) maintains records of reported spills resulting from oil and gas activities. In the four year period January 2003 – March 2008 there were 1549 spills. These spills involved produced water (767), crude oil or gas condensate (449), other materials (134) and unclassified (201). Twenty percent of the spills involved water contamination. Furthermore, the number of spills has increased as the number of wells has increased. For example, in Garfield County, 5 spills were reported in the year 2003, compared to

55 spills reported in 2007. (Colorado Oil and Gas Conservation Commission, Oil and Gas Accountability Project)

Air surrounding oil and gas production areas is particularly susceptible to toxic emissions. Fugitive natural gas emissions may contain many contaminants, such as methane and other hydrocarbons (ethane, propane, butane), hydrogen sulfide (H2S), and water vapor. These emissions can come from production sites, disposal pits or pipelines. In Garfield County, for example, many of these sites tend to be near population centers and adjacent to streams and other bodies of water (see Garfield County map on page 12 below). Some natural gas wells produce a condensate that can contain complex hydrocarbons and aromatic hydrocarbons such as benzene, toluene, ethyl benzene and xylene (BTEX). Natural gas flaring can produce many hazardous chemicals including polycyclic aromatic hydrocarbons (PAHs, including naphthalene), benzene, toluene, xylenes, ethyl benzene, formaldehyde, acrolein, propylene, acetaldehyde and hexane. Glycol dehydrators, used to remove water from natural gas, can produce BTEX leaks into the air. (Oil and Gas Accountability Project)

Oil and gas exploration and production activities have been exempted from standards created to protect health under a number of Federal statutes, including provisions of the Clean Air Act (CAA), the Clean Water Act (CWA), the Safe Drinking Water Act (SDWA), the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or the Superfund Act), and the Emergency Planning and Community Right to Know Act (the Toxics Release Inventory or TRI). These laws are designed to protect the health of the American population by ensuring clean air and water. (Mall 2007)

Because the oil and gas drilling industry is not obliged to comply with certain federal health and environmental regulations (Mall, 2007), there has been virtually no publicly available monitoring of air or water contamination due to the activities of oil and gas drilling and extraction. As drilling for oil and gas moves closer to human populations, hazards associated with these industries are more likely to have a direct effect on the health of those living, working and going to school in proximity to the drilling and production sites. Anecdotal evidence of health effects due to increased drilling has begun to surface. (Oil and Gas Accountability Project) However, in the absence of environmental monitoring data regarding exposure levels and medical evaluation of complaints, it has been scientifically difficult to establish causal relationships between oil and gas activity and health effects. Gaps in the medical literature are profound, as reflected in the literature review that is attached to this white paper. There is a paucity of published literature that directly addresses the health effects of oil and gas exploration and production. However there is a sizeable scientific literature linking many of the exposures to adverse health outcomes in humans.

The National Environmental Policy Act (NEPA) established the Environmental Impact Statement (EIS) as a means for environmental analysis in the United States. When industrial development involving federal resources is proposed, the federal government is tasked to consider effects on the "human environment." In practice, EIS have traditionally focused on environmental effects, with little consideration of public health effects. When public health is considered, simple compliance with regulatory statutes such as the CAA and CWA are commonly used as a proxy for more substantive analysis. Since industrial projects often have impact on the environment in ways that directly or indirectly affect the health and psychosocial structure of local populations, there is a growing recognition that EIS should include a Health Impact Assessment (HIA) in many cases. (Wernham 2007) This white paper is intended to examine the rationale for an HIA as part of the permitting process for oil and gas drilling on the Western Slope of Colorado and other areas with intensive industrial development. As precedent, an integrated HIA/EIS published in 2007 described the impact of oil development on Alaska's North Slope on the local Inupiat populations. (Wernham 2007) The HIA findings predicted impact on health and social structure. The report provided recommendations for mitigation of these effects, thereby improving the probability that oil development could proceed with less adverse impact on the people who live in the region.

Western Slope of Colorado

The American West has seen a dramatic increase in drilling for oil, gas, and coal bed methane. In Garfield County, on the Western Slope of Colorado, there are presently approximately 4521 active wells. Oil and gas drilling increased by 39% between 2000 and 2007. (Colorado Oil and Gas Conservation Commission) While the total number of drilling permits for 2008 is not yet known, it is estimated that by the end of 2008, approximately 3200 permits are expected to be issued in the county. Looking toward the future, it is estimated that Garfield County will continue on a pace of approximately 1000 new wells per year. It is expected by 2023 there will be between 15,000 and 23,000 wells in Garfield County. (BBC Research & Consulting, 2008) As such, this white paper will focus on Garfield County as an illustrative example of the assessment of potential health hazards due to oil and gas drilling near human populations. It is beyond the scope of this white paper to conduct similar examinations of the other Colorado counties experiencing similar growth in oil and gas activity. Lessons learned in Garfield County are likely to be relevant elsewhere in the region.

As a result of the increased health concerns of residents in Garfield County, County commissioners have commissioned several studies attempting to characterize potential exposures in contaminated air and water. (URS Corporation 2006; Garfield County Public Health Department 2007) This white paper will summarize these and other exposure data available in Garfield County in order to help frame the discussion of potential health consequences. This white paper will include available data characterizing the general population of Garfield County, including those populations that may be more susceptible to the effects of toxic exposures. This white paper will also describe the publicly available health statistics for Garfield County. Such health data can provide public health professionals with an early indication of adverse health trends, some of which might be associated with oil and gas activity. In addition, the white paper examines the available baseline psychosocial characteristics of Garfield County residents. The paper concludes with a discussion of the gaps in knowledge and the potential role that a Health Impact Assessment (HIA) may have in filling these gaps and ensuring community health.

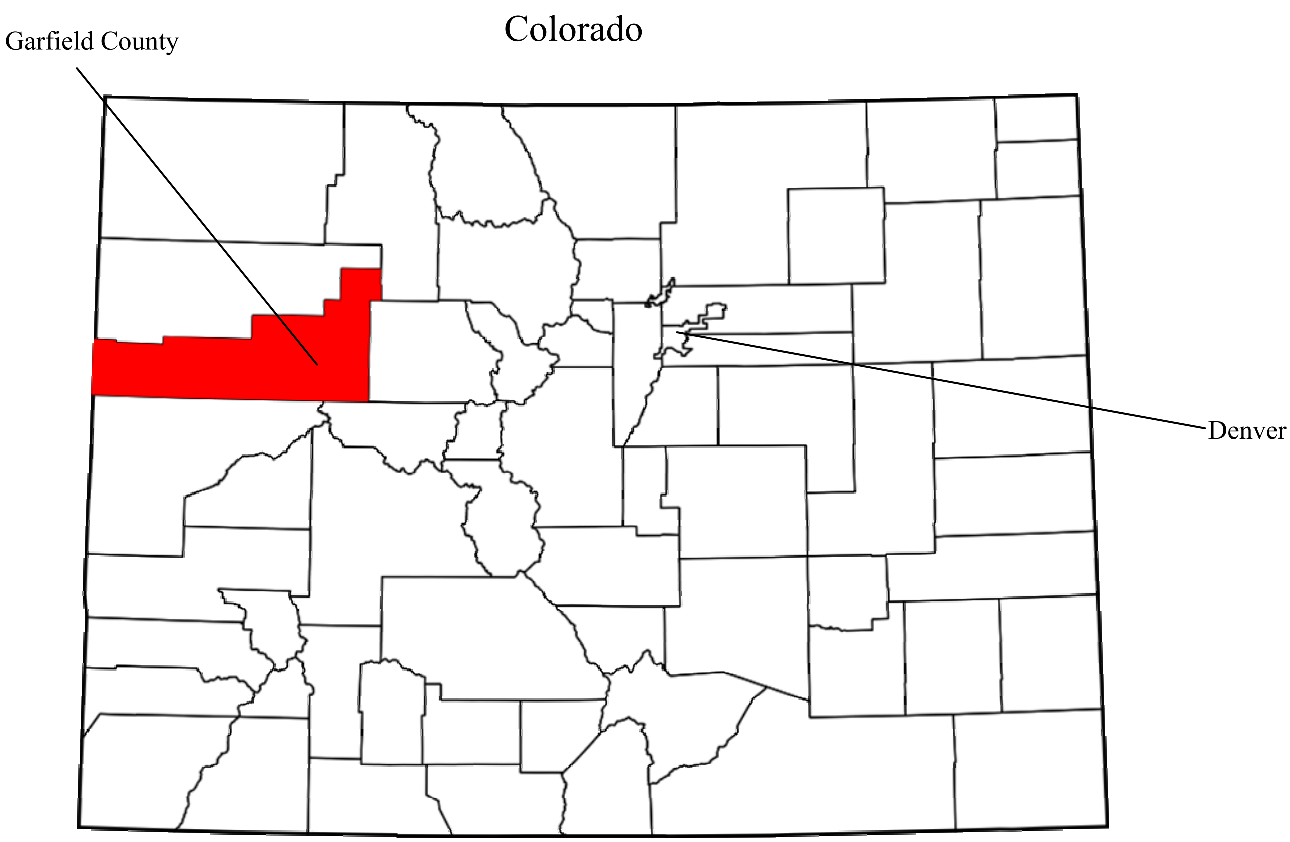
As discussed in the medical and public health literature review (attached), few studies have been published on the health effects of oil and gas exploration and extraction on communities living and working in the vicinity of these activities. A lack of specific evidence, however, does not negate the fact that oil and gas operations use and produce toxic contaminants that adversely affect human health; nor does it negate the potential health effects of the large-scale socio-demographic and economic changes often associated with such projects. Available studies show that exposure to air pollutants, toxic chemicals, metals, radiation, noise and light pollution cause a range of diseases, illnesses, and health problems, including psychological and social disruption. Neighborhoods, schools, and workers in close proximity to oil and gas activities may be at increased risk for cancer, cardiovascular disease, asthma, and other disorders due to uncontrolled or high exposures. Further research is needed to assess the health impact of oil and gas operations on surrounding communities.

Garfield County Community Profile

Understanding the community characteristics can help explain the prevalence of health risk behavior and outcomes. The following sections provide an introduction to Garfield County based on data obtained from a number of publicly available sources. For a complete list of references used for this profile, see Appendix 1. This summary highlights some of the important demographic, geographic, economic, environmental, and social factors that influence many aspects of health.

Geography and Well Locations

Garfield County (2,958 square miles) is located in the northwest region of Colorado, and is bordered to the north by Rio Blanco County, on the east by Eagle County, and on the south by Mesa and Pitkin Counties. Garfield County is made up of six municipalities (listed in decreasing population size): Glenwood Springs, Rifle, Carbondale, New Castle, Silt, and Parachute. Garfield County is primarily a rural county, with most residents (42%), living outside the six major townships. (Garfield County Quick Facts: http://www.garfield-county.com/Index.aspx?page=698)



The Colorado Oil and Gas Conservation Commission provides publicly available data on oil and gas wells in Colorado, such as number of active wells, drilling permits, and location. (Colorado Oil and Gas Conservation Commission: http://oil-gas.state.co.us/)

In 2002, Colorado had just over 22,500 active wells; as of April 7, 2008, the state had 34,734 active wells. Sixty percent of all active wells are located within seven counties throughout Colorado, three of which are located on the Western Slope of Colorado (Garfield, Rio Blanco, and Mesa). (Table 1)

Table 1. Total Active Wells by County (Top 7 drilling counties)

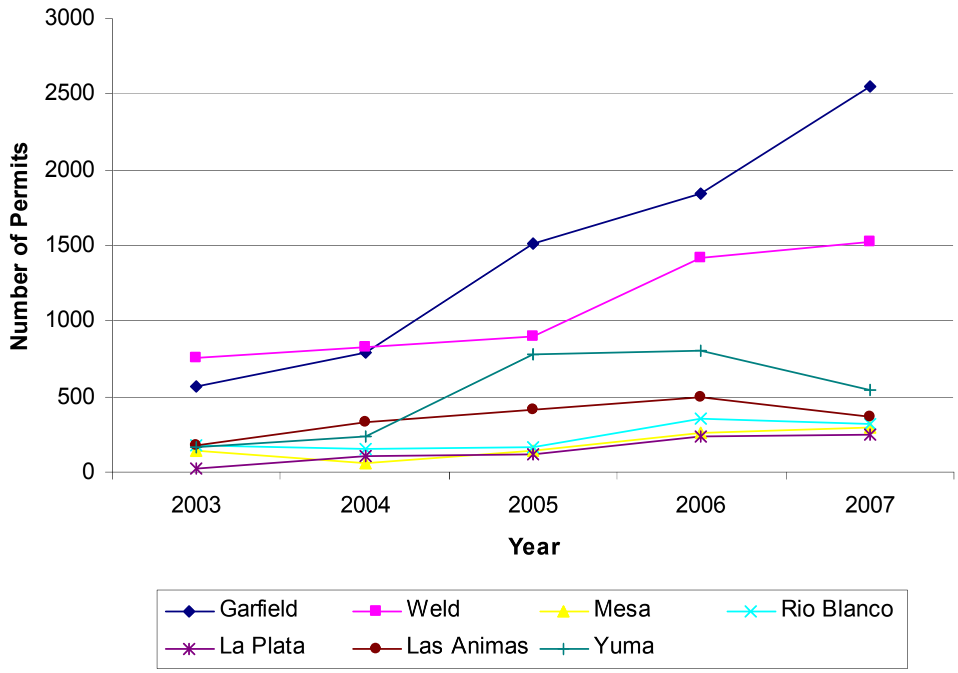
County	**Total Active Wells** (April 7, 2008)
Weld	12,858
Garfield	4,521
Yuma	3,125
Rio Blanco	2,636
La Plata	2,917
Las Animas	2,721
Mesa	660
State Total	34,366

Data Source: Colorado Oil and Gas Conservation Commission

Although close to forty percent of currently active wells are located within Weld County (which is not on the Western Slope), permits for drilling in Garfield County have exceeded permits for all counties since 2005. (Figure 1, Table 2) This dramatic increase in permits demonstrates that Garfield County is rapidly becoming the center of oil and gas extraction activity on Colorado's Western slope. Furthermore, as shown below, many existing wells and permits in Garfield County are located close to population centers, thereby increasing potential human exposure to hazardous chemicals. This white paper focuses on Garfield County as an illustration of the principles and issues that need to be considered when weighing the potential exposure-related health impact of oil and gas development. Similar analyses could be conducted in other counties.

Although we do not yet know the total number of drilling permits issued for the current year, as of May 1, 2008, 1,029 permits, or 35% of all permits issued in the state, have been issued in Garfield County. Currently, most permits issued within the county surround the communities of Rifle, Parachute, and Silt. (Figure 2) It is predicted that by the end of 2008 approximately 3,200 drilling permits will be issued in the county. Looking toward the future, it is estimated that Garfield County will continue at a pace of approximately 1,000 new wells per year. It is expected that by 2023 there will be approximately 15,000 to 23,000, or 3 to 5 times the amount of wells in Garfield County. (BBC Research & Consulting, 2008)

Figure 1. Drilling Permits by County 2003-2007



Data Source: Colorado Oil and Gas Conservation Commission

Consistent with the expansion of oil and gas wells in Garfield County, the number of drilling rigs running per week has also exceeded all counties within the state. On average, during 2007, 58 drilling rigs were running per week. In comparison, Weld County, on average, had 19 drilling rigs running per week during the 2007 year. In the early months of 2008 (January 3-March 25), on average 66 rigs were running in Garfield County per week, compared to Weld County, with an average of 18 drill rigs running per week.

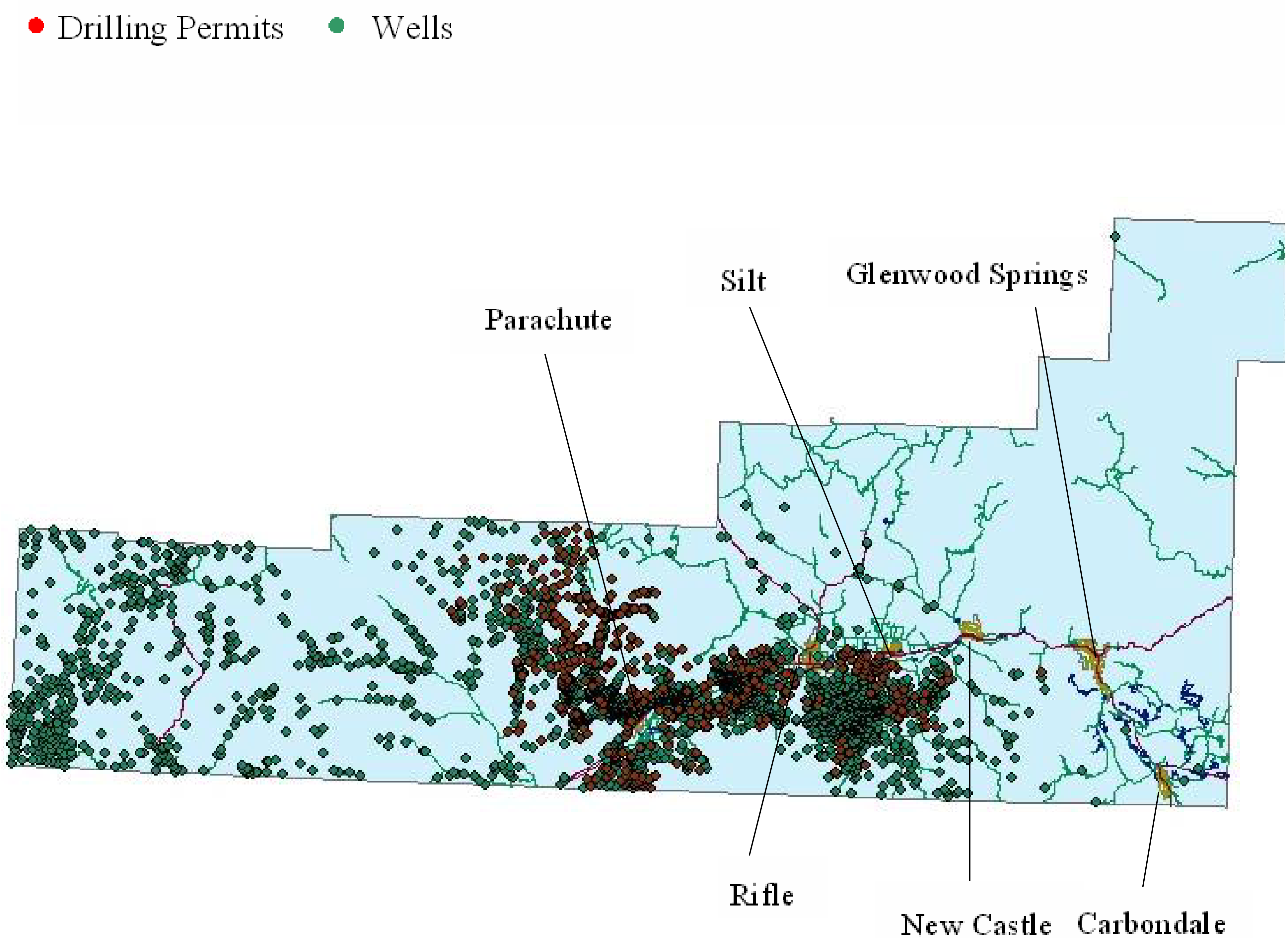
It is important to note that these statistics on drilling do not necessarily reflect the scope, intensity, and location of oil and gas production activity in the state. Some drilling sites can be expected to be active extraction sites, while others may not.

Table 2. Drilling Permit Totals for the Top Seven Counties by Year

County	**2003**	**2004**	**2005**	**2006**	**2007**	**2008** (June 2, 2008)
Garfield	566	796	1,508	1,844	2,550	1,029
Weld	757	832	901	1418	1,527	708
Mesa	138	54	136	265	293	225
Rio Blanco	180	154	161	360	321	200
La Plata	27	102	117	235	251	175
Las Animas	179	332	413	500	362	159
Yuma	162	237	782	798	541	148

Data Source: Colorado Oil and Gas Conservation Commission

Figure 2. Garfield County Wells and Drilling Permits as of April 2008



Demographics

Garfield County has experienced consistent growth since 1970, with the most rapid growth in recent years as local energy development draws in new workers and households to Garfield County. The 2006 population of Garfield County was estimated to be 53,020 people, an increase of 21 percent from the population reported in 2000. An annual growth rate of 3.2 percent (as compared to the state's 1.9%) made Garfield County the fastest-growing county on Colorado's Western Slope. Within Garfield County, the fastest growing community was the town of New Castle, which had an annual growth rate of 9.4 percent, during 2005 to 2006. (Table 3) As energy development increases in Garfield County, the population is projected to increase significantly. By 2035, Garfield County is projected to have a population of 136,697. (BBC Researching & Consulting, 2008)

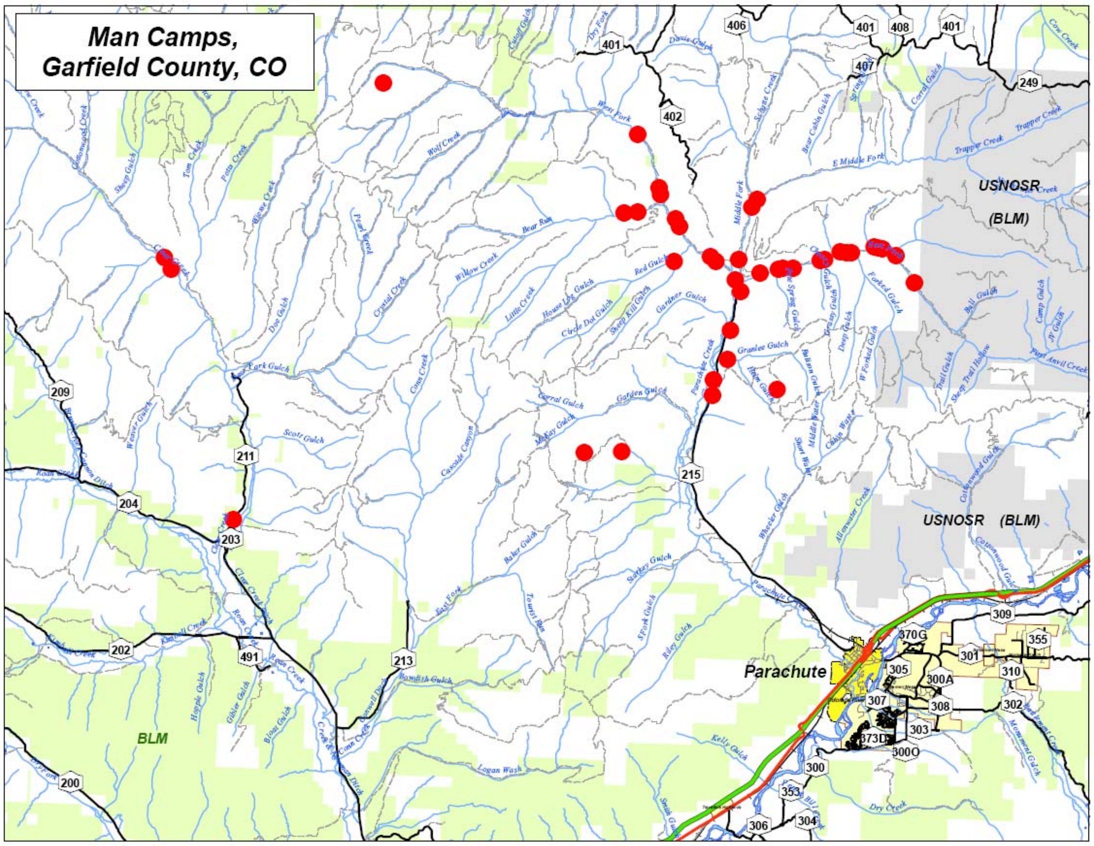
Table 3. Garfield County, Colorado Municipality Populations: 2000-2006

County	2000	2001	2002	2003	2004	2005	2006	Annual Growth Rate 2005-2006
Carbondale	5,196	5,509	5,565	5,689	5,767	5,881	6,088	3.5%
Glenwood Springs	7,736	8,135	8,301	8,406	8,517	8,603	8,743	1.6%
New Castle	1,984	2,268	2,604	2,825	2,949	3,148	3,443	9.4%
Parachute	1,006	1,269	1,297	1,320	1,338	1,360	1,486	9.3%
Rifle	6,784	7,079	7,349	7,541	7,760	8,118	8,706	7.2%
Silt	1,740	1,901	2,039	2,089	2,184	2,319	2,416	4.2%
Unincorporated area	19,345	20,012	20,286	29,526	20,810	21,244	22,138	4.2%
Total Population[1]	43,791	46,173	47,275	57,126	49,325	50,673	53,020	4.4%

Data Source: Colorado Department of Local Affairs. [1]Total population derived by adding each column

Oil and gas development has increased population densities, some of which is the result of an increase in the number of temporary and transient workers. The western slope has a large number of temporary workers living in motel rooms, RV campgrounds, and temporary camps, often called "man camps," in the region. (Figure 3) While there are no data on the exact number of temporary workers, it is estimated that 20 percent of the natural gas workforce is comprised of workers who do not have a permanent residence within the region or the surrounding counties. (BBC Research & Consulting, 2008) In 2006, approximately 6,300 jobs were oil and gas-related (not including supporting jobs) in a four county region (Garfield, Mesa, Moffat, and Rio Blanco). It has been predicted that by 2035 there will be almost 10,000 oil and gas workers in the four county region. (BBC Research & Consulting, 2008) The lack of precise information on this population affects the ability to accurately assess the current and future health of the community.

Figure.3 "Man Camps" Garfield County, Colorado



Source: Garfield County Website: Download Central

According to 2000 U.S. census estimates, 49 percent of the Garfield County population was female and 51 percent male. The median age was 34.2 years. Twenty-seven percent of the population were under 18 years of age, 8 percent under 5 years, and 9 percent were 65 years and older. Fifteen percent of the general population in Garfield County did not have health insurance in 2000. Twelve percent of children under the age of 18 in Garfield County did not have health insurance in 2000. For people reporting race in Garfield County, 92 percent identified as white alone; 0.5 percent identified as Black or African American; 0.7 percent identified as American Indian and Alaska Native; and 0.4 percent identified as Asian. Two percent identified as two or more races. Seventeen percent of the people reporting for Garfield County identified as Hispanic or Latino. Again, there are no demographic data on the temporary oil and gas workers, most of which moved into Garfield County since 2000. These data suggest that approximately one-third of the population, in the year 2000, may be considered to be more susceptible to certain exposures, based on age (27% children and 9% elderly).

Currently, 9533 students pre-kindergarten through 12th grade are enrolled in Garfield County schools across three school districts: Roaring Fork RE-1 (Glenwood Springs, Carbondale), Garfield 16 (Parachute), and Garfield RE-2 (Rifle, Silt, and New Castle). The Roaring Fork RE-1 district is the largest, housing 14 schools and a total of

4864 students. Garfield RE-2 has a total of 7 schools, and a total of 3695 students. The last district, Garfield 16, is made up of 4 schools and a total of 974 students. Colorado Department of Education trend data (2003-2007) show a 12 percent increase in enrollment for the county. Enrollment for the Roaring Fork RE-1 district serving the towns of Glenwood Springs and Carbondale has increased by approximately 6 percent. Enrollment in the RE-2 school district serving the towns of Rifle, Silt, and New Castle, has increased by approximately 15 percent. Enrollment in the Garfield 16 district, serving the town of Parachute, has increased by over 31 percent. These data suggest an increasing population of young people, who are potentially at increased risk for adverse health effects from certain exposures. (http://www.cde.state.co.us/index_stats.htm, http://www.cde.state.co.us/cdereval/rv2007pmlinks.htm)

The energy development boom has increased jobs in Garfield and surrounding Western Slope counties, which in turn has increased the demand for housing, driving home and land values up in the recent years. Housing costs in Garfield County were roughly 35 percent below comparable Denver metropolitan area costs just six years ago. Now the costs often match or exceed Denver area prices. (BBC Research & Consulting, 2008) Housing is also difficult to find in Garfield County. Vacancy rates are at 5%, compared to rates exceeding 25% in 1985. Since 2003, building permits have climbed each year in Garfield County. In particular, the town of Rifle had a 50 percent increase in building permits. This contributes to an understanding of the potential impact of oil and gas industry expansion on infrastructure and social systems.

Traffic congestion in Garfield County increased by 39 percent during the time period of 2000 to 2007, compared to an increase of 11 percent for the state (Northwest Colorado Socioeconomic Analysis and Forecasts, 2008). Surrounding Western Slope Counties experienced a similar increase in traffic congestion: Rio Blanco, 35%, Mesa, 25 %, and Moffat, 23%. Contributing to traffic congestion are a number of important factors, including the increase in vehicular traffic volume due to oil and gas industry activity as well as increased population. As discussed above, the lack of housing within the county for oil and gas employees contributes to commuter traffic and congestion in the county. As discussed in the literature review and elsewhere in this white paper, vehicular traffic contributes to injury rates as well as to air pollution associated health risks.

Conclusions and Recommendations

1. There is a lack of precise demographic data on the Garfield County population. This affects the ability to accurately assess the current and future health of the community.
2. There are no demographic data on the number of temporary oil and gas workers. Most moved into Garfield County since 2000.
3. The available data suggest that approximately one-third of the population may be more susceptible to certain oil and gas industry-related exposures, if exposed.

4. There is a rising population of children, who are potentially at increased risk for adverse health effects from these exposures, if exposed.

Exposure: Known Garfield and Four County contaminants

The purpose of this section is to summarize available exposure data. It is not intended to be a comprehensive analysis of exposure, but rather to provide sufficient information and background for the discussion of potential health effects of interest. In order to be able to determine the impact of oil and gas exploration and extraction activity on the health of a neighboring community, it is necessary to have sufficient exposure data. To be useful, these data must be collected in a systematic, accurate, and current manner. Such data must also be publicly available and provided in a form that can facilitate their use in assessing the relationship between exposure and human health outcomes.

The Western Slope of Colorado has seen a dramatic increase in oil and gas extraction activity. Despite this activity there are very few data regarding the air and water quality impact. Because of citizen concerns, a few, very limited studies have been undertaken. These studies are reviewed below. It should be noted that even with limited sampling and a very limited list of chemicals tested the results of the air sampling demonstrated potentially hazardous levels of benzene. Other volatile organic compounds have also been detected in Garfield County air, as discussed below. Methane has been detected in well water in areas near drilling sites. This study is also reviewed below. Water samples measured at sites removed from active drilling sites had no detectable contaminants. There has been no testing or monitoring of soil quality in Garfield County. These results demonstrate that more comprehensive and ongoing air, water and soil monitoring should be conducted.

<u>Please note</u>: there may be additional sources of exposure information that we were unaware of or were not able to obtain prior to preparing this white paper. If, for example, private corporations or public agencies have conducted sampling that is not in the public domain, we have not had the opportunity to review and include such data sets.

<u>AIR QUALITY</u>

ATSDR 2005-2007

The Colorado Department of Public Health and Environment (CDPHE), in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR), undertook an air sampling project from 2005-2007 to assess possible air quality impacts posed by increasing oil and gas activities in Garfield County, Colorado. Intermittent twenty-four hour sampling occurred at 14 fixed sites, coinciding with an EPA air sampling schedule, over a 24 month period. A total of 232 samples were taken (averaging 24 hours of sampling at each site every 45 days). In addition, twenty-seven 10-15 second grab samples (averaging 10 – 15 seconds of sampling every 27 days) were taken during “odor events,” when odors felt to be caused by oil and gas activities were noted by local citizens.

The study used EPA risk assessment tools to examine carcinogenic and noncarcinogenic effects. For carcinogenic concerns, EPA Region 3 Risk Based Concentrations (RBC) were used in the risk analysis. Chemicals were listed as Contaminants of Potential Concern (COPC) if levels measured could produce greater than 1 excess cancer in one million. For noncancer health effects, if levels were found to be greater than Massachusetts Allowable Ambient Limits (ALLs) or above ATSDR Chronic, Intermediate, Acute Minimal Risk Levels (MRLs) in at least 5% of samples the chemical was listed as a COPC. It should be noted that recent literature suggests adverse health effects due to benzene may occur at lower levels than previously thought.

Results of the limited sampling indicate that local populations may be exposed to chemicals at levels hazardous to health. Benzene was identified at COPC levels at 12 of 14 sites and at 7 of the 8 oil and gas sites. Excess cancer risks ranged from 5-58 cancers/million. Four urban sites had cancer risks ranging from 15-22 cancers/ million and 1 rural site at 8 cancers/million. The Brock oil and gas site had benzene levels associated with excess cancer risk of 58 per million. The Brock site recorded a 24-hour sample of 49 ug/m3. This site also recorded the highest grab sample for benzene at 180 ug/m3 (3 ug/m3=1 ppb). Measurements here and at other locations also exceeded all minimum levels for noncancer health effects as well as for cancer health effects. While the Brock site is highlighted because it had the highest levels of benzene, it should be remembered that 12 of the 14 sites had potentially hazardous levels of benzene, indicating that potential for benzene exposure is the rule and not the exception. Although 86% of the sites tested demonstrated hazardous benzene levels, the CDPHE and ATSDR determined that benzene posed only an intermediate health risk because of lack of data and the hypothesis that other unnamed sources could be contributing to the measured benzene levels. No action is recommended by ATSDR other than a call for more monitoring.

In addition to benzene, other chemicals were found at elevated, potentially hazardous, levels. Methylene chloride (1 site), tetrachoroethene (2 sites), trichloroethene (1 site), 1,4-dichlorobenzene (8 sites), m,p-xylenes (6 sites) and 2-hexanone (3 sites) were noted at levels that could produced carcinogenic or non carcinogenic health effects. Toluene and acetone were also detected, frequently but at levels that did not reach cut-offs set for COPC. Based on these data, in its report ATSDR concluded that these chemicals were unlikely to be a significant hazard.

This conclusion may be problematic for several reasons. First, relatively few samples were obtained relative to the geographic area and the time period of concern. When chemicals are detected using an infrequent sampling scheme, there is no way of knowing if the results are truly representative of exposure. A conservative, precautionary approach would dictate that these results be considered as warnings that these chemicals exist, at levels as yet undetermined. Second, the quantitative measure of concentration for these chemicals may not be accurately represented. There is no way of knowing with certainty if the levels recorded were minimum, maximum or somewhere in between. The grab samples are especially problematic, since they represent only a 10-15 second snapshot, without any information as to how high the levels may actually have reached, nor for how long levels may have been elevated. Similarly, the 24-hour samples may have been taken at a peak, nadir or somewhere in between. In conclusion, the actual level and extent of chemical contamination remains unknown.

The ATSDR did not look at levels of other air toxics that would be expected to be found. Potentially hazardous airborne chemicals associated with oil and gas extraction include particulate matter, nitrogen oxides, sulfur oxides, hydrogen sulfide, ground level ozone, metals (lead, arsenic, mercury, selenium, barium, cadmium, chromium, zinc). Although drilling permits may be granted based upon projected discharges and modeling, in the absence of actual, publicly available data, true exposures remain unknown.

Garfield County and CDPHE have responded to the ATSDR study with plans to continue air monitoring. The CDPHE has released its plan for this monitoring effort. Particulate monitoring will be reduced to only one sampling site, either in Rifle or Parachute, Colorado. They will, however, begin monitoring for particulate matter <2.5 micron diameter (PM2.5), based on accepted literature that has found that PM2.5 is more highly associated with human health risk than is particulate matter <10 micron diameter (PM10) (See Literature Review). Monitoring for hazardous ultrafine airborne particles is not planned, although there is compelling scientific evidence that ultrafine particles (<0.1 micron diameter) pose a particularly high human health risk. Nonmethane organic compounds (NOMC total and 54 species of chemicals) will be monitored for 24 hours every 6 days (264 samples in next year) and low molecular weight carbonyl compounds (LOMCC, e.g. formaldehyde, acetaldehyde, acetone, acrolein, and others) will be sampled for 24 hours every 12 days (180 samples in the next year) at Rifle, Parachute, Bell Ranch and a fourth fixed or mobile location (Rada, 2008).

While this plan represents an improvement in the amount and scope of sampling to be taken at a given site (60 samples per site for NOMC and 30 samples per site for LMWCC), the number of sites has been decreased 70%. Furthermore, the site that registered the highest levels of benzene in the ASTDR study is not included in future monitoring plans. The planned air monitoring also does nothing to address the already documented hazardous levels of benzene.

United States Forest Service Ozone Monitoring 2006-Current

Little is known about ozone levels in the rural, Western Slope of Colorado. Because ozone is highly toxic to plants, the U.S. Forest Service monitors ozone in some forests, including locations in this region. The U.S. Forest Service uses both passive and solar-powered battery-operated continuous monitors to measure ozone. Although new National Ambient Air Quality Standards (NAAQS) for ozone is 75 ppb, the EPA acknowledges that for O3 (and PM2.5) levels substantially below NAAQS are still associated with increased mortality, cardiovascular events, and respiratory problems.

The preliminary results indicate that ozone in the Colorado high country is detected at concentrations that, at times, exceed National Ambient Air Quality Standards. Ozone concentrations on Ajax Mountain in Aspen ranged from 40 parts per billion (ppb) to almost 80 ppb during the months April-August, 2007. Additionally, ozone monitors on the Bell Ranch near Rifle found ozone levels averaging in the 40-50 ppb range, with spikes in ozone levels surpassing 75 ppb throughout the summer months of 2007. These results demonstrate that air quality in these areas may actually be hazardous to humans and that further monitoring by agencies tasked to protect human health is warranted.

Secondary findings are also important. The U.S. Forest Service found that ozone concentrations increase with altitude. CDPHE is installing ozone and PM monitors in Rifle (elevation 5130 f), Cortez (elevation 6201 f), and Palisade (elevation 4728 f). These locations may not be indicative of the ozone levels of communities at higher elevations (Musselman and Korfmacher 2008).*EPA Ozone Monitoring, La Plata County, 2007*

The EPA has two stationary ozone monitors in La Plata County; the first one is located a mile from Ignacio on County Road 517 and the second is on Highway 5505. The first location recorded spikes in ozone levels above 75 ppb and 8 hour average levels in the 58-71ppb range. The second location recorded ozone exceeding NAAQS (82 ppb) on one occasion and the next three highest levels (73, 73, 71 ppb) approached the limits of the standard (75 ppb). The monitoring in La Plata County demonstrates that air quality in some of Colorado's rural areas approaches and may at times exceed established Federal health standards (United States Environmental Protection Agency 2007).

CDPHE Air Quality monitoring

CDPHE has conducted limited air quality monitoring on the Western Slope. In 2006 there were 11 sites monitoring PM10 (Delta, Parachute, Rifle, New Castle, three ranches near Silt, Glenwood Springs, Durango, Grand Junction, and Telluride). In addition, Grand Junction had monitors for PM2.5, carbon monoxide (CO) and meteorological measurements. In 2006, none of the monitors recorded particulate levels exceeding NAAQS, with the exception of those associated with natural occurrence events (high winds or forest fires). It should be noted, however, that particulate levels in Parachute, Rifle and New Castle (towns in areas of the largest growth of oil and gas drilling in Garfield County) have recorded the highest monthly averages for particulate matter and have been trending upward over the last few years. For 2008, CDPHE has added PM2.5, ozone and meteorological monitors in Rifle and ozone and meteorological monitors in Palisade and Cortez. (Colorado Department of Public Health and Environment 2006; Garfield County Public Health Department 2007; Colorado Department of Public Health and Environment 2008)

WATER QUALITY

Garfield County Hydrogeologic Study 2006

In 2006 a report commissioned by the Garfield County Board of County Commissioners was released. This report contained a compilation of existing hydrogeologic data for a 110 square mile area which included the Mamm Creek gas field, south of Rifle and Silt and south of the Colorado River. (URS Corporation 2006)

The results of this report demonstrate many domestic wells, water wells, irrigation wells, monitoring wells, air sparging wells, springs, seeps, ponds, and rivers had detectable levels of methane. Out of 184 locations, 135 locations had detectable levels of methane (73% of locations); 872 samples were taken and 656 samples had detectable levels of methane (75% of samples). In the eastern portion of the study, the West Divide creek area recorded several wells with elevated levels of methane (>2 mg/l) and some with much higher levels (10-26 mg/l). Data from COGCC indicate that at least some of the groundwater and surface water contaminated with methane has been a result of gas development activities, while other sources of methane in domestic water wells remains unknown or is likely due to biogenic sources. In the southeast portion of the study area, domestic water contamination is likely due to older, abandoned wells that have been leaking for almost 30 years.

This study also reports on benzene and other organic compounds in surface waters. Benzene and methane levels in excess of MCL (5 ug/L and 1000ug/L, respectively) have been recorded in seeps in the study area. The two highest benzene recordings were in the West Divide Creek seep area (360 ug/L and 150 ug/L) and these two locations also recorded the highest ethylbenzene (10 and 16 ug/L) and some of the highest toluene (28-130 ub/L), xylene (17-110ug/L) and methane (1.2-12mg/L) measurements.

While this study is preliminary, it demonstrates that hazardous substances are present in the area's surface and subsurface water. The authors of this hydrogeologic report also point out that water sources with high levels of benzene, toluene, ethylene, and xylene (BTEX) chemicals also contain high levels of methane from gas well sources. They propose BTEX measurements as a method for determining gas well contamination of water sources. The authors also note that parts of the study area have undergone extensive oil and gas development, but there are few current data available regarding the groundwater quality in the same area. Some of the recommended follow up (Phase 2) studies include: further evaluation of wells with elevated methane levels, develop a long-term groundwater and surface water sample collection program, sample all domestic water wells on a two-year frequency for methane, major ions, selenium, fluoride and bromide, as well as other recommendations. (URS Corporation 2006)

Garfield County Phase IV Baseline Water Quality Study 2007

The Colorado Oil and Gas Conservation Commission (COGCC) contracted for a water quality field study in July and August of 2006. Seventy domestic water supply wells in Garfield County, between New Castle and Rifle north of the Colorado River were tested for inorganic, organic chemicals and 29 wells were tested for gas composition. Methane, BTEX and Methyl Tertiary Butyl Ether (MTBE) were not detected in any samples tested at STL Laboratories, but methane was detected in some water samples using gas chromatography methods used by the Isotech laboratory.

While this study provided some evidence that wells in the study area did not have the chemicals tested for at the time, it should be noted that the study area of this report differs significantly from that of the 2006 Hydrogeologic Report study area. The 2007 COGCC report study area is *north* of the Colorado River, whereas the report commissioned by Garfield County in 2006 studied an area *south* of the Colorado River. It should be noted that the greater extent of gas drilling in this area is taking place south of the Colorado River. This report illustrates the need not only for further water quality studies in Garfield County, but also for studies that are relevant to the areas where the most drilling activity is occurring. (Garfield County IT Department 2007; S.S. Papadpipulos & Associates 2007)

NOISE

La Plata County Impact Report 2002

Elevated noise levels are associated with all stages of oil and gas development: construction, vehicle noise, pumps and condensers all contribute to well pad noise. COGCC uses the State of Colorado noise guidelines for oil and gas monitoring. According to COGCC Rule 802, sound from oil and gas activities should not exceed the noise levels for predominant land use in the zone where a well exists and noise should be measured 25 feet beyond the property line or at a residential home.

La Plata County did an extensive County Impact Report (CIR) in 2002, assessing the impacts of proposed gas drilling. Contained in this report were measurements of ambient noise in rural residential, subdivision residential, and transportation land use areas in La Plata County. The average residential noise levels ranged from 42-46 decibels (dBA) and were substantially less than those allowed by State of Colorado Noise Guidelines (50 dBA at night and 55 dBA in the day). The La Plata report also used published noise levels for drilling activities to model well pads layouts to meet COCGG requirements. The final staff report made recommendations to change the noise level requirements to reflect the ambient noise of the county. (La Plata County 2002)

We were unable to find any publicly available data that directly measured noise levels associated with oil and gas development activities on the Western Slope. If such information exists, it is not readily available. Noise can contribute to a variety of adverse health effects, as discussed in the accompanying literature review. Of particular note, when noise exposure occurs in combination with exposure to volatile organic compounds, hearing loss can develop at lower levels than with just noise alone. As oil and gas development continues to increase in close proximity to populated areas, noise monitoring and mitigation should be implemented.

Conclusions and Recommendations

1. There are major gaps in the past assessment of air and water quality related to oil and gas development on the Western Slope.
2. Air and water quality studies conducted to date indicate that potential exposures to hazardous emissions exist.
3. Many air toxics are essentially unmeasured in Garfield County, despite the increase in oil and gas development known to produce these chemicals. Air quality measurements should not be considered complete until monitoring of all known potential hazardous substances is performed.
4. Current plans for further air sampling may not be comprehensive enough to enable public health officials to determine the community health impact of oil and gas development.
5. There are no plans for comprehensive and systematic monitoring of surface and subsurface waters. Water monitoring must occur and results made public, in order to protect human health.
6. Although some levels of harmful chemicals in both air and water measured in Garfield County may not fall within a specific regulatory standard, adverse health impacts are known to occur at levels below standards. As discussed in the attached literature review, this must be taken into account when mitigation measures aimed at reducing health impacts are undertaken. (Glass, Gray et al. 2003; Glass, Gray et al 2005)
7. Environmental monitoring must be relevant to the areas where oil and gas development activity is occurring.
8. Environmental monitoring results must be readily available to the public. Unbiased interpretation of the results must occur in a timely manner and be made available to the public.
9. There are no available studies examining the impact of oils and gas development on the noise levels in Garfield County. These studies should be conducted to assess and mitigate adverse effects of increased noise levels.
10. There are no available studies examining the impact of oil and gas development on soil quality in Garfield County. These studies should be conducted to assess and mitigate adverse affects of soil contaminants on human health.

Garfield County Health Status

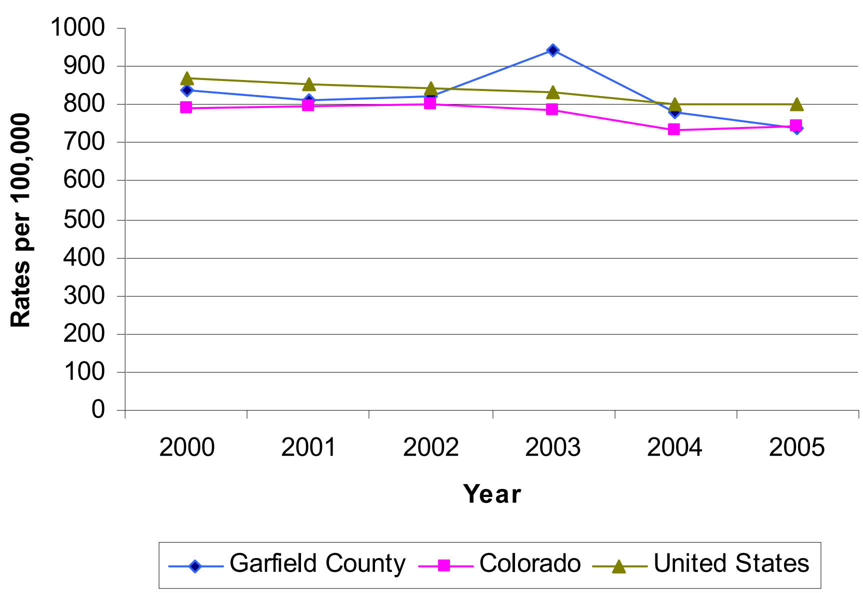
We examined heath status data publicly available for Garfield County residents; outlined below are some of the health status and determinants. A complete list of references can be found in Appendix 1. It is important to note that this is publicly available data. The data have significant limitations, the most notable being that oil and gas development in Garfield County did not start to rapidly expand until 2003. Most publicly available data for the county are still not available for the most recent years. Also, most of the data are population based, therefore lacking the ability to identify rare and individual health events. Listed below are the publicly available data we recovered for Garfield County, Colorado.

- Mortality Data (General, Infant): 1990-2005
- Cause of Death: 1990-2005
- Cancer Statistics: 1992-2002
- Cardiovascular Disease: 2000-2006
- Low Birth Weight: 2006-2006
- Asthma: 1993-2001
- Chronic Obstructive Pulmonary Disease (COPD): 1990-2006

Mortality

Mortality rates in Garfield County declined during the five-year period (2000-2005) with the exception of 2003, when the oil and gas industry started to rapidly expand in Garfield County, and the rates were higher than both U.S. and Colorado rates. (Figure 4.) Infant mortality rates are consistently lower in Garfield County (5/1,000) when compared to statewide rates (6.2/1,000), providing a good baseline health status when examining more recent years.

Figure 4. General Mortality Rates 2000-2005



Data Source: Garfield County Births and Deaths 2006

According to the Colorado Health Information Dataset: Death Statistics Section, the leading causes of death in 2006 for Garfield County closely mimicked those for the leading causes of death across the state and surrounding Western Slope Counties, with Garfield County having slightly higher mortality rates for heart disease, unintentional injuries, cerebrovascular diseases, Alzheimer's disease, suicide, and diabetes mellitus, compared to state rates. Although, cardiovascular disease was the number one cause of death in Garfield County in 2006, age-adjusted rates for the county have declined since 2000. In 2000 age-adjusted mortality rates for cardiovascular disease were 269.2/100,000. All four counties on the Western Slope had higher age-adjusted mortality rates for: diabetes mellitus, Alzheimer's disease, unintentional injuries and suicide when compared to state mortality rates. (Table 4)

Table 4. Leading Causes of Death for Garfield County Colorado (2006)

Cause of Death	**Age-Adjusted Rate** (Colorado)	**Age-Adjusted Rate** (Garfield)
Heart Disease	157.8	163.4
Malignant neoplasm's	158.8	138.4
Unintentional Injuries	42.0	63.1
Cerebrovascular diseases	40.5	46.2
Chronic lower respiratory diseases	50.4	43.7
Alzheimer's disease	29.7	42.3
Suicide	14.9	15.8
Diabetes mellitus	17.0	20.6

Data Source: Colorado Health Information Dataset: Death Statistics

In the remainder of this section, the white paper addresses five major health conditions: cancer, cardiovascular disease, low birth weight, asthma, and chronic obstructive pulmonary disease (COPD). We have emphasized these five because of their potential importance. Based on the literature review, these are among the likely health conditions that may potentially be caused by or aggravated by the contaminant exposures encountered in oil and gas exploration and extraction. As such, it is important to have accurate baseline and prospective data on these and other such health outcomes of concern. It is important to note that since latency periods exist for some diseases (especially for many cancers) and their significant exposures, even current health statistics may not reflect the current population health status.

Cancer

As indicated in the literature review, certain exposures seen in oil and gas exploration and extraction are considered significant cancer risks. Since 1992, both cancer incidence and mortality rates have declined in Garfield County. Garfield County overall cancer incidence rates were significantly higher in males compared to state incidence rates, for all years that public data were available. Overall cancer mortality rates for males were higher in Garfield County when compared to the state for the time periods of 1992-1998 and1999-2000, but were slightly lower in the 2000-2001 time period than state rates. Overall females in Garfield County have lower rates of cancer incidence and mortality than state rates. Specific cancer incidence and mortality rates showed males with higher lung cancer mortality rates compared to state rates and higher prostate cancer incidence rates, and both males and females having higher bladder cancer incidence rates compared to state rates. (Figures 5,6.)

Figure 5.

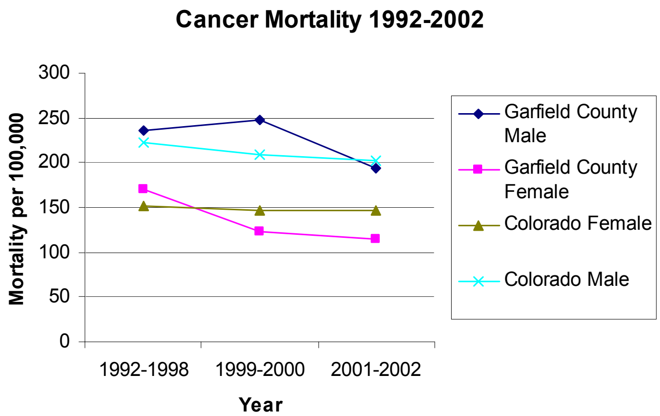
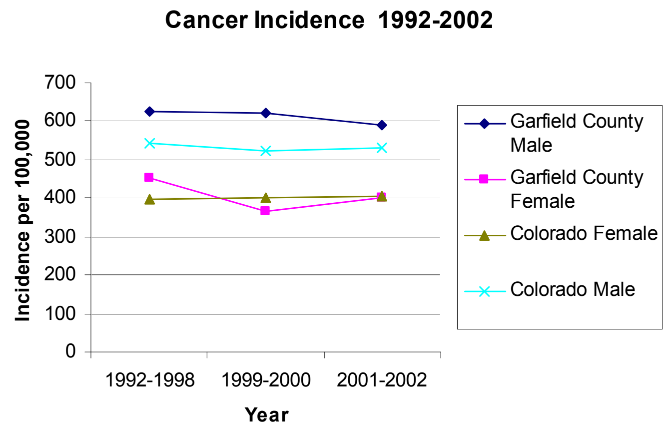


Figure 6.



Data Source: Cancer in Colorado: 1992-2002

Low Birth Weight

As indicated in the literature review, certain exposures seen in oil and gas exploration and extraction are considered significant risk factors for fetal outcome, including low birth weight. As such, this is an outcome of potential importance for tracking purposes. Colorado has a relatively higher percentage of low weight births than the United States overall. Garfield County has consistently has a lower percentages of low weight births then Colorado state percentages. The percentage of low birth rates in Garfield County, in 2005 was 6.8 percent, falling below the state percentage of 9.3 percent. In 2005, the percentage in Garfield County rose to 8.8 percent, still lower then state percentages, but increasing from the prior year. Continued monitoring of low birth weight infants in Garfield County is needed, as low weight infants are at a much higher risk for long-term morbidity, susceptibility to respiratory problems, and early death.

Asthma

Literature examining health effects of air pollutants produced by both stationary (e.g. industrial sources) as well as mobile sources (e.g. fossil fuel combustion emissions from vehicles and traffic density) have shown clear relationships with respiratory disease, most notably asthma and chronic obstructive pulmonary disease. A recent health study completed by the Saccomano Institute reported that children in Garfield County had an increased asthma rate, as discussed below in more detail. Asthma incidence in Colorado is mostly estimated by use of hospital discharge records. The age adjusted rate for asthma, obtained from hospital discharge records (principal diagnosis), in Garfield County for the nine-year period of 1993 to 2001 was 7.9/10,000. The age-adjusted rates for surrounding counties were similar with Moffat having a slightly higher incidence, 12.8/10,000 and Mesa and Rio Blanco having a slightly lower incidence of 7.5/10,000 and 6.7/10,000, respectively. Publicly available data are only available through the year 2001. Because oil and gas development activities did not rapidly expand in the region until the year 2003, asthma data for more recent years such as increased rates reported in the Saccomano Institute study are of more value. It is also important to note that not all asthma related incidents are accounted for with hospital discharge data, as not all asthma related incidents will require admittance to hospitals. Emergency room visit data and outpatient clinic data for asthma incidence and prevalence in Garfield County would also be of more use.

Chronic Obstructive Pulmonary Disease (COPD)

As mentioned above, clear relationships have been established through literature between COPD and air pollutants given off by stationary and industrial sources. Currently there are no true COPD prevalence data for the state of Colorado. Recent data on COPD mortality specific to Garfield County are not publicly available. However, we do know that during the years 1990 to 2004 Garfield County had age adjusted rates of 90-70 deaths due to COPD per 100,000 residents. We also know COPD mortality rates in Colorado are one of the highest in the nation, despite being one of the states with the lowest smoking prevalence, and that rural and frontier counties in Colorado, like Garfield County, have higher mortality rates compared to urban regions in Colorado. In the recent study conducted by the Saccomano Institute, they reported residents of Silt had an increased rate of COPD compared to the rest of Garfield County.

Summary of recent "Community Health Risk Assessment"

The Saccomanno Institute in Grand Junction, Colorado recently completed a two-year study of the health trends in Garfield County. Although this study is as yet unpublished, the major findings have been the subject of public presentations. Because of its relevance to Garfield County and as an illustration of the type of research that is needed, this white paper summarizes the major conclusions and considers the available information from this project. ("Community Health Risk Assessment: An assessment of risk related to the natural gas industry in Garfield County Part II: Health Study.")

This study was completed in two parts: one focusing on exposure, the other on health. In the health study, four-county (Mesa, Garfield, Montrose, Delta) comparisons were made using seven sets of available statistics from the Colorado Department of Public Health and Environment (birth statistics, death statistics, birth defects, adolescent health measures, reportable conditions, West Nile virus, and Cancer statistics), as well as data from a behavioral risk factor study survey and injury hospitalization and death rates/causes, hospital and medical insurance data sets. In addition, the researchers conducted a telephone and mailed household survey to obtain self-reported health status information (participation rate of 18%).

The authors of this study observed some trends of illness in Garfield County, as compared to other Western Colorado counties. According to the authors, a number of the trends may be important indicators to track prospectively, including alcohol and drug disorders, birth and pregnancy outcomes, children in Garfield county having an increased seizure and headache hospital admittance, bronchitis and asthma rates, and respiratory infections and inflammation. The authors of this study have recommended a prospective medical monitoring system to identify any changes in baseline data or trends. (Teresa Coons and Walker 2008)

A critical assessment of the study design, methodology, results and conclusions will have to await a more complete release of the data.

Conclusions and Recommendations

1. Publicly available information about health status of Garfield County residents is incomplete.
2. Recent data, which is most important, are lacking and often delayed in public distribution.
3. Trends from the Saccomonno Institute study support the need for better prospective monitoring. According to those authors, these trends include alcohol and drug disorders, birth and pregnancy outcomes, increased seizure and headache diagnoses for hospital admittance of children, bronchitis and asthma rates, and respiratory infections and inflammation.
4. In light of the rapid pace of oil and gas activities in Garfield County, and the lack of recent available data, one is not able to make any definitive conclusions about the health status of Garfield County residents.
5. At this point in time, there are many uncertainties regarding the health effects of oil and gas industry activity on general markers of health within the surrounding communities.
6. This lack of information, combined with the lack of comprehensive, systematic health and exposure monitoring and recording, make it difficult to draw any definitive conclusions about the causality and severity of these effects.
7. Ongoing surveillance of both asthma and COPD in Garfield County is needed. A way to measure and subsequently monitor both incidence and prevalence for the county should be implemented. These are diseases that occur in great enough frequency to act as meaningful sentinel events for monitoring purposes.
8. Continued monitoring and interpretation of data concerning low birth weight is warranted.
9. By improving our measurement and monitoring of health outcomes in Garfield County, it should be possible to better intervene and mitigate any adverse impact resulting from oil and gas development.

Worker Health

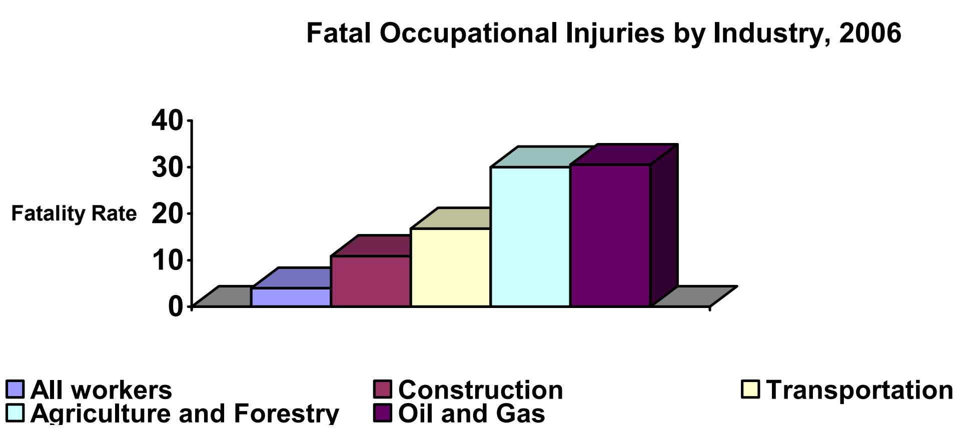
Although the majority of this white paper addresses exposures to neighboring communities, it is important to note that the health impact on the community includes those who work in the oil and gas industry or who work in industries that support this development.

Occupational Fatalities

An increase in oil and gas production has led to a rise in employment in this industry. Nationwide, the average number of workers employed in the oil and gas industry has increased almost 32% from 2003 to 2006, as discussed in the accompanying literature review. An increase in oil and gas extraction activities has been significantly correlated with an increase in the rate of fatal occupational injuries among oil and gas extraction workers employed in the U.S. The average annual rate of fatal occupational injuries in the U.S. in the oil and gas industry from 2003 to 2006 was 30.5 per 100,000 workers. This rate is high compared to the overall national rate of 4.0 fatalities per 100,000 workers for all workers for these same years. Fatalities that occurred in the oil and gas industry for this time period were attributable to transportation incidences and being struck by machinery or equipment. (MMWR April 25, 2008 / 57(16); 429-431)

The oil and gas industry is considered a high risk industry for fatality as demonstrated by the rates above. Oil and gas workers in the U.S. experience a disproportional rate of occupational fatalities compared to other industries except agriculture and forestry. In 2006, compared to other high-risk industries, the fatality rate per 100,000 workers was 31.9 for the oil and gas industry, 30.0 for agriculture and forestry, 16.8 for transportation, and 10.9 for construction. Notably, fatalities among oil and gas workers accounted for nearly two-thirds of the fatalities in the mining industry as a whole. (MMWR April 25, 2008 / 57(16); 429-431; http://www.bls.gov/iif/oshwc/cfoi/cfch0005.pdf)

Figure 7.



Further detail describing fatalities among oil and gas workers can be obtained by accessing the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI). Occupational fatalities are classified by industry, event or exposure, including transportation incidents, assaults and violent acts, contact with objects and equipment, falls, exposure to harmful substances and fires/explosions. CFOI does not report fatalities caused by occupational illnesses due to latency issues.
(http://www.bls.gov/iif/oshcfoi1.htm)

The Colorado Department of Public Health and Environment provides detailed data describing occupational fatalities in Colorado by selected industry. Fatalities in the mining industry (all mining) from 2003 to 2006 have represented approximately 5% of all work-related fatalities in Colorado for those years. Fatality rates for the oil and gas industry specifically are not available in Colorado. Fatalities in the mining industry in Colorado have been lower than other high risk industries.
(http://www.bls.gov/iif/oshstate.htm#CO)

Occupational Injuries and Illnesses

Survey of Occupational Injuries and Illnesses (SOII)

The BLS Survey of Occupational Injuries and Illnesses (SOII) reports incidence rates of non-fatal occupational injuries and illnesses by industry. In the U.S. the overall rate of non-fatal injuries and illnesses among private industry employees in 2006 was 4.4 per 100 full-time workers. Comparing goods-producing industries, the injury and illness rate was 3.5 for mining, 5.9 for construction, and 6.0 for both agriculture and manufacturing.
(BLS, USDL 07-1562 http://www.bls.gov/iif/oshwc/osh/os/osnr0028.pdf)

Injury characteristics reported in the SOII include days away from work, the 'physical' nature of the injury such as a sprain or burn, part of the body affected, source of injury such as chemical, machinery, tools or equipment, and the 'physical' event or exposure such as fall or transportation incident. In the U.S. in 2006, industry sectors experiencing the most injuries were manufacturing (20%), health care and social assistance (16%), and retail (15%). Within the goods-producing industry, 20% of non-fatal injuries occurred in manufacturing, 10% in construction, 1.3% in agriculture and forestry, and 0.6% in mining. Illnesses categories in the SOII include skin diseases or disorders, respiratory conditions, poisonings, and 'all other illnesses.' In the U.S. in 2006, mining accounted for 0.4% of all non-fatal occupational illnesses. (BLS, USDL 07-1562
http://www.bls.gov/iif/oshwc/osh/os/osnr0028.pdf)

Nationwide non-fatal injury and illness data are reported for sectors within the mining industry, as reported below. These data, however, are not comparable to other industry sectors due to differences in data collection and reporting standards. Therefore, comparisons are not made.

The average incidence rates reported by mining subsector (per 10,000 full time workers) of nonfatal occupational injuries from 2003 to 2006 nationwide was 2.0 for oil and gas extraction workers, 5.3 for workers involved in drilling oil and gas wells, and 3.1 for workers performing support activities for oil and gas operations. (SOII Table SNR05 for years 2003 – 2006 http://www.bls.gov/iif/oshsum.htm)

The average incidence rates by mining subsector (per 10,000 full time workers) of nonfatal occupational illnesses from 2003 to 2006 nationwide was 13.5 for oil and gas extraction workers, 13.6 (excluding 2004) for workers involved in drilling oil and gas wells, and 8.8 for workers performing support activities for oil and gas operations. (SOII Table SNR08 for years 2003-2006 http://www.bls.gov/iif/oshsum.htm) Since Colorado is one of seven states that do not participate in the Survey of Occupational Illnesses and Injury, comparison of state data with national data cannot be accomplished.

Colorado Workers' Compensation Data

The Colorado Division of Workers' Compensation collects data on employer/employee submitted work-related injury and illness claims, providing another source of data with which to estimate health impact in workers. Occupational injuries and illnesses can be described by industry, county, part of the body, nature of injury and illness and cause of injury or illness.

Data are currently available and reported for the calendar years 2001 to 2003. In Colorado, the mining industry represented 0.6% of total average annual employment. Approximately 1% of all lost-time claims filed with the state were from the mining industry, including fatalities. The fatality rate for the mining industry per 10,000 employed decreased from 7.79 in 2001 to 2.29 in 2003.

When separated into mining subsectors, workers in the support activities had the highest number of lost-time claims (1%) compared to mining (except oil and gas) (0.5%) and oil and gas extraction (0.1%). Fatality rates were not available by sub-sector.
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_03.pdf
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_02.pdf
http://www.coworkforce.com/dwc/PUBS/Work_Related_Injuries_01.pdf

Colorado Hospital Association Data

The Colorado Hospital Association collects data on hospitalizations occurring in Colorado. Estimates of work-related hospitalizations need to be determined by identifying hospitalizations for which workers' compensation is the payer. Although we have requested this information, the data were unavailable at the time of completion of this white paper.

Conclusions and Recommendations

1. In any assessment of health impact on a region, occupational fatalities, injuries and illnesses should be taken into account along with the health impact on the local community.
2. National data indicate significant rates of occupational illness, injury and fatality associated with the oil and gas industry.
3. We were unable to obtain specific fatality rates for the oil and gas development-associated subsectors in Colorado. Further analysis is needed to determine the fatality rates in oil and gas extraction, drilling oil and gas wells, and support industries, such as construction trades.
4. We were unable to obtain data on the rates of nonfatal occupational injuries and illnesses for Colorado. These data need to be determined in Colorado. At this time, Colorado is one of only seven states that do not participate in the SOII.
5. Workers' compensation and hospital discharge data may be important additional sources that can be used to estimate the health impact of the oil and gas industry for workers.

Social and Psychological Health Effects

While limited research has examined the physical health consequences associated with oil and gas development, even less research has focused on the social and psychological health effects of these activities (Mall, 2007). A review of the available literature about the social and psychological implications of oil and gas exploration reveals some interesting trends found in industrial communities throughout the world.

The literature review attached to this paper suggests a number of social and psychological concerns that may be associated with industrial activity moving into populated areas. These concerns include possible increases in domestic violence, rape, assault, child abuse, suicide, homicide and crime. (Bhatia, 2007, Srinivasan, 2003, Wernham, 2007, Forsyth, 2007, Luthra, 2007, Seydlitz, 1993, Kettl, 1998) Given the limited number of studies and the mixed nature of the results, further study in this area is warranted.

Garfield County Crime Rates

Crime rates for Garfield County, for years 2000-2005, were calculated using data describing the number of arrests made in the county (Lowden, 2007) and the population information described above. In Garfield County, between 2000 and 2005, the total number rate of adult violent arrests continually increased. (Table 5) Although there are some fluctuations from year to year, there is an overall increase in the rate of violent crime arrests and drug violations in Garfield County from 2000-2005. While the cause of these increases remains to be determined, this finding is consistent with studies finding that violent crime rates can increase in communities involved in rapid growth of industrial activity. Nonviolent crime rates did not increase across the same time period. (Table 6)

Table 5. Rate per 10,000 residents (Number) of Arrests for Violent Crimes and Drug Violations, Garfield County, 2000-2005

Year	Population	Murder	Rape	Other Sex Crimes	Robbery	Aggravated Assault	Violent crimes total	Drug violations
2000	43,791	0 (0)	.68 (3)	.23 (1)	0 (0)	7.54 (33)	8.45 (37)	19.41 (85)
2001	46,173	0 (0)	.65 (3)	1.52 (7)	.86 (4)	9.31 (43)	12.34 (57)	23.39 (108)
2002	47,275	0 (0)	.85 (4)	2.32 (11)	.21 (1)	10.15 (48)	13.54 (64)	29.83 (141)
2003	57,126	.18 (1)	.35 (2)	1.05 (6)	.18 (1)	6.65 (38)	10.15 (48)	22.06 (126)
2004	49,325	0 (0)	.61 (3)	1.01 (5)	.20 (1)	14.60 (72)	16.42 (81)	20.48 (101)
2005	50,673	0 (0)	1.18 (6)	1.18 (6)	.20 (1)	17.17 (87)	19.73 (100)	39.67 (201)

Table 6. Rate per 10,000 residents (Number) of Arrests for Nonviolent Crimes, Garfield County, 2000-2005

Year	Popula-tion	Burglary	Larceny/Theft	Motor Vehicle Theft	Arson	Nonviolent crimes total
2000	43,791	2.97 (13)	31.74 (139)	1.60 (7)	0 (0)	36.31 (159)
2001	46,173	4.55 (21)	16.46 (76)	1.95 (9)	.87 (4)	23.82 (110)
2002	47,275	5.08 (24)	25.38 (120)	.63 (3)	.21 (1)	31.31 (148)
2003	57,126	2.63 (15)	19.43 (111)	1.58 (9)	0 (0)	23.63 (135)
2004	49,325	3.65 (18)	18.04 (89)	.81 (4)	.41 (2)	22.91 (113)
2005	50,673	5.92 (30)	17.37 (88)	2.76 (14)	.20 (1)	26.25 (133)

Conclusions and Recommendations

1. The literature supports the concept that rapid industrial change can have deleterious effects (in addition to possible positive effects) on the psychosocial welfare of a local population.
2. The data shown above indicate that there has been an increase in violent crimes and drug violations in Garfield County. Further study is needed to determine if industrial development, in the form of oil and gas drilling, is contributing to this increase, especially since literature suggests that this is possible.
3. At this point in time, there are many unknowns about the effects of oil and gas industry activity on psychosocial health outcomes. This lack of information, combined with the lack of a comprehensive, systematic health and exposure monitoring make it impossible to draw any definitive conclusions about the causality and severity of these effects.
4. Improved monitoring of the psychosocial health Garfield County residents is needed in order to intervene and mitigate any adverse impact resulting from oil and gas development.

White Paper Conclusions and Recommendations

Community at Risk

1. There is a lack of precise demographic, exposure and health information on the Garfield County population. This affects the ability to accurately assess the current and future health of the community.
2. There are no demographic data on the temporary oil and gas workers. Most moved into Garfield County since 2000.
3. The available data discussed above suggest that approximately one-third of the Garfield County population (27% children and 9% over 65) may be more susceptible to certain oil and gas industry-related exposures.
4. As discussed above, there is an increasing population of children in Garfield County, who are potentially at increased risk for adverse health effects from these exposures.

Hazardous Exposure Information

1. There are major gaps in the past assessment of air and water quality related to oil and gas development on the Western Slope.
2. Air and water quality studies conducted to date indicate that potential exposures to hazardous emissions exist.
3. Many air toxics are essentially unmeasured in Garfield County, despite the increase in oil and gas development known to produce these chemicals. Air quality measurements should not be considered complete until monitoring of all known potential hazardous substances is performed.
4. Current plans for further air sampling may not be comprehensive enough to enable public health officials to determine the community health impact of oil and gas development.
5. There are no plans for comprehensive and systematic monitoring of surface and subsurface waters. Water monitoring must occur and results made public, in order to protect human health.
6. Although some levels of harmful chemicals in both air and water measured in Garfield County may not fall within a specific regulatory standard, adverse health impacts are known to occur at levels below standards. As discussed in the attached literature review, this must be taken into account when mitigation measures aimed at reducing health impacts are undertaken. (Glass, Gray et al. 2003; Glass, Gray et al 2005)
7. Environmental monitoring must be relevant to the areas where oil and gas development activity is occurring.
8. Environmental monitoring results must be readily available to the public. Unbiased interpretation of the results must occur in a timely manner and be made available to the public.
9. There are no available studies examining the impact of oil and gas development on the noise levels in Garfield County. These studies should

be conducted to assess and if necessary, mitigate adverse effects of increased noise levels.

10. There are no available studies examining the impact of oil and gas development on soil quality in Garfield County. These studies should be conducted to assess and if needed, mitigate adverse affects of soil contaminants on human health.

Health Status of the Community

1. Publicly available information about health status of Garfield County residents is incomplete.
2. Recent data, which is most important, are lacking and often delayed in public distribution.
3. Trends from the Saccomonno Institute study support the need for better prospective monitoring. According to those authors, these trends include alcohol and drug disorders, birth and pregnancy outcomes, increased seizure and headache diagnoses for hospital admittance of children, bronchitis and asthma rates, and respiratory infections and inflammation.
4. Sources of health statistics are available only up to years 2001 (asthma), 2002 (cancer), 2005 (mortality), and 2006 (cardiovascular disease, COPD, low birth weight) Changes in health may not yet be apparent in these statistics. Since drilling has been rapidly increasing since 2003, the health of the residents of Garfield County may be impacted, yet this may not yet be reflected in the available data.
5. At this point in time, there are many uncertainties regarding the health effects of oil and gas industry activity on general markers of health (such as mortality, birth outcomes, cancer, etc) within the surrounding communities.
6. This lack of information, combined with the lack of comprehensive, systematic health and exposure monitoring and recording, make it difficult to draw any definitive conclusions about the causality and severity of these effects. Given the marked anticipated expansion of oil and gas activities, the current lack of information will seriously impede adequate planning for protecting human health.
7. Ongoing surveillance of both asthma and COPD in Garfield County is needed. Implementation of effective monitoring systems, such as reporting to the county health department, should be established. These are diseases that occur in great enough frequency to act as meaningful sentinel events for monitoring purposes.
8. Continued monitoring and interpretation of data concerning low birth weight is warranted.
9. By improving measurement and monitoring of health outcomes in Garfield County, it should be possible to better intervene and mitigate any adverse impact resulting from oil and gas development.

Worker Health

1. In any assessment of health impact on a region, occupational fatalities, injuries and illnesses should be taken into account along with the health impact on the local community.
2. As noted above, national data indicate significant rates of occupational illness, injury and fatality associated with the oil and gas industry.
3. We were unable to obtain specific fatality rates for the oil and gas development-associated subsectors in Colorado. Further analysis is needed to determine the fatality rates in oil and gas extraction, drilling oil and gas wells, and support industries, such as construction trades, since national statistics suggest they could be significant.
4. We were unable to obtain data on the rates of nonfatal occupational injuries and illnesses for Colorado. Without these data rates of occupational illness and injury due to oil and gas activities in Colorado are unknown. At this time, Colorado is one of only seven states that do not participate in the Survey of Occupational Illness and Injury (SOII).
5. Workers' compensation and hospital discharge data may be important additional sources that can be used to estimate the health impact of the oil and gas industry for workers.

Psychological and Social Impact

1. The literature supports the concept that rapid industrial change can have deleterious effects (in addition to possible positive effects) on the psychosocial welfare of a local population.
2. The data shown above indicate that there has been an increase in violent crimes and drug violations in Garfield County. Further study is needed to determine if industrial development, in the form of oil and gas drilling, is contributing to this increase, especially since literature suggests that this is possible.
3. At this point in time, there are many unknowns about the effects of oil and gas industry activity on psychosocial health outcomes. This lack of information, combined with the lack of a comprehensive, systematic health and exposure monitoring make it impossible to draw any definitive conclusions about the causality and severity of these effects.
4. Improved monitoring of the psychosocial health Garfield County residents is needed in order to intervene and mitigate any adverse impact resulting from oil and gas development.

General Conclusions/Recommendations:

1. The literature review conducted in parallel with this white paper yielded important information regarding the impact of exposure on human health and welfare. A more comprehensive literature review that includes foreign language literature, older studies, reviews, formal assessment of quality of

evidence, and conflict of interest considerations would be expected to yield additional useful information.

2. The available data and lines of evidence indicate that there is an acute problem with toxic emissions of uncertain proportions and a possible emergent problem for the health of the citizens of Garfield County.
3. The available data regarding the health and social impact of oil and gas development need further analysis.
4. Data, such as air and water quality data collected by the oil and gas companies, that may have been collected but are not in the public domain should be made available for analysis and publication.
5. In the interest of public health, the credible evidence currently available about the impact on the health and welfare of the population by oil and gas development requires action now as outlined in this white paper. It is important not to ignore what is already known.
6. There is an immediate need for specific information on exposures and the impact from oil and gas development on all aspects of human health. This white paper and literature review indicate a number of fertile areas for further study.
7. An adequate monitoring program should be developed through a rigorous scientific process that addresses all currently recognized data gaps and health risks. This process should be developed in a transparent and explicitly unbiased way.
8. A Health Impact Assessment (HIA) is a practical tool to evaluate future impacts, alternatives and appropriate strategies to promote and protect human health. An integrated HIA/EIS published in 2007 described the impact of oil development on Alaska's North Slope on the local Inupiat populations. (Wernham 2007) The HIA findings predicted impact on health and social structure. The report provided recommendations for mitigation of these effects, thereby improving the probability that oil development could proceed with less adverse impact on the people who live in the region.
9. An HIA could provide a framework for exposure assessment (from air and water quality monitoring), health data collection and monitoring (for example asthma, COPD incidence and prevalence, birth outcomes), and recommendations for mitigation of potential adverse effects.
10. Given that oil and gas extraction activities are known to use and produce chemicals that are hazardous to human health and that these activities are occurring in close proximity to human populations in Garfield County, a Health Impact Assessment of oil and gas development in Colorado should be done. At the present time there is no systematic collection of air or water quality data, assessment of exposure, nor of health or social outcomes. Through an HIA, air and water quality monitoring systems and health and social outcome monitoring systems could be established. Given that even limited air and water quality studies revealed dangerous levels of benzene and other chemicals of potential concern, continued ignorance of the status of the air and water quality and the potential health impacts in Garfield County should not be considered acceptable. An HIA should be a critical

component of planning for future expansion of oil and gas activities, so that these activities do not put local residents at risk. Because an Environmental Impact Statement is intended to consider the effects of the development in question on the "human environment," an HIA should be considered a necessary part of a complete Environmental Impact Statement. An HIA, or a similar assessment, should be a part of any oil and gas permitting process that occurs near human populations. Without an HIA, a comprehensive EIS should be considered incomplete.

11. While this white paper focuses on Garfield County, Colorado as an illustration of the potential exposure-related health impact of oil and gas development, the principles of exposure and the related health issues should be considered generally applicable wherever oil and gas development is occurring.

Closing Statement

Oil and gas development has the potential to impact human health when toxic chemicals are released into the air and water near human population centers. Without precise demographic, exposure and health information of the Garfield County population, assessment of the current and future health of the community is compromised. Air and water quality studies conducted in Garfield County demonstrate that potential exposures to hazardous emissions exist. As noted above and in the literature review, although some levels of harmful chemicals in both air and water measured may not fall within a specific regulatory standard, adverse health impacts are known to occur at levels below standards. This must be taken into account when mitigation measures aimed at reducing health impacts are undertaken. Furthermore, publicly available information about the health status of Garfield County residents is incomplete. This lack of information, combined with the lack of comprehensive, systematic health and exposure monitoring and recording make it impossible to draw any definitive conclusions about the causality and severity of health effects. Given the marked anticipated expansion of oil and gas activities, the current lack of information will seriously impede adequate planning for protecting human health. Additionally, in any assessment of health impact on a region, occupational fatalities, injuries and illnesses should be taken into account along with the health impact on the local community, given that national data indicate significant rates of occupational illness, injury and fatality associated with the oil and gas industry. Also, the literature supports the concept that oil and gas boom and bust cycles have deleterious effects on the psychosocial welfare of a local population. Further data collection, analysis and subsequent recommendations could mitigate the psychological and social impacts oil and gas drilling. A Health Impact Assessment of oil and gas development in Colorado should be done as a critical component of planning for future expansion of oil and gas activities and as such would be essential to an adequate Environmental Impact Statement and other planning and assessment processes. A comprehensive EIS must include an HIA in order to be considered complete.

Furthermore, the principles of exposure and the related health issues should be considered generally applicable wherever oil and gas development is occurring.

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Health Impact Assessment for Battlement Mesa, Garfield County Colorado

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Executive Summary

This Health Impact Assessment (HIA) was conducted by members of the faculty and staff of the Department of Environmental and Occupational Health, Colorado School of Public Health (CSPH) at the request of the Garfield County Board of County Commissioners (BOCC), to help address community concerns regarding future land use decisions. The purpose of this HIA is to provide the BOCC with specific health information and recommendations relevant to Antero Resources Corporation (Antero) plans for natural gas development and production in the residential community of the Battlement Mesa Planned Urban Development (PUD), Garfield County, Colorado. To this end, CSPH worked in collaboration with Garfield County Public Health (GCPH) to conduct a qualitative and quantitative analysis of existing environmental, exposure, health, and safety data pertinent to the Battlement Mesa community. CSPH offers the BOCC specific recommendations for its consideration in Antero drilling permit decisions. In addition, the HIA provides baseline information for use in the design of a future prospective exposure and health monitoring project.

ES1 Introduction

Recent domestic energy production has brought industrial processes, and potentially exposures, into close proximity of residential urban, suburban and rural communities across the United States. Garfield County, Colorado is at the epicenter of natural gas development in the Piceance Basin and experienced rapid growth of the industry from 2003 – 2008, and a sudden downturn in 2009. Now, in 2010, permitting for the purpose of development and production is resuming and is expected to continue to increase.

Natural gas development and production is known to produce a variety of physical and chemical hazards that may cause negative health effects. In 2008, CSPH completed a white paper and literature review, outlining potential environmental hazards, vulnerable populations, and possible health outcomes in Garfield County. The 2008 Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County, Colorado (referred to as the Saccomanno Study) documented baseline health status and negative health outcome trends potentially linked to natural gas development in Garfield County. Air monitoring in Garfield County has documented levels of some air toxics in ambient air that increase the risk of negative health effects for citizens. Furthermore, recent review of large scale "boom and bust" natural gas development in small and rural communities, such as those found in Garfield County, have the potential to affect community infrastructure. Taken together, this information suggests that natural gas permitting decisions within the residential community of Battlement Mesa has the potential to adversely affect health.

Battlement Mesa is community with a large number of retired citizens as well as young families. According to the 2000 United States Census estimates, the total population of the Battlement

Mesa/Parachute zip code was 5,041; the median age was 37.five years; 26.0 percent of the population were under 18 years of age, 7.2 percent under five years, and 19.8 percent were 65 years and older. In 2000, the County population was 43,791, rising 30% to 56,298 in 2009.

The Antero project is anticipated to include 200 natural gas wells on 9 pads, a centralized water storage facility with a covered/lined waste pit, and 8.4 miles of water and gas pipeline. Preliminary plans indicate that well pads and pipelines will be distributed throughout the PUD, raising the probability that health impacts could affect the entire community.

Community groups, including Battlement Mesa Service Association (BMSA, the homeowners association) and Battlement Mesa Concerned Citizens (BCC) and Grand Valley Citizens Alliance, expressed concerns about the proximity of natural gas development to homes, recreational areas and schools. At stakeholder meetings, citizens have expressed concerns regarding airborne volatile organic compounds (VOCs), diesel and other particulate matter (PM); hydraulic fracturing (also know as fracking) fluid, hydrocarbons, and VOCs in soil and water; increased risk of fires, explosions, and motor vehicle accidents; and changes in community "livability."

In November 2009, Battlement Mesa Concerned Citizens formally requested BOCC and GCPH address health concerns before Antero development activities begin. (Attachment 1) The BOCC expressed a desire for the HIA to be conducted by CSPH expeditiously, so that results could be available prior to permitting decisions. At that time, it was anticipated that Antero would be submitting their Major Land Use Impact Review (also known as MLUIR) and Comprehensive Drilling Plan in late spring 2010 and that these documents would be available as part of the basis for the HIA. At this time, however, Antero had not submitted either document. Therefore, we have used public meeting minutes, slides from power point presentations, the Surface Use Agreement with the surface owners the Battlement Mesa Company (BMC) and other information provided to us by Antero as sources for this report. Should Antero ultimately submit permit proposals that substantially differ from this information, our assessments may not necessarily reflect those differences.

The stakeholders for the Antero drilling plan include the residents and citizen groups of Battlement Mesa and nearby communities, Antero and other operators, GCPH, BOCC, the Battlement Mesa Consolidated Metropolitan District which provides drinking water and waste water services to Battlement Mesa, BMC, the Grand River Hospital District and other medical services providers, Colorado Department of Public Health and Environment (CDPHE), and Colorado Oil and Gas Conservation Commission (COGCC). There has been broad support for the HIA from all stakeholders, reflecting a common search for a means to address the concerns of potentially impacted residents in a systematic and impartial manner.

GCPH has been extremely instrumental in helping CSPH accomplish the HIA, by facilitating meetings with stakeholders and Antero; providing local contacts and context, environmental data, review and input on the scope, and analysis of the HIA; acting as the liaison between the

CSPH and the BOCC; providing web support for HIA related minutes, presentations, and this report; and providing information to local media. In addition, at the CSPH, the Mountain and Plains Educational and Research Center has provided outreach support. The Pew Health Impact Project provided funding for consultation with Habitat Health Impact Consulting, a Canadian firm with expertise in HIAs related to resource extraction.

ES2 The HIA Process

An HIA involves several defined steps: screening, scoping, assessment, recommendations and implementation, reporting and monitoring.

This HIA was screened and scoped using information from the white paper and literature review previously conducted by CSPH, concerns raised by the citizens (Table 3), the 2008 Saccomanno Report, as well as input from the BOCC, GCPH, CDPHE, COGCC and Antero obtained in meetings over the course of the last nine months. As a result, the HIA focuses on eight areas of health concern (stressors) associated with natural gas development and production: air emissions, water and soil contaminants, truck traffic, noise/light/vibration, health infrastructure, accidents and malfunctions, community wellness, and economics/employment.

Assessment of each stressor includes a review of its general impact on physical, mental and/or social health as described in relevant medical and social science literature; a compilation and analysis of existing environmental and health data describing current conditions in Battlement Mesa; the means by which Antero plans for drilling might alter the current conditions, and finally a characterization of the stressor's impact on health. Several physical health outcomes linked to potential exposures are considered, including respiratory, cardiovascular, cancer, psychiatric, and injury/motor vehicle-related impacts on vulnerable and general populations in the community. The Battlement Mesa Baseline Health Profile (Appendix C) provides supporting documentation of baseline physical and social health determinants. In addition, a Human Health Risk Assessment (Appendix D) provides a comprehensive review of available air quality and water contamination data and a systematic assessment of related health risk.

The HIA offers recommendations to the BOCC to help it address mitigate some of impacts of the Antero plan. It is important to recognize that it is not possible to mitigate all impacts. We have provided a relative rank for each stressor, to help emphasize where the most important impacts may occur.

Adoption of any recommendations of the HIA is at the discretion of the BOCC. We will assist in implementation, if requested by the BOCC, by continuing with stakeholder and professional presentations. We will continue to monitor how this HIA is used, in order to measure its value as a public health tool.

ES3 Battlement Mesa Baseline Health Profile

Several measures of health are best determined by using zip code to define a community. We use the zip codes 81635 and 81636, which are used by the residents of Battlement Mesa, Parachute and surrounding areas. Because these zip codes are shared, Parachute is included along with Battlement Mesa in the descriptions of physical health determinants and some social health determinants. Some of the social health determinant measurements were not available at a zip code level and so we provide descriptions of these at a county level. While the assessments of stressors focus on the impacts to those living within the Battlement Mesa PUD, others living nearby may experience some effects as well. The Battlement Mesa Baseline Health Profile is available in Appendix C.

ES3.1 Vulnerable Populations

Greater than 45% of the population may be considered to be more vulnerable to certain exposures, based on age. Additional factors, such as pre-existing disease, pregnancy and behaviors such as smoking history, alcohol use, nutrition, and genetic factors can also influence vulnerability to disease. Furthermore, occupational and residential exposures may also contribute to risk of disease. Although these factors can contribute considerably to vulnerability to disease, such information was not available to the HIA team and represents an important information gap that will need to be addressed in the future.

ES3.2 Physical Determinants of Health

To assess the baseline physical health of the Battlement Mesa/Parachute area, the CSPH team obtained and analyzed inpatient hospital diagnoses, cancer, birth, and death information from the CDPHE for the years 1998-2008. The analysis included health diagnoses, birth outcomes, and causes of death with a known association between disease and the exposures of concern, as well as those for which community members voiced concerns of elevated occurrence of disease. Major categories of disease and death included depression and those involving the nervous system, ear/nose/throat, vascular system and pulmonary system. Major categories of cancer included: Hodgkin lymphoma and non-Hodgkin lymphoma, multiple myeloma, leukemia, melanoma, breast cancer, prostate cancer, bladder cancer, colorectal cancer, and cancer of the adrenal gland. Birth outcomes included low birth weight and preterm delivery. Health for Battlement Mesa/Parachute residents was compared to the health of Colorado residents.

Overall, the citizens of Battlement Mesa appear to be generally healthier than other citizens of Colorado. They experienced fewer hospitalizations and fewer deaths. Battlement Mesa women experienced the same rates of cancer and of negative birth outcomes as other women in Colorado. In Battlement Mesa men, we observed a slightly higher than expected rate of prostate cancer, which we felt is an observation likely due to variability of small numbers or statistical chance (when multiple independent tests are compared, there is a statistical probability that 5 % of the tests will be abnormal by chance alone). No other differences were noted between men in Battlement Mesa when compared with other Colorado men.

ES3.3 Social Determinants of Health

To evaluate the baseline community health in Battlement Mesa/Parachute, the CSPH team obtained available information regarding sexually transmitted infections, crime, substance abuse, and education. Where information concerning Battlement Mesa was not available, we looked at Garfield County data.

Overall, the incidence of sexually transmitted infections in Garfield County rose during the years 2005- 2008, peaking between 2007 and 2008. Between the years 1992-2005, for adults, violent crime arrests doubled; property arrests fluctuated throughout the period, and increased slightly; and drug violations increased almost ten-fold. In the same time period, for juveniles, violent crime arrests increased; property arrests fluctuated but did not change significantly; and drug violations increased almost ten-fold. Substance abuse information extracted from the GCPH's 2006 assessment on community needs indicates depression, anxiety and stress along with tobacco smoking and alcohol abuse appear to be the top indicators of the burden of mental health and substance abuse, respectively, in Garfield County.

ES4 Assessment of Health Impacts

The HIA team developed a method for assessing and comparing potential health impacts for several areas of concern (stressors) by identifying and defining seven attributes relevant to the importance of potential health effects: direction of potential health effects (i.e., a positive or negative impact on health); the relationship of geography to health effects (i.e. proximity to natural gas development and production activities); the likelihood of health effects occurring as a result of Antero development plans; the presence of people considered especially vulnerable to the effects of the stressor; the estimated duration of exposure; the frequency of exposure when it does occur; and severity of the potential health effect.

To assist in characterizing the relative importance of health effects within this HIA, we assigned a numerical rank to each stressor. The lowest possible rank is 6 and the highest possible rank is 15 (six stressors are assigned values of 1 to 2 or 1 to 3). A negative (-) number indicates that the stressor is likely to produce negative health effects, a positive (+) number indicates that the stressor is likely to produce positive health effects. Some stressors may produce both negative and positive health effects and are therefore given a mixed (+/-) numerical rank. These rankings may be used to help describe the relative importance of each potential health effect within the context of this HIA only. It is important to note that these ranks do not represent a quantitative estimate of risk and have no relevance outside the context of this HIA.

These assessments take into account Antero's proposed control plans and mitigation strategies, to the extent that they are known (from public presentations, Surface Use Agreement, and other information provided by Antero). Any significant deviation from the available information will not necessarily be reflected in this HIA.

ES4.1 Summary of Air Quality Assessment

The Air Quality Assessment relies upon the Human Health Risk Assessment (Appendix D) to determine the potential for air quality compromise. Plans for drilling throughout the community suggest that all areas within the PUD have the potential to be impacted by local emissions.

The Antero natural gas development plan is likely to change air quality and produce undesirable health impacts in residents living in close proximity throughout the community. Air quality is most likely to be acutely impacted during well pad construction and well completion stages and by truck traffic. Long term compromise of air quality is possible if fugitive emissions from production equipment are not controlled and the impacts to air quality are expected to occur constantly and/or reoccur. Children, older adults, and individuals with respiratory diseases may be more vulnerable to the air contaminants and could experience short-term and/or long-term disease. Health impacts may include respiratory disease, neurological problems, and there may be an increased risk of cancer. Medical attention would be necessary for some of these conditions. Some of these health consequences would not be reversible, and therefore should be considered moderate to high magnitude impacts. Using the numerical ranking scheme, air quality impacts on health are expected to produce a negative rank of -14.5 on a scale of ±6-15.

ES4.2 Summary of Water and Soil Quality Assessment

The primary drinking water source for Battlement Mesa is the Colorado River and the intake is upstream of areas potentially impacted by the Antero drilling plan. The primary drinking water source is therefore not likely to be impacted by Antero's Battlement Mesa natural gas development and production plans. The secondary water source is a series of ground water wells located "downhill" from some of the planned well sites. Since the hydrology of the area is not well understood, the likelihood that these wells could be compromised by drilling in the PUD is unclear, but their location suggests that they could be compromised by natural gas development and production activities.(See Appendix D for supporting documentation).

Impact on water quality in Battlement Mesa is not expected to occur frequently and it is unlikely that contamination of drinking water will occur as a result of Antero development plans. However, should water and soil contaminant exposures occur, these changes would produce undesirable health impacts. Areas in close proximity to the development areas would be most likely to show contamination of soil and shallow water. Impacts could be community-wide, should the need for compromised secondary water wells arise. Localized effects of wind erosion and surface run-off may impact children more than adults. Children, older adults, and individuals with pre-existing illnesses may be more vulnerable to water and soil contaminants. Reversal of water quality degradation could take years, and thus any impacts could be enduring. Should exposure occur, health impacts may include cancer, skin and eye irritation, neurological problems. It is likely that medical attention would be needed for some of these resulting conditions and that some of these health consequences would not be reversible; therefore an impact would be considered moderate to high in magnitude. Using the numerical ranking scheme, compromise to water and soil quality would produce a negative rank of -11.5 on a scale of ±6-15.

ES4.3 Summary of Traffic Assessment

The traffic assessment relies on estimated average traffic counts provided to us by Antero. While such numbers are somewhat useful for the purpose of this HIA, the estimates may not reflect true numbers of vehicles on any given day. The Garfield County Geographic Information Systems Services is working on a map with the traffic routes Antero anticipates using for their natural gas development and production. This map also will contain information concerning school bus stops in Battlement Mesa, provided to the CSPH team by the Garfield County District 16 transportation office.

When considering safety risks to residents of Battlement Mesa, increased traffic is likely to create negative health impacts. Because the haul routes include the entire circle of the Battlement Mesa Parkway as well as other roads within and on the perimeter of the PUD, the impact of the traffic is likely to be community wide. Certain parts of the community will experience a greater impact for the entire duration of the Antero project (i.e., those homes next to CR300/Stone Quarry Road) while others will be impacted by very high volume traffic during the construction of some of the pads (i.e., along River Bluff Road). Because children often walk and ride bicycles and are not as safety conscious, children are considered more vulnerable than most adults to the impacts of traffic. The duration of exposure to increased traffic will likely be long, spanning the entire duration of the development the gas wells, at this time expected to be at least five years. The traffic will be frequent in some cases (River Bluff Road) where it is estimated that several hundred trucks passing a day for several months. Increased traffic is associated with increased risk of traffic accidents. Traffic accidents can cause minor to severe/fatal injuries and as such, there is wide range of potential health impacts. Using the numerical ranking scheme, impact due to traffic produces a negative rank of -13 on a scale of ±6-15.

ES4.4 Summary of Noise, Vibration, and Light Assessment

Anticipated noise, vibration and light exposures associated with the Antero development within the PUD may produce negative health effects. Of the three, noise is likely to have the most important impact on health. Increased noise is expected to be associated with construction and development phases and with truck traffic on haul routes. While all or most parts of the community may be near noise sources at different times, it is not likely that the entire community will be affected by noise during the development of an individual pad or by truck traffic. There are some residences that are close to haul routes and may experience elevated noise due to truck traffic for the entire development period (five years). Children may be more vulnerable to noise disturbance associated with truck traffic passing by the St. John Elementary School and the

Grand Valley Middle School during school hours. In addition, persons working at home may also be more vulnerable to noise disturbance. The elderly, particularly those with impaired hearing, may also be more vulnerable to noise pollution. Pad development will last several months, while nearby truck traffic may last several years for some residents, and thus, duration of exposure is expected to be medium to long, depending on location. On the other hand, major elevations in noise levels are not expected to occur during normal production phases in the 20 years subsequent to well development. Should well maintenance (workover) be conducted, noise levels are expected to increase during the reworking phase, which can last several days per well. When noise occurs, it is expected to be constant (e.g. diesel generators) and/or frequently reoccurring (e.g. truck traffic), depending upon the source. It is unlikely that noise exposure will cause noise-induced hearing loss or other noise-related health effects. In general, health impacts are likely to result from annoyance due to noise above background and may cause sleep disturbance, displeasure, fatigue, etc. It is not likely that medical attention will be necessary for most people, although some may seek medical assistance. Therefore the impacts are rated as low- medium magnitude. It is possible that in some individuals, noise levels will produce significant annoyance and may produce larger health effects. Using the numerical ranking scheme, impacts to safety due to noise, vibration, and light increases produces a negative rank of -10.5 on a scale of +/-6-15.

ES4.5 Summary of Community Wellness Assessment

Community wellness is difficult to define and more difficult to measure. We describe crime rates, mental health, substance abuse and suicide, occurrence of sexually transmitted infection and enrollment in K-12 education as measures of community wellness. Other factors, such as recreational opportunities and social cohesion do not lend themselves to measurement, but were considered in the assessment. Antero estimates an average of 120-150 persons to be working in Battlement Mesa. This estimate was used to evaluate the impacts on these aspects of community wellness.

Effects on community wellness are expected to be mixed. Positive effects might include less stress over finances, if increased demand for local business benefits the local economy, and increased access to social resources, services and infrastructure that expand to support a growing and changing population. For example, increased school enrollment can lead to more educational opportunity (Jacquet, 2009). Negative effects may include increased substance abuse, crime, sexually transmitted infection, demands on the education system beyond current capacity, interference with recreational activity and decreased social cohesion. Community impacts would be expected to be community wide, affecting the entire geographic extent of the Battlement Mesa PUD. It is possible that the elderly or youth of the community are more vulnerable to impacts on community well-being. Elderly may be more vulnerable to crimes of theft or burglary, and are the likely group most affected by changes in social service availability and accessibility. Children would be most affected by changes in school enrollment and class size. They may also be affected by changes in outdoor areas used for play, which may overlap with areas prone to more industrial activity or along haul routes. We expect the community impacts to continue for the duration of the development phase of Antero's project (five years). However, because the Antero project is relatively small, it is expected that exposure to factors that impact community wellness will actually be infrequent and unlikely. If impacts do occur, they are anticipated to have low to medium impacts on citizens in the community. The overall magnitude of negative health effects are expected to be low to medium and may be related to distress over changes to the community, to increased availability of illegal substances, and more widespread sexually transmitted infection. The overall magnitude of positive health effects are expected to be low and related to decreased financial stress for some residents and possible increased resources for schools. Given adequate coverage and support offered by social infrastructure, we expect the residents of Battlement Mesa will be able to successfully adjust to the impact on community well-being. Using the numerical ranking scheme, impacts to community wellness produce a mixed rank of ± 11.5 on a scale of ±6-15.

ES4.6 Summary of Economic and Employment Assessment

The economic and employment assessment is based upon Antero's estimate of an average of 120-150 workers, (both direct Antero employees and subcontracted workers) for a 2 rig operation over the five year development period. It is important to note that these numbers represent an estimate of the average number of workers and may not reflect employment on any given day.

The economic and employment changes related to Antero gas development in Battlement Mesa may produce mixed health effects. Positive effects would be related to higher wages for some residents, while negative effects would be related to higher inflation and no wage increase for others. Economic impacts would be experienced community wide and those on fixed incomes would be more vulnerable to the negative effects of inflation. The impacts of increased economic activity are likely to last the duration of the five year development period. The frequency health impact (stress, sleep disturbance) as a result of the economic activity is likely to be infrequent to constant, depending upon the individual circumstances. It is, however, unlikely that there will be large positive or negative economic impacts from the Antero development, given the relatively small economic scale of project and the probability that such impacts will be absorbed into Garfield County as a whole. Health impacts due to changing economic conditions are expected to be of low magnitude. Using the numerical ranking scheme, impacts on the economy and employment produce a mixed rank of ± 10.5 on a scale of ± 6-15.

ES4.7 Summary of Health Infrastructure Assessment

The assessment of changes to health infrastructure impacts on health is also based upon Antero's estimate of an average of 120-150 workers, on a two rig operation over the five year development period.

Changes to local health infrastructure associated with an increase in workforce and population in Battlement Mesa and the associated potential increase in health care utilization could have mixed health impacts on Battlement Mesa community. Positive impacts could occur if the workers are insured and therefore support the existing healthcare system when it is used. On the other hand, if workers are uninsured, their use of medical services could strain the health system. However, like the economic impacts, health care system impacts are anticipated to be small given that Antero estimates an average workforce of 120-150 workers. Health care utilization is likely to be spread into Garfield County, depending upon where the workers live. Impacts of uninsured workers are likely to be noted by providers, but it is unclear that this would reach a level that would negatively impact either clinical or public health services. The potential for increased utilization of the health care services to strain existing services is small unless a large number of workers are uninsured and they all utilize the same services. It is not expected that the extent of such a strain would lead to decreased availability and quality of clinical services. Likewise, insured workers will support local health services but the extent of such support may not be sufficient to lead to increased availability and quality of services. Local tax revenues from the Antero project will contribute to the overall county fund, but are not likely to be large enough to directly impact public health services in Battlement Mesa. Should health services be impacted in Battlement Mesa, the impacts would affect the entire community, and those that utilize health care services most frequently such as the elderly, young children and disabled may be more vulnerable to negative impacts such as decreased availability. Likewise, those groups would benefit from expanded health care services. Should health service impacts occur, they are likely to be noted in the first few years of Antero's project as the health infrastructure adjusts to new needs. Impacts to the health care infrastructure are not anticipated to last the entire duration of the project. The frequency of both positive and negative on impacts the health care system and therefore on the community are likely to be sporadic, given that the relatively small number of workers and families associated with the project. It is possible that large financial strain to local providers, particularly emergency care providers, could occur should expensive emergent care become necessary for an uninsured worker, but this is anticipated to be an infrequent event. Potential impact to vulnerable groups, the community at large and the multiple years of potential exposure create a relatively high ranking, however, it is unlikely that Battlement Mesa citizens will experience positive or negative health impacts as a result of changes to the health care infrastructure related to the project. Any impacts to health as a result of changes to the health care infrastructure are expected to be low. Using the numerical ranking scheme, impacts on the economy and employment produce a mixed rank of ± 10 on a scale of ±6-15.

ES4.8 Summary of Accidents and Malfunctions Assessment

The assessment of accidents and malfunctions relies on a review of past accidents and malfunctions in Garfield County, Colorado from the COGCC incident database and individual cases in other areas. The very nature of accidents and malfunctions makes it difficult to predict whether or how an incident may impact health. Review of several years of COGCC data however, indicates that reportable incidents occur in approximately 6% of wells permitted, state wide, in Garfield County and for Antero's previous operations, as well. Therefore, it is possible to predict that with 200 wells being drilled in Battlement Mesa, there may be approximately 12 incidents that could be considered an accident or malfunction.

When considering the possible health impacts due to an accident or malfunction, the impacts are likely to be negative. Depending upon the size and nature of the incident, health and safety impacts may be felt by those only in close proximity, or throughout the PUD. Again, depending upon the nature of the incident, certain populations may be more vulnerable to health impacts. For instance, elderly or frail and those living in the assisted living facility, may have difficulty evacuating an area quickly. Children in school may also be slower to evacuate. Those with underlying medical conditions such as pulmonary or cardiovascular disease may have negative health effects related to fires or air emissions at levels that are may not have significant impact to others. Accidents and malfunctions are likely to be short in duration and infrequent. Given the 6% rate of incidents in the industry and within Antero's other operations in Garfield County, incidents are likely to occur and it is possible that health impacts will occur. The health impacts will be low to high in magnitude, potentially ranging from minor irritation to more severe exacerbation of underlying health conditions to severe injury or death. Using the numerical ranking scheme, impacts to health due to accidents and malfunctions produce a negative rank of -10 on a scale of ±6-15.

ES5 Recommendations

At the end of each assessment we have provided several recommendations aimed at decreasing negative public health impacts, improving positive ones, and filling information gags. The summary recommendations that could be acted upon in the near future are listed below, and more long term summary recommendations are listed in the following section.

- **Promote Pollution Prevention:** Require Antero to use best available technology and rapidly adapt new technology, to reduce emissions of air, water and soil pollutants as well as noise reduction and control. Establish a system for short-term odor monitoring and reduction during gas well completion.

- **Protect Public Safety:** Review pipeline system for routes that avoid proximity to homes, schools or other areas used by residents. Require best available technology to avoid accidents and malfunctions and regular inspection of facilities and pipelines. Review emergency response plans and periodically test emergency response system.

- **Address Boomtown Effects**: Develop plans to address temporary and permanent population influx that may affect demand and capacity of social services, schools and other key community facilities and programs. Identify gaps in access to public health or social services and implement monitoring of community health needs.

ES6 Next Steps and Conclusions

This HIA used the compiled baseline health characteristics of Battlement Mesa, current ambient environmental conditions in Garfield County and Antero's proposed gas development and production plans to evaluate probable and possible health impacts of Antero's project to the residents of Battlement Mesa. Through this process we have attempted to address the concerns of the citizens outlined in the BCC petition.

At the end of each assessment we have provided recommendations aimed at decreasing potential negative health impacts, based upon existing information. However, we also identified numerous gaps in information that limited this evaluation and may limit future evaluations of health in Battlement Mesa. Recommendations intended to address some of these gaps are provided in the HIA. Some of these issues will be addressed in an environmental health monitoring study (EHMS) currently being developed by CSPH investigators. These "next steps" recommendations can be summarized as follows:

- **Establish Baselines:** Improve monitoring of environmental exposures and health effects. Past environmental monitoring (i.e., air, traffic) and public health tracking (e.g., substance abuse, mental health) are insufficient to establish current health impacts among Battlement Mesa/Garfield County residents during gas development and production.

- **Enhance Environmental Monitoring**: Establish monitoring and data systems to conduct ongoing measurement of environmental exposures. Such exposures include 1) pollution of air, water and soil impacts; 2) physical hazards such as traffic, noise, vibration and light, and 3) psychosocial and community changes. Where feasible, tie environmental monitoring to risk-based environmental standards.

- **Improve Health Effects Tracking Systems:** Develop a robust health tracking system for Battlement Mesa/Garfield County so that providers report health conditions potentially related to natural gas development and production to the county health department.

- **Ensure Transparency:** Make exposure and health monitoring data from all public and industry interventions and monitoring available to the Battlement Mesa/Garfield County residents public in a timely manner.

- **Enhance Current Regulations:** Utilize findings of the HIA and future studies to complement ongoing state and local efforts to protect public health.

Because natural gas development and production will continue to grow in Garfield County, other parts of the region and state, as well as other parts of the country, the results of this HIA and the future EHMS will likely have application beyond the study area and will contribute to filling many knowledge gaps about natural gas development and production and health.

In addition, because the domestic natural gas resource is part of the national policy to increase domestic energy production and reduce greenhouse gas emissions, a high level discussion of the health implications of this policy needs to take place. While municipal, county and state governments have begun to respond to citizen concerns, a national discussion of the benefits and risks associated with this policy is due. As outlined in this HIA, in addition to potential local economic benefits of energy development, there are potential local negative impacts to the physical and social health of the community. It will be important to understand public health implications in the context of national priorities for domestic energy production.

Table of Contents

Annotated Acronym Definitions

Antero: Antero Resources Corporation

BCC: Battlement Concerned Citizens: Grassroots citizen group formed in response to the Antero gas project.

bgs: below ground surface

BMC: Battlement Mesa Company: Owner of mineral and surface rights in Battlement Mesa.

BMSA: Battlement Mesa Service Association: Home owners association for Battlement Mesa residential communities.

BOCC: Garfield County Board of County Commissioners: Requested county environmental health to develop proposals to respond to citizens health concerns. Have indicated that HIA and health study proposals will satisfy this request.

BTEX: Benzene, Toluene, Ethyl-benzene, Xylene

CDPHE: Colorado Department of Public Health and Environment: Has consultative responsibility to the state permitting agency for comment health and environmental concerns, but has no regulatory responsibilities.

COGCC: Colorado Oil and Gas Conservation Commission: Colorado regulatory and permitting agency. Maintains databases for water quality, spills, and well locations Databases include federal and tribal lease owners as well as state lease owners. Provides permitting for state lease owners only.

CR: County Road

CSPH: Colorado School of Public Health: Faculty within the school, in the Division of Occupational and Environmental Health are primary investigators.

dB: decibel

EHMS: Environmental and Health Monitoring Study

EnCana: EnCana Oil and Gas (USA) Incorporated

EPA: United States Environmental Protection Agency

GCPH: Garfield County Public Health Department: county health agency with environmental health program. Environmental health program directed to respond to citizen concerns and has strong ties to all stakeholder groups. Environmental health program considered a regional leader in health and gas E&P.

HIA: Health Impact Assessment

µg/L: micrograms per liter

µg/m^3: micrograms per cubic meter

PM: Particulate Matter

PM$_{2.5}$: Particulate Matter of 2.5 microns or less

PM$_{10}$: Particulate Matter of 10 microns or less

PAH: polycyclic aromatic hydrocarbon

ppb: parts per billion

PUD: Planned Urban Development

RV: Recreational Vehicle

Saccomanno Study 2008 Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County, Colorado

SGM: Schmueser/Gorden/Meyer Inc.

SIR: Standardized Incidence Ratio

tpy: tons per year

VdB: vibration decibels

VOC: Volatile Organic Compound

vt/d: vehicle trips per day

USGS: United States Geological Survey

Part One: Health Impact Assessment

Preface

HIA is used to evaluate objectively the potential health effects of a project or policy before it is built or implemented. HIA can provide recommendations to increase positive health outcomes and minimize adverse health outcomes. The HIA framework is used to bring potential public health impacts and considerations to the decision-making process for plans, projects, and policies that fall outside of traditional public health arenas, such as transportation and land use. - Centers for Disease Control [1]

The health of an individual human being is determined by a complex interaction of social, economic, genetic, and environmental factors which he or she experiences throughout life. Income, access to clean drinking water, unpolluted air, social support from friends and family, healthy food, access to education, and a whole host of other factors combine to have a profound effect on the health of an individual.

Similarly, when social, economic, and environmental conditions are common to a group of people, those conditions can influence the health of the population as a whole. Public policies have the potential to impact population health. While there are public programs and policies designed to influence population health (e.g. food safety regulations), population health is not accounted for in all or even most of the policies that can impact health. To improve the accessibility and utility of existing scientific knowledge as it applies to program and policy development, public health researchers have developed the Health Impact Assessment (HIA) approach. While HIAs vary in their goals and methods, the general approach is consistent across HIAs: A group of public health experts works with community stakeholders to identify the potential health risks and potential benefits to public health of a proposed policy, program, or project. The HIA team then collects information to assess how likely public health will be impacted. Based on the potential impacts and the estimated likelihood of those impacts, the HIA team offers recommendations to maximize public health gains and minimize negative effects of the program, project or policy at hand.

While the goal of an HIA is to anticipate and provide recommendations that advance public health, it cannot be expected to prevent all negative health impacts of a given decision. A HIA is an approach to incorporating public health into decision-making processes. As opposed to costly retrofitting and remediation, HIAs are proactive and preventive public health tools that have the potential to save health care costs in the long-term. HIAs are open processes that necessarily include stakeholder participation, review, and input as an essential part of the methods. Through this open dialogue, the HIA seeks to generate realistic and broadly supported recommendations to protect public health.

A HIA differs from a scientific epidemiological study in that an epidemiological study typically evaluates the effects of exposures on populations after the exposures have occurred, whereas, a

HIA is conducted before a project or policy is started, with the ultimate goal of identifying potential exposures and determining if there are needs to mitigate their impact on health. Both kinds of investigations provide valuable information to those concerned with understanding and protecting public health.

Regarding Ozone and Human Health

The impact of ground level ozone and ozone precursors are not included in this HIA. The Antero project itself will contribute ozone precursors (volatile organic compounds (VOCs) and nitrogen oxides), however, it is the sum of the ozone precursors produced in the county that contributes to ozone levels county wide. Ozone can cause important negative health effects and should be the considered when discussing public health in Garfield County. However, the impact of Antero's contribution to ozone on the health of Battlement Mesa citizens is not discussed in this assessment.

Regarding Climate Change and Human Health

This Health Impact Assessment does not account for the potential health effects of climate change. There is reason to believe that fossil fuel combustion has changed the global climate[2]. There is also reason to believe that climate change will impact human health[2]. However, it is in the opinion of the HIA authors that while this specific natural gas development contributes to climate change, is not likely to influence the global climate enough to have a measurable impact on the health of Battlement Mesa residents.

1 Introduction

This report summarizes the Battlement Mesa HIA commissioned by the Garfield County Board of County Commissioners (BOCC) with the Colorado School of Public Health (CSPH). The introductory section provides context for the HIA, a site description, and Antero Resources Corporation's (Antero) plans for Battlement Mesa.

1.1 The Battlement Mesa Community

The Battlement Mesa Planned Urban Development (PUD) is a 3,200-acre unincorporated jurisdiction divided into several neighborhoods, the names of which are:

- The Reserve
- Battlement Creek Village
- Willow Creek Village
- Willow Ridge Apartments
- Willow Park Apartments
- Eagles Point
- Valley View Village
- Fairway Villas
- Stone Ridge Village
- Monument Creek Village
- Canyon View Village
- Mesa Ridge
- Mesa Vista
- Tamarisk Village
- Tamarisk Meadows
- Saddleback Village

The community sits on a 500 foot mesa approximately to the south of Colorado River and mesas continue to rise above the community for another 500-1000 feet. There has been natural gas development and production going on for the last several years outside the PUD.

A 2005 academic study describes Battlement Mesa's transformation from a company town to a retirement community. Depending on the neighborhood, homes range from $85,000 to $450,000 in price and from 1,500 square feet to 4,400 square feet in size. While the community is often thought of as a "retirement community" (4), in fact there are also many families with children that live in Battlement Mesa. [3]

1.1.1 Parachute

Because the town of Parachute shares a zip code with Battlement Mesa, the HIA includes Parachute in several sections, including the health outcomes baseline analysis. Parachute is a small town adjacent to Battlement Mesa. Parachute sits at the base of the Parachute Creek valley, between the Battlement Mesa PUD to the south and a large natural gas field to the north, at an elevation of 5,000 feet. Both Interstate-70 and the Colorado River run through the town. Parachute has a population of approximately 1,300 people and there are small family ranches outside the town limits. There is significant industrial activity in Parachute Creek valley and on the surrounding mesas, including natural gas development and production, a gas processing plant and a bicarbonate of soda plant.

1.1.2 Demography[4]

According to the 2000 United States Census estimates, there total population of the Battlement Mesa/Parachute zip code was 5,041; 49.3 percent of the Battlement Mesa/Parachute population was female and 50.7 percent male. The median age was 37.5 years. 26.0 percent of the population were under 18 years of age, 7.2 percent under five years, and 19.8 percent were 65 years and older. For people reporting race in Battlement Mesa/Parachute, 93.4 percent identified as White, 0.5 percent as Black or African American; 9.7 percent of the population identified as Hispanic or Latino (of any race). In Colorado in 2000, 9.7 percent of the population was 65 years and over compared to 19.8 percent of the population in the Battlement Mesa/Parachute zip code.

Demographics
Population Battlement Mesa/Parachute, 2000 Total population: 5, 041 Males: 2,487 (49.3) Females: 2,554 (50.70) Mean age 37.5 Garfield County 2000 Total population: 43,791 2009 Total population estimate: 56,298 % change 2000-2009: 28.6%

Demographics
Vulnerable populations Battlement Mesa/Parachute Under 18: 1,311 (26.0) Over 65: 998 (19.8) Total <18, >65: 2309 (45.8)

Although the Battlement Mesa PUD is often described as a "retirement community", it is difficult to precisely define a "retirement community". Several objective measures reflect the characteristics of Battlement Mesa's population. In 2000, the percentage of Battlement Mesa residents, excluding Parachute, aged 65 years and older was approximately twice the national average (24.5 % vs. 12.4%, respectively). Furthermore, whereas 63.9% of the United States population (aged 16 years and older) was participating in the labor force, only 48.9% of Battlement Mesa residents were either working or looking for work in 2000.

While the lower labor force participation rate of Battlement Mesa residents and the higher proportion of people aged 65 years and over are likely indicators of a high retiree population in the PUD, almost half of the PUD residents aged 16 years and over were either working or looking for work. More than a quarter of the family households in Battlement Mesa had children under the age of 18 years (27.2%). So, while the Battlement Mesa PUD is home to higher proportions of people aged 65 years and over than the United States as a whole, the community is not homogeneously "retired."

1.1.3 Economy

Currently, the Battlement Mesa community is entirely residential. The only businesses in the PUD support the local residents. While several natural gas operators drill extensively the area surrounding the PUD, there are currently only two natural gas wells in the PUD itself. The businesses within the PUD include:

- A grocery store
- Two gas stations
- Several medical facilities
- A public golf course
- Banks
- A café
- A recreation center (paid for by homeowner association dues)
- A local newspaper

In addition to the local businesses, the PUD is home to two churches (with five others in Parachute), a 40-unit assisted living facility in the Battlement Mesa PUD serving seniors of low to moderate income,[3] and three schools – Underwood Elementary School (grades 1-3), St. John Elementary School (grades 4-5) and Grand Valley Middle School (grades 6-8). Battlement Mesa students attend the Early Childhood Center for pre-kindergarten and kindergarten and Grand Valley High School in Parachute for grades 9-12. These schools are all in Garfield County District 16.

1.2 Antero's Plan to Drill Within the Battlement Mesa PUD

The combination of technological advances (e.g. hydraulic fracturing), Federal and State economic incentives to develop natural gas resources and population growth in previously uninhabited (or sparsely inhabited) areas have contributed to a relatively new phenomenon. Whereas oil and gas development has historically taken place in locations that are geographically distant from human habitation (other than, perhaps, the housing for oil and gas workers themselves), it is increasingly common for drilling activities to occur in rural, suburban and urban areas close to where people otherwise unaffiliated with the industry live, work and play[5]. Throughout the country and in Garfield County, the residents in close proximity to drilling activities are raising concerns about the potential impacts drilling may have on air quality, water quality, public safety and public health[6]. The human health impact natural gas development and production has not been thoroughly studied.

In the Spring of 2009, Antero announced plans to purchase surface rights and mineral rights from the Battlement Mesa Community (BMC), as well as its intent to develop natural gas within the Battlement Mesa PUD[7]. The contract that establishes the PUD requires the Garfield County BOCC to review and any proposed land-use changes within the Battlement Mesa PUD through a *Major Land Use Impact Review* (also know as the MLUIR) process. The Garfield County BOCC has the authority to require modifications to the plans outlined in a given Major Land Use Impact Review application. Because its plans pertain to the Battlement Mesa PUD, Antero will submit a Major Land Use Impact Review to the BOCC before initiating their drilling activities. In addition to county review, Antero will also submit plans through a state permitting process, conducted by the Colorado Oil and Gas Conservation Commission (COGCC). Under a 2008 rule[8], natural gas operators may submit Comprehensive Drilling Plans to COGCC[9]. If Antero submits a Comprehensive Drilling Plan to COGCC, COGCC will review the development project as a whole, which streamlines permitting for individual wells within Antero's project. The Comprehensive Drilling Plan has not been submitted as of the date of this HIA report. Antero has, however, entered into a legally-binding Surface Use Agreement with the BMC. This Surface Use Agreement outlines characteristics of its natural gas drilling plans for the Battlement Mesa PUD. While not as detailed as a Major Land Use Impact Review or Comprehensive Drilling Plan, the Surface Use Agreement between Antero and the BMC provides some information regarding Antero's plans for the Battlement Mesa project. Furthermore, Antero held several community meetings during 2009 and 2010 where plans for Antero's project were described and the power point presentations from these meetings are available online[10-11]. These sources of information plus information provided to the CSPH team are used to as a basis for this HIA. Appendix A includes a summary of the natural gas drilling process. Appendix B includes a review of energy development in the Piceance basin and the Surface Use Agreement between Antero and BMC.

1.3 Community Concerns

After Antero announced its intentions to drill within the Battlement Mesa PUD, community members living in Battlement Mesa expressed concern regarding potential environmental, health, and safety impacts. Citizen concerns have included but are not limited to:

- The proximity of drilling and gas production to homes, recreational areas and schools
- “Vulnerable” populations with diminished immune capacity
- Exposure to airborne volatile organic compounds (VOCs), diesel emissions, particulate matter (PM) and other air contaminants
- Exposure to fluids used in the fracking process, hydrocarbons and VOCs through soil or water exposure routes
- Potential increased risk of fires, explosions and/or motor vehicle crashes
- Changes in community “livability”

A grassroots advocacy organization, the Battlement Mesa Concerned Citizens (BCC) formed under a parent organization, the Grand Valley Citizens Alliance. In November 2009, the BCC submitted a citizen petition to the Garfield County BOCC requesting that BOCC require Antero to address health concerns before drilling for natural gas within the Battlement Mesa PUD (Attachment 1).

While the human health impacts of natural gas development and production have not been specifically studied using state-of-the-art public health epidemiologic research methods, there has been substantial research related to exposures of potential concern in the natural gas industry. For instance, drilling for natural gas has the potential to increase occupational and community exposures to VOCs such as benzene, toluene, ethyl-benzene and xylene (BTEX). Heavy metals released in drilling activities, particulate matter (PM) generated by transportation activities and diesel fuel combustion, and ozone precursors (ozone formation) are also known to be associated with natural gas development. Some constituents of fracking chemicals may pose health risks to workers or community members.

Sufficient exposures to these chemical compounds are associated with serious negative health outcomes such as lung disease in children and adults (i.e., asthma, chronic bronchitis, obstructive disease), cardiovascular disease, poor birth outcomes (premature birth, low birth weight), various cancers, and other long and short-term health issues [12-16]. Environmental contaminants to which people may be exposed include air emissions, ground and surface water pollution and soil contamination. In addition, physical hazards can include increased truck traffic and domestic explosions associated with gas seepage into domestic water supplies. Social hazards can include a variety of community disruptions associated with boom-and-bust cycles, itinerant workforces and industrialization of residential areas[17].

1.4 Initial Responses to Community Concerns

In response to community concerns, Antero has held several informational community meetings[11] and has responded to community concerns by modifying its some the drilling plans, for example the removal of drilling pad C (replaced by the Parks and Rec pad). The Surface Use Agreement between Antero and BMC includes some measures which are intended to reduce the impact on the community's health and quality of life.

Even before it commissioned the HIA, Garfield County had undertaken many steps in response to community concerns regarding natural gas development and production in the county. Garfield County Public Health Department (GCPH), the county health department, initiated and managed the Saccommano Report and currently manages on-going ambient air monitoring stations at several locations in Garfield County. The Garfield County Oil and Gas Department initiated and managed an intensive study water quality and hydrology of the Mamm Creek Gas Field. GCPH also has participated in numerous Colorado Department of Public Health and Environment (CDPHE), COGCC, and United States Environmental Protection Agency (EPA) air and water studies documenting:

- Air toxics (e.g. benzene) in ambient air, at levels higher than levels measured in a neighboring county with no gas development [18]
- Evidence of ground-level ozone formation, which once exceeded the EPA 8 hour standard of 75 parts per billion (ppb) in 2008 [19]
- Ground water containing thermogenic methane in natural gas development and production areas [20-22]
- Trends in health impacts consistent with potential exposures (via a county-wide health assessment) [23]
- Citizen concerns over oil and gas impacts to health (via county-wide surveys)[24]

More recently, the BOCC instructed GCPH to address the BCC's concerns raised in its citizen petition. GCPH approached the CSPH with a request to collaborate on a HIA. Subsequently, the BOCC agreed to contract with the CSPH to conduct this HIA. Through funding from the Pew Health Impact Project, a Canadian HIA consultation firm with experience in resource development projects, Habitat Health Impact Consulting has provided technical assistance to the CSPH for this HIA.

2 HIA Methods

Methods for the HIA were based upon guidelines provided by the Pew Health Impact Project[25], as well as those found in the Merseyside Guidelines for HIA[26]. There are seven steps for this HIA, including scoping, screening, assessment, recommendations, implementation, reporting, and evaluation.

2.1 Screening

This HIA is was performed in response to a citizen petition to the Garfield County BOCC requesting a health an environment study be conducted to evaluate potential health impacts of Antero's natural gas project in Battlement Mesa. Garfield County has several years of experience with natural gas development and production and with community concerns over air and water degradation and the potential health impact. The county has responded by initiating ongoing ambient air monitoring and had previously commissioned the 2008 Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County, Colorado (referred to as the Saccomanno Study) [23]. Based upon the results of the air monitoring and the recommendations of the Saccomanno Study, GCPH determined that an HIA could be used to provide decision makers (the BOCC) with valuable information that could allow them to respond to citizen concerns and help them in making informed decisions.

2.2 Scoping

The Scope of the HIA was defined in part by the requests outlined in the BCC petition (Attachment 1). The CSPH team determined that assembly and analysis of baseline health, environmental, and social data were possible within the framework of a HIA. In order to further elucidate specific stakeholder concerns, the CSPH team conducted a series of stakeholder meetings with citizens, the industry state regulatory agency, the state health department, and Antero representatives (Tables 1 and 2). As a result of this stakeholder process, a Scope of Work was written that was informed by citizen concerns in order to provide a framework for the HIA. This work ultimately led to a focus on eight areas of health concern (stressors) specific to natural gas development and production: air emissions, water and soil contaminants, truck traffic, noise/light/vibration, health infrastructure, accidents and malfunctions, community wellness, and economics/employment.

2.3 Assessment

The assessment of the stressors began with a demographic characterization of the population of Battlement Mesa and a baseline health characterization of the community by compiling information from a variety of sources. A Battlement Mesa Baseline Health Profile is included in

Appendix C. This information was used to describe the general population, as well as identify potentially high risk sub-populations. A health literature review, previously conducted by members of the CSPH team, was used to identify potential health risks and vulnerable subpopulations associated with natural gas development and production [27-28]. A human health risk assessment was conducted using longitudinal air and water quality data (Appendix D). All this information was used to develop assessments of air quality, water and soil quality, traffic, noise, community wellness, economics/employment, health infrastructure, and accidents/malfunctions.

Each assessment of the stressors includes a review of its general impact on physical, mental and/or social health as described in relevant medical and social science literature; a compilation and analysis of existing environmental and health data describing current conditions in Battlement Mesa; the means by which Antero's plans for drilling could alter the stressor; and finally a characterization of the stressor's impact on health. Several physical health outcomes linked to potential exposures are considered, including respiratory, cardiovascular, cancer, psychiatric, and injury/motor vehicle-related impacts on vulnerable and general populations in the community. The Battlement Mesa Baseline Health Profile (Appendix C) provides supporting documentation of baseline physical and social health determinants. In addition, the Human Health Risk Assessment (Appendix D) provides a comprehensive review of available air quality and water and soil contamination data and a systematic assessment of related health risk.

Of note, as of the date of this report, Antero had not submitted a Major Land Use Impact Review to Garfield County nor had they submitted a Comprehensive Drilling Plan to the COGCC. As such, based on consultation with GCPH, this HIA has been conducted based upon information provided by Antero to the public in community meetings and provided to the CSPH, by request, from Antero. If the ultimate Major Land Use Impact Review/Comprehensive Drilling Plan presented by Antero differs from the information available to the CSPH team, then it is possible that there will be other risks/benefits not identified in this report.

2.4 Recommendations

At the end of each assessment we have summarized what is known and not known about the impact of the Antero plans on the stressor. We then have provided several recommendations aimed at decreasing negative impacts or improving positive ones. In general, recommendations focus on continued monitoring of air and water sheds and strict enforcement of existing regulations; use of best available current technology and rapid adoption of new technologies to decrease emissions; traffic and noise mitigation; economic benefits used locally to mitigate negative local effects; and planning for the impacts of increased population, as well as for the loss of economic activity when development ends in five years should help decrease social impacts.

2.5 Reporting

This document represents the Draft HIA and Recommendations. This Draft HIA will be delivered to the Garfield County BOCC, and will be presented at a BOCC meeting. The GCPH will post this report on their Battlement Mesa HIA website for public review. There will be a 30-day public comment period, after which stakeholder review and input will be considered in the preparation of the final HIA. There will be a presentation to the community after the report is finalized. External review was provided by Habitat Health Impact Consulting and Dr. Teresa Coons, co-author of the Saccomanno Study. CDPHE provided review of the sections describing Physical Health Determinants and the Human Health Risk Assessment.

2.6 Implementation

Implementation of any recommendations in this report is the responsibility of the BOCC. The CSPH team will assist the BOCC with dissemination and education of the community regarding the findings of the report as needed by conducting community meetings.

2.7 Evaluation

In order to determine the value of this HIA and HIA process to the Garfield County BOCC and stakeholder groups, the CSPH will monitor Antero's project permitting process at both the county and state level. Our evaluation of HIA effectiveness will be, in part, determined by whether potential health impacts and mitigation strategies were considered when the permitting process occurs. In addition, CSPH will seek specific comments from GCPH and Garfield County BOCC on their assessment of the HIA and HIA process. Furthermore, the CSPH will present the HIA and descriptions of the HIA process at several scientific, professional, and community meetings in 2010-2011. Finally, an evaluation report will be delivered to the BOCC by December 31, 2010.

3 Summary of Battlement Mesa Baseline Health Profile

The health of a community can be estimated by measuring a variety of outcomes, including physical health outcomes, social outcomes, rates of injuries, educational climate, and others. There are many factors that can influence health status, such as age, genetic background, personal habits, employment, and environmental exposures or other hazards. The BCC requested that baseline health of the Battlement Mesa community be assessed prior to drilling within the PUD.

In order to determine the baseline health of citizens and the Battlement Mesa/Parachute community, both physical and social health were considered. Where available, information specific to the Battlement Mesa/ Parachute was obtained. Because of the shared zip codes (81635 and 81636), it was not possible to distinguish between the two areas. In some instances, zip code level information was not available in which case county level data are presented. The physical health of Battlement Mesa citizens, based on zip codes, is described by standardized incidence ratios (also known as an SIR). The standardized incidence ratio is a fraction: the proportion of people with a particular health condition divided by the expected proportion of people who have that same health condition. The state of Colorado was used as the reference (expected) population for these comparisons. The health of the community is described by available zip code level statistics for sexually transmitted infection; county level statistics for crime, substance abuse and motor vehicle crashes; and School District 16 educational information. The full and more detailed Battlement Mesa Baseline Health Profile is available in Appendix C.

3.1 Vulnerable populations

It is important to note that within a population there are individuals and groups of individuals which are at increased risk or which are more vulnerable to disease and to injury. Increased vulnerability is dependent upon a number of factors that can be categorized as demographic factors, genetic factors, and acquired factors. Age is an important factor in determining health risk. According to the 2000 United States Census data for the 81635 zip code, greater than 45% of the population may be considered to be more vulnerable to certain exposures, based on age (26 % under the age of 18 and 19.8 % over the age of 65). Acquired factors such as pre-existing disease, pregnancy, and behaviors such as smoking history, alcohol use, and nutrition, as well as genetic factors, can also influence vulnerability to illness and injury. Furthermore, occupational and residential exposures may also contribute to risk of illness and injury. Although these factors can contribute significantly to vulnerability, such information is not available to the HIA team. Future characterization of the prevalence of the factors that influence health would greatly enhance our understanding of this community, especially if that information can be collected prospectively.

3.2 Physical determinants of health

To assess the baseline physical health of the Battlement Mesa/Parachute area, the CSPH team obtained and analyzed inpatient hospital diagnoses, cancer, and death information from the CDPHE for the years 1998-2008. Inpatient hospital diagnosis data were derived from the Colorado Hospital Association Discharge Dataset. Birth data were calculated by the CSPH team using Colorado Birth Registry Data for the years 1998 - 2008. Aggregated counts and the standardized incidence ratio of select diagnoses, birth outcomes, and cancer types are presented in Appendix C. The CSPH team chose to analyze health diagnoses, birth outcomes, and causes of death that are understood to be associated with exposures related to natural gas processes, as well as those for which community members voiced concerns of elevated occurrence of disease. Major categories of disease and death include depression and those involving the nervous system, ear/nose/throat, vascular system and pulmonary system. Major categories of cancer include cancers with known association with exposures of concern, cancers for which there has been community concern, and the five most common cancers in Colorado. These cancers included: Hodgkin and non-Hodgkin lymphoma, multiple myeloma, leukemia (all types), melanoma, breast cancer, prostate cancer, bladder cancer, colorectal cancer, and cancer of the adrenal gland. It is important to keep in mind that just because an exposure to a contaminant is associated with a cancer, it does not mean an individual exposed to the contaminant will get that cancer. The amount of exposure and length of exposure to a contaminant also are important factors in determining the risk of cancer and other diseases. Birth outcomes analyzed included low birth weight and preterm delivery.

Within the hospital data analysis, we looked at several discharge diagnoses and determined that people living in the Battlement Mesa/Parachute zip codes had fewer or equal rates of these diagnoses as their counterparts in Colorado. Battlement Mesa/parachute men and women had fewer than expected diagnoses involving the nervous system, ear/nose/throat and the vascular system and the pulmonary system. Within the cancer data, men in Battlement Mesa/Parachute had a slightly higher than expected prostate cancer rate. This finding is felt to be likely due to slight variation in a small number of cancers. Another possibility is that this slight elevation could simply be due to the fact that when comparing multiple independent health outcomes, there is the likelihood that 5 % of the tests will be abnormal by chance alone. Women had no higher than expected cancer incidence. There were no lower than expected cancer incidences in men or women. Fewer Battlement Mesa men and women died when compared with other Colorado residents. There were fewer deaths associated with nervous system diseases, and major cardiovascular diseases. There were no more negative birth outcomes than expected for the Battlement Mesa/Parachute zip codes.

Physical determinants of health
Hospitalization diagnoses Higher than expected: None Lower than expected: Females: Nervous system, ENT, Vascular, Pulmonary Males: Depression, Vascular, Pulmonary
Cancer Higher than expected: Prostate (felt to be a statistical variation) Lower than expected: None
Mortality Higher than expected: None Lower than expected: Females: Total deaths, Cardiovascular Males: Total deaths
Birth outcomes Higher than expected: None Lower than expected: None

3.3 Social determinants of health

To assess the baseline community health in Battlement Mesa/Parachute the CSPH team obtained available information regarding sexually transmitted infections, crime, substance abuse, motor vehicle crashes, and education from a variety of sources, as summarized in Appendix C.

Information regarding sexually transmitted infections for the years 2005-09 was obtained from the Disease Control and Environmental Epidemiology Division, CDPHE. During this time period, the incidence of chlamydia and gonorrhea in Garfield County rose, peaking between 2007 and 2008. Other sexually transmitted infections (syphilis and HIV) had three or fewer cases each year in Garfield County, and no cases in Battlement Mesa/Parachute.

Information regarding crime was obtained from the Colorado Bureau of Investigation as reported Parachute Police Department for the years 2000-2009, data for the year 2001 was not available. Due to its close proximity and similar community composition, data were analyzed as a surrogate for criminal activity in Battlement Mesa. For the years obtained, total arrests peaked in 2008, with a total of 339 arrests. All categories of arrests: violent offenses, nonviolent offenses, prostitution/sex offenses, substance use offenses, and the category of other offenses fluctuated throughout the period, with an increase in all categories of arrest during the years of 2005-2008.

Significant efforts were made to obtain data on mental health, substance abuse, and suicide specific to residents of Battlement Mesa. We were unable to obtain primary data, however, substance abuse information is publicly available for Garfield County from the Community Health Initiative website. Substance abuse data were extracted from the Garfield GCPH Department's 2006 assessment on community needs. From these data, depression, anxiety, and stress along with tobacco smoking and alcohol abuse appear to be the top indicators of the burden of mental health and substance abuse, respectively. It is important to note that the survey respondents were self-selected through survey distribution at libraries, city halls, community centers, health clinics, and mailings to some randomly selected homes.

Data on school enrollment were collected from the Colorado Department of Education. In 2009, at which time there were 1,229 students enrolled in Colorado School District 16, there was an increase of nearly 400 students (19.0%) since 2005 and 35.7% since 2000. While total enrollment increased significantly, proportional enrollment by grade remained relatively stable. Since 2000, there was a shift in the racial and ethnic profile of students enrolled in the district schools. The percentage of Hispanic children doubled from approximately 15% in 2000 to 30% in 2009 and the percentage of Caucasian, non-Hispanic children decreased from 82% to 65%. Proportions of African American, American Indian, and Asian children are small and remained stable. Student teacher ratios remained stable through the initial period of the oil and gas boom in 2003, with the highest student-teacher ratio seen in the early education setting. Student teacher ratios are not available beyond 2004.

Social determinants of health
Sexually transmitted infections (number of cases, baseline →peak) Battlement Mesa/Parachute Chlamydia: Females: 4→12 Males: 2→7 Garfield County Females: 39→93 Males: 13→27
Crime Violent Crime: 10→18 Nonviolent Crime : 34→40 Prostitution/sex offenses: 0→1 Substance use offenses: 69→46 Other offenses: 63→76
Hospitalization for Alcohol/Drug Abuse and Suicidal Behavior Garfield County 2003-05: 275 persons
Education, Garfield County District 16 Enrollment 2000: 906 2005: 1033 2009: 1,229 (35.7% increase)

3.4 Limitations

Limitations for the data described in the Battlement Mesa Baseline Health Profile section of this document can be found in the Appendix C.

4 Assessment of Health Impacts

Eight potential stressors to health were identified and assessed: air quality; water and soil quality; traffic and transportation; noise, vibration and lighting; community wellness; employment and economy; health system infrastructure; and accidents and malfunctions. These assessments take into account Antero's proposed control plans and mitigation strategies, to the extent that they are known (from public presentations, Surface Use Agreement, and other information provided by Antero). Any significant deviation from the available information will not necessarily be reflected in this assessment. Each stressor was then characterized based on seven attributes relevant to public health: direction of health effects; geographic extent; likelihood; vulnerable populations; duration of exposure; frequency of exposure; and magnitude/severity of health effects. For each attribute, consistent definitions were created and numerical values were assigned to each level of the attributes, as shown in the tables below. The characterization consists of describing and ranking each potential health impact in terms of each attribute. To compare the relative importance of the potential stressors to one another, these numeric rankings were summed for each health impact to create a relative rank. Both the numerical value assigned to each attribute level and the summed rank are qualitative with the sole purpose of helping to describe the relative importance of each potential health impact to the other potential health impacts identified in this HIA. As such, any individual ranking is only meaningful when used in context with another ranking within this HIA. The numeric levels and summed ranks do not represent a quantitative estimate of risk, nor should they be used to compare health impacts identified in this HIA to other HIAs, risk assessments, or health standards.

Direction of Potential Health Effects

Positive	Changes that may improve health in the community	+
Negative	Changes that may detract from health in the community	-

Geographic Extent of Health Effects

Localized	Effects mainly occur in close proximity to drilling or other related activities	1
Community-wide	Effects occur across most or all of the Battlement Mesa PUD	2

Presence of Vulnerable Populations within Battlement Mesa

Yes	Disproportionately affects subpopulations that are more vulnerable to health impacts (e.g. children, the elderly or people with pre-existing health conditions)	2
No	Affects all subpopulations evenly	1

Duration of Exposure

Short	Lasts less than one month	1
Medium	Lasts at least one month but less than one year	2
Long	Lasts one year or more	3

Frequency of Exposure

Infrequent	Occurs sporadically or rarely	1
Frequent	Occurs constantly, recurrently and/or numerously	2

Likelihood of Health Effects

Unlikely	There is little evidence that health effects will occur as a result of this the Antero drilling in the PUD	1
Possible	Evidence suggests that health effects may occur, but are not common in similar situations	2
Likely	Evidence suggests that health effects commonly occur in projects of this type	3

Magnitude/Severity of Health Effects

Low	Causes health effects that can be quickly and easily managed or do not require treatment	1
Medium	Causes health effects that necessitate treatment or medical management and are reversible	2
High	Causes health effects that are chronic, irreversible or fatal	3

EXAMPLE:

The following characterization of a hypothetical health impact from Antero's plan illustrates how attribute levels are assigned and then summed to provide a relative ranking for the potential health.

Impact	Direction of health effects	Geographical Extent of exposure	Vulnerable populations	Duration of exposure	Frequency of exposure	Likelihood of health effects as a result of Project	Magnitude of health effects	Rank
Hypothetical	Negative:-	Localized: 1	No: 1	Short: 1	Infrequent: 1	Unlikely: 1	Low: 1	-6

The hypothetical health impact may produce **negative health effects** only in areas in close proximity to the development areas and is **localized.** No particular pollution is more vulnerable to the health effect. The duration of the hypothetical impact is expected to be less than a month, **short,** and only occur once, **infrequent**. It is **unlikely** to occur and any health effects could be easily managed at home and would be **low**. The hypothetical health impact is has a ranking of -6 out of 15.

The following sections provide an assessment, characterization, and recommendations for each potential health impact.

4.1 Assessment of Air Quality on Health in Battlement Mesa

"What happens if the air is so bad that I have to close all my windows and shut off my swamp cooler?"
June 15 stakeholder meeting

Exposure to airborne contaminants from natural gas development and production is a major concern to Battlement Mesa residents. There is the potential for release of hundreds of airborne contaminants during most if not all natural gas development and production. The potential for release of contaminants to air increases with well installation errors, blow outs, or well fires. Sources of contaminants during these operations include the natural gas resource itself, chemicals used in well development operations, such as fracking, wastes from well development activities such as produced water, and diesel exhaust from trucks and generators.

4.1.1 Air Quality and Health

Natural gas development and production and the diesel engines used to support them have the potential to release hundreds of hydrocarbons, carbonyls, and other contaminants into the air. People can be exposed to these contaminants as they breathe ambient air in and outside of their homes. Some of these contaminants, such as benzene, diesel exhaust, and $PM_{2.5}$, are human carcinogens. Others, such as carbonyls, alkanes, ground-level ozone, and 1,2,4-trimethylbenzene, can act as irritants of the eyes, skin, and respiratory tract or cause neurological effects[29-30]. In addition, hydrocarbons, carbonyls, and nitrogen oxides serve as precursors for ground level ozone formation. The health effects of many other of the potential contaminants are not known. Descriptions of health effects of the air contaminants of potential concern are presented in Section 4 of the Human Health Risk Assessment (Appendix D). The Human Health Risk Assessment reviews ambient air data collected in Garfield County between 2002 and 2009.

In addition to the effects that each of these substances can produce by itself, there is also the possibility of complex health reactions occurring as a result of the interaction of multiple substances. There is some indication that complex mixtures can act additively or synergistically to increase effects on human health. For example, studies on air pollution indicate that continuous exposure of healthy human adults to sulfur dioxide or nitrogen dioxide increases ozone absorption, suggesting that co-exposure to other gaseous pollutants in the ambient air may enhance ozone absorption. Studies that evaluated response to allergens in asthmatics (allergic and dust-mite sensitive) suggest that ozone enhances response to allergen challenge. Other studies have reported increased response (lung tissue injury, inflammatory and phagocytosis) to the mixture of PM and ozone compared to either PM or ozone alone[30-31].

4.1.2 Current Air Quality Conditions

There are several sources of air emissions that currently affect air quality in Battlement Mesa. The main sources are vehicle emissions and natural gas development and production, as described below.

Battlement Mesa residences are located one mile from Interstate-70, which likely has some impacts on the current ambient air quality. The Garfield County emissions inventory indicates that highway vehicles were a primary contributor to carbon monoxide, sulfur dioxide, and nitrogen dioxide emissions in 2007[32]. The current traffic in the Battlement Mesa PUD, described in Antero's traffic analysis, also has impact on the current ambient air quality.

With the exception of two natural gas wells, Battlement Mesa does not currently house any industrial activity. While there are many gas wells located to the north, east, and south of the PUD boundaries, the impact on the ambient air quality within the PUD is estimated to be similar to other rural locations in Western Garfield County without significant natural gas development and production. There currently is no baseline air quality data specific to Battlement Mesa, although the GCPH plans to begin collecting air quality data (carbonyls, SNOMCs, and meteorology) in Battlement Mesa beginning in the Fall of 2010. Therefore, this can be verified when the results from the ambient air sampling in Battlement Mesa are available.

The air quality measurements and risks determined for the Silt-Daley and Silt-Cox monitoring sites in the Human Health Risk Assessment performed with the 2005-2007 ambient air study data and background samples collected in the 2008 Garfield County Air Toxics study were employed to estimate baseline air quality and risk within the Battlement Mesa PUD[33-34]. The Silt-Daley and Silt-Cox monitoring sites are described as rural sites without natural gas development and production.

The average PM_{10} levels at Silt-Daley (9.2 $\mu g/m^3$) and Silt-Cox (13.6 $\mu g/m^3$) were well below the 150 $\mu g/m^3$ National Ambient Air Quality Standard. Chemical speciation of the PM_{10} samples indicated that the main source of carbon in the samples is most likely from a combination of oil and gas production and building heating[18]. The 24-hour average $PM_{2.5}$ levels measured in background samples the Garfield County Air Toxics Study Summer 2008 ranged from 4.9 to 10. 3 $\mu g/m^3$, and were well below the 35 $\mu g/m^3$ National Ambient Air Quality Standard [34].

Baseline cancer risk estimates ranged from 6.2 excess cancers per 1 million individuals at Silt-Daley to 21 excess cancers per 1 million individuals at Silt-Cox, after adjusting for a 30-year exposure duration and 350 day/year exposure frequency. The difference in cancer risk between the two sites is because different contaminants are driving the risk. The cancer risk at Silt-Daley is driven by benzene, which was not detected at Silt-Cox. The cancer risk at Silt-Cox is driven by 1,4-dichlorobenzene, which was not detected at Silt-Daly. At both sites the non-cancer hazard was less the one, below which health effects are not expected to occur.

It is important to note that 2005-2007 and 2008 studies were limited to determining only 128 possible air contaminants. Several other potential air contaminants, such as, ozone, and PAHs, were not measured[33] and therefore not included in the Human Health Risk Assessment or other Human Health Risk Assessment conducted by CDPHE in the past.

EnCana Oil and Gas (USA) Incorporated (EnCana) began conducting ozone measurements in 2007 at their mountain station in Garfield County. The mountain station is located at 8407 feet above sea level in a remote area with very little natural gas development and production. Ozone levels averaged over 8 hours ranged from 17 ppb to 74 ppb. While Encana's ozone data are from a rural area within Western Garfield County, it may not be a good estimate of ambient ozone levels in the Battlement Mesa PUD. This is because of the 3200 foot elevation difference between the two areas (the elevation of the PUD is approximately 5200 feet above sea level). Ground level ozone concentrations vary by elevation, with higher concentrations at higher elevations.

4.1.3 Antero Drilling Plans in Battlement Mesa and Air Quality

Garfield County's 2007 emission inventory indicates that the oil and gas industry (point and non-point sources combined) is the highest contributor to nitrogen dioxide, benzene, and sulfur dioxide emissions within Garfield County. For example, the oil and gas industry contributes five times more benzene to the inventory than any other emission source listed. The oil and gas industry also is a significant contributor to VOC, PM_{10}, and carbon monoxide emissions[32]. Therefore, it is expected that Antero's project will impact air quality in the PUD.

The VOC emissions from natural gas development and production have the potential to degrade the air quality within the PUD, if they are not adequately controlled. There is the potential for the production tank on each well pad to emit 37 tons per year (tpy) VOCs (including methane), based on Antero's estimate of 0.36 tpy benzene and the composition of the condensate at the Watson Ranch Well located on the south east border of the PUD (Antero Battlement Mesa Natural Gas Development Plan Meeting #7, October 7, 2009, Information provided by Antero). Antero has specified that they will use combustors to control VOC emissions from production tanks[7] to achieve a 95% VOC control efficiency in compliance with COGCC rule 805b[9]. Applying a 95% control efficiency to the potential VOCs emissions results in 18.6 tpy VOC emissions from the production tanks on all 10 proposed well pads combined. Production tanks are only one of a number of potential sources of VOCs emissions from natural gas production activities. Some sources, such as flow back operations, are likely to cause a higher emission rate of VOCs, while others may have VOC emissions similar to the production tanks. It is important to note that while combustors may decrease VOC emissions, they have the potential to increase carbon monoxide, carbon dioxide, and nitrogen oxides emissions.

COGCC Rule 324A requires operators to take precautions to prevent significant negative impacts to air; COGCC Rule 317 requires that any gas escaping during drilling must be directed a safe distance from the well and burned (flared); and COGCC Rule 805b requires that gas facilities and equipment shall be operated in such a manner that odors and dust do not constitute a nuisance or hazard to public welfare. However, natural gas development and production may have some impact on localized air quality at residences near the well pad, as evidenced by odor complaints to COGCC and the Garfield County Oil and Gas Department from Battlement Mesa residents in July 2010 (COGCC complaint reports)[9]. The odor complaints occurred during flow back operations at Antero's Watson Ranch Pad located on the southeast border of the PUD, within approximately ½ a mile from several residences, and resulted in COGCC issuing a notice of alleged violation (also known as NOAV) to Antero on 7/14/2010. In the 2005 to 2007 Garfield County Ambient Air study, air samples collected when residents noticed odors (thought to be from natural gas development and production), contained levels of benzene, ethylbenzene, toluene, and xylenes that were greater than EPA regional screening levels for residential ambient air[18]. EPA Regional Screening Levels are health-based levels above which health effects may occur.

Diesel exhaust from heavy trucks and generators has the potential to impact air quality within the PUD. The transportation and traffic assessment discusses the number of expected truck trips that were used to estimate the annual emissions from Antero's projected heavy truck activity as summarized in the following table.

Estimated Annual Emissions from Trucks

Contaminant	five year Well Development (Phases 1 through 3)	20 - 30 Years of Well Production and Operations
PM (tons/year)[1]	0.26 to 0.75	0.05 to 0.12
Nitrogen dioxide (tons/year)[2]	0.35 to 0.45	0.068
Carbonyls (tons/year)[3]	0.063 to 0.082	0.012
Alkanes (tons/year)[4]	0.05 to 0.064	0.0097
PAHs (tons/year)[5]	0.14 to 0.18	0.027

[1]assuming a PM emission rate of 0.64 to 1.4 grams per mile [35], a fuel efficiency of 5.5 miles per gallon of diesel, and 10 miles within the PUD per trip
[2]assuming a nitrogen dioxide emission rate of 0.84 grams per mile[36], a fuel efficiency of 5.5 miles per gallon of diesel, and 10 miles within the PUD per trip
[3]assuming a carbonyl emission rate of 0.15 grams per mile[36], a fuel efficiency of 5.5 miles per gallon of diesel, and 10 miles within the PUD per trip
[4]assuming an alkane emission rate of 0.121 grams per mile[37], a fuel efficiency of 5.5 miles per gallon of diesel, and 10 miles within the PUD per trip
[5]assuming a PAH emission rate of 0.0.338 grams per mile[37], a fuel efficiency of 5.5 miles per gallon of diesel, and 10 miles within the PUD per trip

The estimated emissions are based on the period of time during which trucks are moving and do not include emissions created during idling and emissions from diesel powered generators. Each of the proposed truck routes is near at least one Battlement Mesa housing area[38].

With the following control measures in place, project dust from construction activities, well pads, and access roads is not expected to significantly impact Battlement Mesa air quality. COGCC rule 805b requires operators to employ practices for control of fugitive dust caused by their operations. Antero has specified the following dust control measures: (1) soiltac and/or liquid dust suppressants will be used; (2) all access roads and well pads will be graveled; (3) truck traffic will not exceed 20 miles per hour (mph); and (4) all contractors will be notified they must obey traffic laws and that they will be disciplined, up to removal from Antero's project, if they fail to comply[7].

Fugitive emissions from pipes, valves, pneumatic devices, and wellheads have the potential to impact Battlement Mesa air quality and can do so over the life of the well, estimated to be at least 20 years. In addition, VOCs may be vented during maintenance ("pigging") of pipes, occurring intermittently over 20 years. COGCC rules require that no bleed valves be used on pneumatic devices, where technically feasible. Appendix B discusses specific requirements for pipelines within the PUD, as agreed in the Surface Use Agreement. No centralized compressor stations will be located in the PUD[7].

Appendix D contains a Human Health Risk Assessment that was performed by the CSPH team to estimate the potential impacts to the public health from Antero's proposed project. The Human Health Risk Assessment was conducted using five years of data from the Bell-Melton Ranch monitoring station, the 2008 Air Toxics study, and the 2005-2007 air study. Three exposure scenarios were evaluated: (1) chronic exposure of all residents within the Battlement Mesa PUD; (2) chronic exposure of residents within the PUD living adjacent to a well pad; and (3) acute exposure of child residents living within the PUD living adjacent to a well pad. The Human Health Risk Assessment concludes that there is a potential for natural gas development and production within the Battlement Mesa PUD to adversely impact public health. The highest risk is projected for residents living adjacent to well pads through acute exposure to air contaminants emitted during well completion activities. Following is a summary of the conclusions of the Human Health Risk Assessment:

- These non-cancer hazards and cancer risks may be significantly underestimated because there is currently little or no information for many contaminants associated with natural gas operations. They may be even higher if information were available for polycyclic aromatic hydrocarbons (PAHs), chemicals in fracking fluids, ozone, $PM_{2.5,}$ PM_{10}, and contaminants without toxicity values. In addition, little information is available for soil and water.
- For Battlement Mesa residents living adjacent to a well pad, the estimated Hazard Index of 40 for acute non-cancer hazard and the estimated Hazard Index of 2 for the chronic

non-cancer both are greater than one, above which health effects may occur. Both of these hazard estimates are driven by trimethylbenzenes and benzene in ambient air.

- For chronic exposure of Battlement Mesa residents living adjacent to a well pad, the estimated lifetime excess cancer risk of 83 cancers per one million people, while within EPA's acceptable range of one to 100 cancers per one million people, exceeds EPA's goal of less than one cancer per million people and is near the high end of the acceptable range. This translates to a population attributable risk of less than one cancer for a population of 5,041. The contribution of benzene, methylene chloride, and ethylbenzene also exceed the contribution of these contaminants to the baseline cancer risks measured at the Silt-Daley and Silt-Cox monitoring stations.
- For chronic exposure of Battlement Mesa residents not living adjacent to well pads, the estimated Hazard Index of 0.6 for non-cancer hazards is less than one, below which health effects are not expected to occur.
- For Battlement Mesa residents not living adjacent to well pads, the estimated lifetime excess cancer risk of 71 cancers per one million people, while within EPA's acceptable range of one to 100 cancers per one million people, exceeds EPA's goal of less than one cancer per million people and is near the high end of the acceptable range. This translates to a population attributable risk of less than one cancer for a population of 5,041.

4.1.4 Characterization of the Air Quality on Health

The impact of air quality due to the Antero project in Battlement Mesa on the health of local residents can be characterized as follows:

Impact	Direction of health effects	Geographical Extent of exposure	Vulnerable populations	Duration of exposure	Frequency of exposure	Likelihood of health effects as a result of Project	Magnitude of health effects	Rank
Air Quality	Negative(-)	Community wide	Yes	Long	Frequent	Likely	Moderate to High	-14.5*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

When considering anticipated air contaminant exposures associated with the Antero development within the Battlement Mesa PUD, air quality will likely produce **undesirable health effects** in the areas both in near development areas and **community wide.** Much of the community will be near sources of air contamination and ambient air quality will affect the entire community. Children, older adults, and individuals with respiratory diseases may be more vulnerable to the air contaminants and are considered **vulnerable populations**. Air quality degradation may last for the duration of Antero's project, from well pad preparation through well abandonment, and therefore could be long in duration. The impacts to air quality are expected to be **frequent** and occur constantly and/or reoccur. It is **likely** that contaminant concentrations in residential ambient air may be high enough to cause short-term and long-term disease. Health effects may include respiratory disease, neurological problems, and cancer. It is likely that medical attention will be necessary for some of these effects and that some of these effects will not be reversible. Therefore the impacts are rated as **moderate to high** magnitude. Using the numerical ranking scheme, air quality impacts are expected to produce a negative rank of -14.5 on a scale of ±6-15.

4.1.5 Findings and Recommendations from Air Quality Assessment

What we know: Air pollution is a hazard to the public health. GCPH and CDPHE ambient air studies, air toxics studies, and the broader scientific literature demonstrate that natural gas development and production contribute diminish air quality. These studies also show that the largest volume of emissions to air occur during well development. The Human Health Risk Assessment in this HIA, previous CDPHE risk assessments, and Saccomanno Study all conclude that there is likely to be an increased risk of cancer and other chronic and acute health effects from residential exposure to air emissions that can result from natural gas development and production. There have been several odor complaints associated with the Watson-Ranch well pad at the perimeter of the PUD filed with the COGCC. These odor complaints resulted in COGCC issuing a Notice of Alleged Violation.

What we do not know: The ambient air quality within the Battlement Mesa PUD is not known. The levels of air emissions during all stages of natural gas development and production are not known. Many types of possible emissions, such as PAHs and fracking chemicals, as well as the contribution of PM and ozone have not been assessed. It is not known if the set backs of wells from occupied buildings are adequate to protect public health.

<u>Recommendations to Reduce Impacts to Public Health from Air Pollution</u>

Based on these findings, the following are some of the suggested ways to reduce the potential impact of air emissions.

1. Require submission of a quality assurance project plan (also known as a QAPP) to GCPH for review and approval for all monitoring specified in these recommendations to assure monitoring information will be adequate for informing public health decisions.
2. Require Antero monitoring results conducted in response to CDPHE consultation (dated 4/12/2010) be made available to the public in a timely manner to provide accessible information and transparency.
3. Require corrective action when odor events occur, including notification of the GCPH and residents to reduce impacts.
4. Require adherence to COGCC 805b green completion practices, with no variances, and EPA natural gas STAR program to reduce VOC emissions to the lowest level technically possible.
5. Require use of electrically powered generators in place of diesel powered generators for well drilling and fracking operations to reduce VOC, PAH, and PM emissions.
6. Require a valid emissions permit from the CDPHE for each well pad, per COGCC rule 805b to establish inspection and monitoring requirements.

7. To reduce VOC emission, require pilot lights on production tank combustors remain lit through use of appropriate technology, such as spark igniters.
8. Require adherence to dust control measures and traffic measures specified in the Surface Use Agreement.
9. Require that Antero establish and implement a plan that ensures all trucks used for its plan within the PUD meet emission standards specified in the Clean Fuel Vehicles (heavy trucks) for the Clean Fuel Fleet Program (CFR Part 88.105-94) to reduce VOC, PAH, and PM emissions.
10. Require truck loads of dirt, sand, aggregate materials, drilling cuttings, and similar materials be covered to reduce dust and PM emissions.
11. Require pits at the water storage facility to be covered to reduce VOC emissions.
12. Require air monitoring of water storage facility for VOC/BTEX and report results to GCPH.

The recommendations to address information gaps are in Section 5.

4.2 Assessment of Water and Soil Quality on Health in Battlement Mesa

> "What will be the effect of chemicals on the water supply?"
> *June 15 stakeholder meeting*

The impact of natural gas development and production on water and soil quality and the water supply is a major concern to Battlement Mesa residents. Surface run-off, and infiltration from drilling cuttings and produced water stored in pits on well pads or off-site locations; well installation errors; and uncontrolled well development (kick backs, blow outs, and well fires) could result in emissions of contaminants to groundwater, subsurface soil, surface soil and surface water. Spills of fracking fluids, drilling muds, condensate, and diesel could result in contamination of surface soil. Run-off and infiltration then could result in subsequent contamination of surface waters and of groundwater and subsurface soil, respectively. Exhaust from diesel engines (through dry deposition of particulates) and wind erosion from drill cuttings could contaminate surface soils (through deposition of particulates). If the groundwater or subsurface soil is contaminated, VOCs could infiltrate and accumulate in the air of buildings. Sources of contaminants include the natural gas resource itself, chemicals used in well production activities, wastes from well production activities, and exhaust from machinery used in well production and maintenance.

4.2.1 Water and Soil Quality Impacts on Health

Natural gas development and production and the diesel engines used to support them have the potential to release hundreds of metals, salts, hydrocarbons, carbonyls, and other contaminants to groundwater, surface water, and soil. People can be exposed to these contaminants through ingestion of water, incidental ingestion of soil, dermal absorption from water, inhalation of soil particulates, inhalation of VOCs released from water during activities such as showering, and inhalation of VOCs in building air. Some of these contaminants, such as benzene[39] and several of the PAHs, are human carcinogens. Others, such as the carbonyls, alkanes, and 1,2,4-trimethylbenzene, can act as irritants of the eyes and skin or cause neurologic effects[29]. Specific health effects of several potential contaminants are described in the Air Quality Assessment and in the Human Health Risk Assessment (Appendix D).

Significant contamination of water supplies with salts, such as those containing chloride, can make the water unsuitable for human consumption and stress water treatment facilities. The water requirements for natural gas development and production are large, with the potential to tax local water supplies, particularly in the event of a drought.

4.2.2 Current Conditions of Water and Soil Quality

The primary source of drinking and domestic water in Battlement Mesa is the Colorado River. The Battlement Mesa Water Treatment Plant draws water from two intakes located in the middle of the river for treatment. The available baseline groundwater and surface water data specific to Battlement is Mesa is limited to the annual testing of the surface water intake and back-up groundwater wells at the Battlement Mesa Water treatment facility. These results indicate that there is no VOC, herbicide, pesticide or carbamate contamination of either drinking water supply. In addition, a domestic well at the Historic Battlement Mesa Schoolhouse was sampled on May 17, 2010 in response to an anonymous request from a landowner in the vicinity of Antero's Watson Ranch Well. The COGCC concluded the laboratory analysis did not indicate any impacts to this domestic water well from natural gas production operation[40].

A baseline water quality study for the Piceance Basin was performed in 2006 [22]. Seventy groundwater samples were collected from water supply wells located north of the Colorado River and south of the upland "Hogback" between the communities of Rifle and Parachute. The inorganic results are not applicable to Battlement Mesa, because the water chemistry between these two areas could be quite different. However, the BTEX and methyl-tert-butyl-ether (also known as MTBE) results could be somewhat representative of Battlement Mesa, because they are not naturally occurring. No measureable concentrations of BTEX, methyl-tert-butyl ether, or methane were detected in any of the samples.

There is no baseline data for surface soil or subsurface soil within the PUD and current conditions are not known.

The Colorado Department of Labor & Employment's Oil and Public Safety Division has permitted ten underground storage tanks within the PUD, summarized in the following table.

Permit Holder	**Fuel**	**Tank Capacity (gallons)**
Battlement Mesa Service	Gasoline	1,000

Permit Holder	Fuel	Tank Capacity (gallons)
Battlement Mesa Service	Diesel	1,000
Battlement Mesa Golf Course	Gasoline	2,000
Battlement Mesa Golf Course	Diesel	1,000
Kum and Go, Stone Quarry Road	Gasoline	20,000
Kum and Go, Stone Quarry Road	Gasoline	12,000
Kum and Go, Stone Quarry Road	Diesel	12,000
Kum and Go, Tamarisk Trail	Gasoline	10,000
Kum and Go, Tamarisk Trail	Gasoline	10,000
Kum and Go, Tamarisk Trail	Gasoline	8,000

These underground storage tanks have the potential to leak and contaminant subsurface soil and groundwater with fuel contaminants, including benzene. The permit holder is required to perform weekly leak tests on the underground storage tanks and the Oil and Gas Public Safety Division performs an annual inspection of the underground storage tank. Review of the Oil and Gas Public Safety Division files on August 18, 2010 indicated no leaks or contamination of soil or groundwater associated with these underground storage tanks.

There also are natural gas productions operations occurring on the border of the PUD that could potentially impact the water and soil quality within the PUD, as well as the water supply. Other potential sources of contamination to groundwater and soil are the golf course and landscaping operations (e.g. application of fertilizers, herbicides and pesticides).

In the event that the Battlement Mesa Water Treatment Plant was shut down, drinking and domestic water for Battlement Mesa residents would be supplied from four groundwater wells along the south bank of the Colorado River. These wells are not supplied with water from the Colorado River and it is believed that the source of water in these wells is from an up-gradient aquifer. There could be a hydrologic connection between these wells and the aquifer on Battlement Mesa, allowing for a conduit of natural gas extraction activity contaminants to the secondary drinking water source, although this has not been verified.

4.2.3 Antero Drilling Plans in Battlement Mesa and Water and Soil Quality

The Mamm Creek field, located approximately 20 miles to the east of Battlement Mesa in Garfield County, has experienced extensive natural gas development and production, with over 1100 gas wells installed between 2000 and 2007. The two phase hydrogeologic study conducted between 2006 and 2007 on the Mamm Creek field [21-22] provides data that is useful in estimating potential impacts from natural gas development and production on water quality in Battlement Mesa. An increasing temporal trend of methane and chloride groundwater concentrations coincident with the increasing number of gas wells installed was observed in the hydrogeologic study[21-22, 41]. The isotopic methane data indicate a thermogenic origin of methane, which may be attributed to the Williams Fork gas. The increasing chloride concentrations are attributed to Williams Fork production water.

In the Mamm Creek field hydrogeologic study, chloride concentrations did not exceed regulatory limits and there is no regulatory limit for methane. Benzene was only detected in groundwater and surface water samples collected in proximity to the West Divide Creek seep and the Amos well. Many of the benzene concentrations in these samples exceeded the 5 µg/L regulatory limit and the 0.41 µg/L EPA Regional Screening Level for tap water. At the West Divide Creek seep, a faulty cement job on the casing of the Schwartz well resulted in the migration of natural gas and BTEX over 2,000 feet southeast of the well and seepage into Divide Creek. At the Amos well, Williams Fork gas from poorly installed wells are believed to be responsible for the contamination.

Pavillion Wyoming, a community of approximately 166 residents located in Fremont County, also has experienced intensive natural gas development and production, with 211 active gas wells, 30 plugged and abandoned wells, 20 “shut-in” wells, and 37 production pits in an 8 square mile area. In response to complaints from Pavillion residents of odors and off-tastes in domestic water, EPA conducted sampling of both domestic and monitoring wells in the area between 2009 and 2010. The sampling results indicate that domestic wells are contaminated with low levels of petroleum hydrocarbons and thermogenic methane and that the shallow groundwater is heavily contaminated with petroleum hydrocarbons and BTEX. Natural gas development and production are the most likely source of the petroleum hydrocarbons and BTEX. Several inorganic compounds, such as sodium, sulfate, and nitrate, also were detected which could have sources other than natural gas development and production. The hydrologic connection between the drinking water aquifer and shallow groundwater is not well characterized. In their health consultation based on EPA’s results, ATSDR found the quality of the drinking water in several of the domestic wells was not acceptable and concluded that exposure to some of the contaminants could result in health effects[42-43]. While the groundwater contamination that occurred in Pavillion is not directly comparable to Battlement Mesa because of differences in the natural gas resource and state regulations, it does indicate that natural gas development and production can adversely impact groundwater quality.

Review of water quality data in the USGS and COGCC databases indicate that groundwater and surface water contamination from natural gas development and production at levels with the potential to impact water quality and exceed regulatory levels results from incidents such as loss of well control during development, well installation errors, and spills from produced water pits, as described in the Accidents and -Malfunctions Assessment. Available routine monitoring data in these databases indicate routine natural gas development and production (i.e. without incidents) may not be a significant source of water contamination, however, routine monitoring is limited and may not be representative of all instances of gas development and production. It is noted, that samples are most often collected in response to a complaint or incident or as part of a remedial action. There is very little data for routine monitoring of impacts to water quality at gas wells or exploration and production (also known as E&P) waste pits, with the exception of required monitoring in the 3-mile perimeter of Project Rulison. This small about of data limits the ability to make a true estimate of exposures from groundwater and surface water.

The Mamm Creek field hydrogeologic study results and USGS and COGCC databases indicate that routine natural gas development and production could impact water quality in Battlement Mesa, but not to an extent that causes exceedence of regulatory standards and triggers regulatory action. It is possible that increasing chloride concentrations could eventually affect the potable groundwater. Incidents resulting from well installation errors, uncontrolled well development, and spills could significantly affect the potable groundwater and water quality, as well as soil quality, in Battlement Mesa.

While there is no permanent surface water body in the PUD, there are intermittent drainages and creeks that could discharge to the Colorado River. Monument Creek, one of the major drainages off of Battlement Mesa discharges to the river downstream of domestic water intakes. It still is possible that surface run-off could introduce contaminants from upstream well pads into the river. However, the Colorado River has a high volume of water and it is most likely that any contamination would be diluted to non-harmful concentrations. The annual surface water quality results have not indicated any detectable levels of contamination from natural gas development and production at the intakes. In addition, natural gas operators must inform the Battlement Mesa Water Treatment Plant of upstream spills or incidents affecting the river (COGCC rule 317B) [9]. In the event of such a spill or incident, the intakes to the treatment plant can be shut down. The treatment plant routinely stores a week's supply of water allowing time for remediation of spills. The Battlement Mesa Metropolitan District is subject to the protections of COGCC Rule 317B, which regulates natural gas operations in surface water supply areas.

Antero is proposing to employ pitless drilling systems on the well pads within the PUD and to distribute and store production water at a centralized water storage facility, within the PUD. COGCC rule 904 requires liners for pits at centralized water storage facilities and has a provision[9], at the discretion of the director, for the installation of leak detection systems in sensitive areas such as the PUD. COGCC rule 908 requires that centralized water storage facilities be permitted[9]; the geologic and hydrogeologic characterization of site; control of public access; fire lanes; surface water diversion systems, waste characterization profiles; an operating plan; baseline groundwater sampling and analysis; groundwater and surface water monitoring (at the discretion of the COGCC director); and groundwater and soil sampling when a pit is closed and the site remediated. Adherence to these rules, including the discretionary leak detection and monitoring, will significantly reduce the potential for impacts to water and soil quality from produced water and other exploration and production waste stored in the centralized pit. However, leaking pipelines and spills from chemical and production water hauling trucks could still create the potential to impact surface water quality. COGCC rules do not specifically address water pipeline leaks.

Any spills that occur on the pads could potentially impact water and soil quality by surface run-off and infiltration during precipitation events. This potential is evidenced in a sample of snow melt collected from a project Rulison well pad contained levels of benzene greater than regulatory limits[44]. COGCC rule 603 specifies that in high density areas, such as the PUD, berms (or other secondary containment devices) capable of containing 150 percent of the fluid in the largest tank within the berm be constructed around produced water and condensate tanks[9]. However, this rule does not provide for containment of spills that may occur outside the berm perimeter, such as during transfer of chemicals and materials to and from trucks and at well heads.

Wind erosion and surface run-off from drill cuttings stored on Antero's pads could impact surface water and surface soil quality. The COGCC rules do not specifically address drill cutting stored on well pads[9].

At time of preparation of this HIA, it was not known if Antero is planning for deep injection of exploration and production wastewater within the PUD. COGCC rule requires written permission from the COGCC director prior to construction of an injection well. The HIA would need to be updated to include potential impacts to public health, if injections wells are proposed.

The Battlement Mesa Metropolitan District has a capacity of 6 million gallons of water per day. Currently, 3-3 ½ million gallons per day are used, allowing for the accommodation of Antero's water needs during well development operations. If water capacity were to significantly decrease, the needs of Battlement Mesa would take precedence to Antero's needs.

It is unlikely that Antero's proposed project will have a significant impact on the primary domestic water supply for Battlement Mesa. The potential for a significant impact to the secondary water supply may exist. If the potable groundwater is impaired, Battlement Mesa may not have a back up source of domestic water. In addition, there is the potential for the Antero's project to impact the water quality of intermittent streams, creeks, and puddles, as well as soil quality. Finally, it is possible that shallow aquifer contamination could cause VOC off gassing into Battlement Mesa homes, but since the hydrology of the area is not well understood, the likelihood of such an occurrence is not clear.

4.2.4 Characterization of the impact on Water and Soil Quality

The impact of water and soil quality due to the Antero project in Battlement Mesa on the health of local residents can be characterized as follows:

Impact	Direction of health effects	Geographical Extent of exposure	Vulnerable populations	Duration of exposure	Frequency of exposure	Likelihood of health effects as a result of Project	Magnitude of health effects	Rank
Water and Soil Quality	Negative(-)	Community wide	Yes	Long	Infrequent	Unlikely	Moderate to High	-11.5*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

When considering anticipated water and soil contaminant exposures associated with the Antero development within the Battlement Mesa PUD, water and soil quality may produce **negative health impacts** in the areas in close proximity to the development areas and community wide. If the domestic water supply were to be contaminated, the health effects would be **community wide**. Effects of wind erosion and surface run-off could be more localized, and could impact children more than adults. Children, older adults, and individuals with pre-existing disease may be more vulnerable to water and soil contaminants and are considered a **vulnerable population**. The duration of water quality degradation could be **long** and may last through the life of the Antero's project, from well pad preparation through well abandonment. The impacts to water quality are expected to be **infrequent**. It is, however, **unlikely** that contaminant concentrations in water and soil will be high enough to cause short-term and long-term disease because the current supply of domestic water is the Colorado River and the COGCC has extensive rules to protect this resource. If exposure were to occur, health impacts may include skin and eye irritation, neurological problems, and cancer. It is likely that medical attention would be necessary for some of these impacts and that some of these impacts will not be reversible. Therefore the health impacts, if exposure were to occur, are rated as **moderate to high** magnitude. . Using the numerical ranking scheme, water and soil quality impacts are expected to produce a negative rank of -11.5 on a scale of ±6-15.

4.2.5 Findings and Recommendations from Water and Soil Quality Assessment

What we know: Water pollution is hazardous to the public health. Garfield County Oil and Gas studies, EPA studies, and other studies demonstrate that natural gas development and production can release contaminants to domestic water supplies and compromise water quality. Individual circumstances can influence the potential contamination of water. In Garfield County, accidents and malfunctions have been the most common cause of water contamination from natural gas development and production. If a domestic water resource is contaminated, remediation is time and cost intensive and may not restore the water resource to a quality for domestic use.

What we do not know: The hydrogeology in Battlement Mesa has not been characterized and the relationship between groundwater, domestic water supplies, and the Colorado River in not well understood. The quality of groundwater in the Battlement Mesa PUD is not known and the extent of routine natural gas development and production on water quality is not known.

Recommendations to Reduce Impacts to Public Health from Water and Soil Pollution

Based on these findings, the following are some of the suggested ways to reduce the potential impact of water and soil pollution.

1. Require COGCC rules 317B, 603, 904, and 908, including those at the discretion of the director, be applied with no variances or exemptions, to prevent pollution of water and soil.
2. Require Antero to develop and implement plans to ensure removal of mud from vehicles leaving the well pads and access roads to prevent tracking of mud onto Battlement Mesa and Garfield County roads.
3. Require full disclosure of all chemicals, with their volumes, concentrations, and Material Safety Data Sheets (also known as MSDS), used in natural gas development process to GCPH and Battlement Mesa Residents.
4. Require continuation of all baseline and continuing monitoring requirements for groundwater, surface water, and soil and leak detection to prevent pollution of potential domestic water supplies.
5. Require the berming of the down gradient well pad perimeters, as well as surface water diversion ditches for each well pad to prevent pollution of water and soil.
6. Require monthly inspection of water and gas pipeline for leaks to prevent water and soil pollution.
7. Require immediate notification of GCPH (in addition to COGCC) in the event of a spill of five barrels to protect public health.
8. Require that drill cuttings be covered during storage on well pads to prevent wind transport and soil pollution.
9. Place an inlet protection system, similar to the system in place for Rifle and planned for Parachute, on the two intakes for the Battlement Mesa water treatment plant that would shut off the intakes if contaminants are detected to protect public health.

The recommendations to address information gaps are in Section 5.

4.3 Assessment of Transportation and Traffic on Health in Battlement Mesa

Will there be motor vehicle accidents and related injury and death? *February 3, 2010 stakeholder meeting*

Increases in transportation and traffic can impact health and safety of a community by increasing the risk of motor vehicle accidents, release of hazardous pollutants, creation of road dust, and impediment of walking and biking routes. Development of natural gas wells can cause significant increases in a variety of traffic, especially large truck traffic. Workers driving at high speeds may place residents at risk for severe injury or death. Residents living in Battlement Mesa have expressed concerns that traffic associated with the Antero gas project will impact the health and safety of those living in the community. This assessment will address traffic impacts to the safety of Battlement Mesa citizens. Air quality, noise, and quality of life impacts due to increased traffic are addressed in other sections.

4.3.1 Traffic and Safety

Vehicular traffic is a known hazard to safety. Increases in traffic are associated with increased risk of motor vehicle injury and death, due to vehicle-vehicle, vehicle-pedestrian, and vehicle-bicycle accidents. Motor vehicle accidents can be associated with speeding, poor traffic management at intersections, and heavy vehicle movement. Numbers of injuries/fatalities are directly related to vehicle volume and severity of injury is directly related to vehicle speed[45-46].

4.3.2 Current Traffic Conditions

Currently, large truck traffic within the PUD is mainly from delivery trucks supplying the local businesses, including gas stations and convenience and grocery stores. There are established county approved haul routes along the perimeter of the PUD, while most roads within the perimeter are limited to small vehicles. There are two entries into Battlement Mesa. The main entrance is just south of Exit 75 off of Interstate-70. A traffic analysis conducted by Schmueser/Gordon/Meyer, Inc. (SGM) for Antero in September 2009 [38] found that this entrance had the highest traffic count in Battlement Mesa with 8,662 vehicle trips per day (vt/d). The second entry into Battlement Mesa is from Exit 75 via US 6 west to County Road (CR) 300 (CR 300/Stone Quarry Road) on the southwest side of Battlement Mesa. Traffic counts at the US 6/CR 300 intersection were 2,300 vt/d, but were only 648 vt/d on CR 300 where it enters the PUD west of the recreational vehicle (RV) park. Other counts indicate that on West Battlement Mesa Parkway there were 5,340 vt/d and on CR 307 (River Bluff Road) there were 371 vt/d. Since there is no current industrial activity and very few retail stores, it is assumed that the large majority of these vehicle trips were passenger cars and light trucks, although this is not specifically stated in the traffic report. The report also projects an increase of 2.3% vehicle trips annually unrelated to the Antero drilling plan, based on average annual growth of Garfield County.

Motor vehicle accidents in Garfield County are handled by the county sheriff's office, local municipal law enforcement and the Colorado State Patrol. When looking at accidents handled by the state patrol, Garfield County had the 9th highest number of motor vehicle accidents in the state in 2008, with 1,091 accidents total (14 fatal crashes, 116 that resulted in injury and 961 that resulted in property damage)[47]. Data from the county sheriff's office and data specific to Battlement Mesa are not currently available.

Top 10 Colorado Counties 2008 Fatal, Injury, and Property Damage Crashes by County as Covered by the Colorado State Petrol (not all Colorado Crashes)
http://csp.state.co.us/TS_CrashStat.html

County	**Fatal**	**Injury**	**Property Damage**	**Grand Total**
Jefferson	19	395	2,530	2,944
El Paso	20	278	1,953	2,251
Adams	13	233	1,773	2,019
Mesa	7	211	1,188	1,406
Larimer	14	275	1,080	1,369
Weld	28	258	1,065	1,351
Eagle	6	132	1,073	1,211
Douglas	10	145	1,032	1,187
Garfield	14	116	961	1,091
Boulder	14	182	860	1,056
Grand Total	**290**	**3,895**	**23,028**	**27,213**

Children attending school in Battlement Mesa arrive and leave via passenger car, school bus, walking, or bicycle. Underwood Elementary (grades 1-3), St. John Elementary (grades 4-5) and Grand Valley Middle School (grades 6-8) are in Battlement Mesa. The Early Childhood Center (PreK-Kindergarten) and Grand Valley High School are in Parachute. Some students are not offered bus service if they live within a "Walk" zone. Specifically, students attending Underwood Elementary and living in Saddleback Village, Tamarisk Village, Tamarack Meadows are not offered bus service; children attending St. John Elementary and living in Willow Ridge, Willow Park, Valley View, Monument Creek Village, Canyon View, and Stone Ridge are not offered bus service; and children attending Grand Valley Middle School and living in Mesa Ridge, Eagle's Point, Willow Ridge, Willow Park, and Valley View are not offered bus service. (Battlement Mesa early childhood students and high school students are all offered bus service and ride together.) School hours in Battlement Mesa schools are 8:40 am -3:40 pm at Underwood (early release at 2:10pm); 8:25am- 3:25pm at St. John (early release at 1:55pm); and 7:50am-7:15pm at Grand Valley Middle School (1:45pm early release). A map detailing Antero's planned haul routes and school bus stops will be included in the final report.

4.3.3 Antero Drilling Plans in Battlement Mesa and Traffic

Traffic associated with natural gas development is related to earth moving construction of well pads; movement of materials and waste to and from the well site; installation of pipelines; long term production; maintenance operations; final reclamation of the site after production is completed; and travel of workers to/from work. The most traffic intensive phases involve pad construction, drilling and well completion and pipeline construction.

Antero has described a three phase development plan for the Battlement Mesa project as described in the public meetings powerpoints. Phase 1 will develop the Stierberger Pad, Pad E, Pad G, and the water storage facility (Pad F) on the south side of the PUD. Phase 2 will develop the Parks and Rec Pad, Pad A, Pad B, and Pad D on the north side of the PUD. The Parks and Rec pad replaces the Pad C originally planned. Phase 3 will develop the L and M pads on the northeast side of the PUD. Each phase will involve access road, pad and pipeline construction needed to develop the wells and tie them to the water movement system and the gas gathering lines at the eastern edge of the PUD.

The traffic analysis conducted by SGM used estimates from previous Antero development sites in the Mamm Creek area to project average and maximum trips per day, for the Battlement Mesa project. Trips per day range from 2 (production phase) to 280 or more (intensive construction phase). Drilling completion, light construction, and pipeline installation range from on average 16-31 vt/d and a maximum of 30-46 vt/d. The duration of the pad construction ranges from 10-30 days and the other phase durations *per well* are drilling (18 days); completion (30 days); pipe installation (60 days/ mile); duration of each phase per pad was not calculated but efficiencies associated with drilling multiple wells sequentially on a pad will reduce the time of each phase on a pad. Production is projected to last 20 years. Reclamation after production is expected to have 7-10 vt/d for 11 days per pad.

Although initial presentations to the public describe well development phases to last 3-4 years, more recent estimates in the traffic analysis indicate that well development is expected to occur for at least five years, maybe longer, depending on economic and regulatory conditions. Well development phases will overlap on different well pads so that while pad construction is occurring on one pad, drilling is accomplished on another and completion may be occurring on another pad. Therefore, traffic will be overlapping as well, with trucks associated with construction, drilling, pipeline and completion using the haul routes simultaneously. Trips per day for each of these phases are added to estimate the number of trips per day expected during the first five years when well development is occurring. The number of trips per day is estimated to be 90-120 vt/d when light construction is occurring. When more intense well pad construction is occurring (during the Phase 2 well pad construction) traffic is projected to be 340 vt/d for approximately 120 days. Some activities will occur 24 hours a day and the vehicle trips will be spread throughout the day and night. Antero has stated they will limit truck hauling to hours outside of school zone hours. The majority of these trips are expected to be heavy trucks.

Antero plans to use county haul routes for traffic. During all phases entrance and exit from Battlement Mesa will be via the US 6/ CR 300 route (Stone Quarry Road), on the southwest side of the PUD. Phase 1 also will utilize CR 303, CR 308 and CR 302. Phase 2 will utilize CR 303, CR 308, East Battlement Mesa Parkway, South Battlement Mesa Parkway, and CR 307 (River Bluff Road). Phase 3 will utilize CR 303, CR 308, East Battlement Mesa Parkway, North Battlement Mesa Parkway, and West Battlement Mesa Parkway. The county restricts hauling on CR302, CR 307, South Battlement Mesa Parkway, and West Battlement Mesa Parkway. It is assumed that Antero will be required to obtain special permits to use these roads.

School buses for all the schools use and cross Antero haul routes. Although all children in the PUD may be impacted by crossing the haul routes while going to and from school, middle school age children may be the most impacted since the middle school is near two haul routes and children this age are more likely than younger children to be walking or bicycling on their own. According to the traffic analysis plan, Antero has decided to avoid any heavy truck hauling during school zone hours. Children going to/from school outside of school zone hours will be crossing haul routes while truck traffic is occurring.

Antero has planned mitigations to decrease impacts of traffic on the Battlement Mesa Community. Of significance, Antero has committed to building a water management system comprised of water distribution pipes going from the well pads to the water storage site on the south side of the PUD. This water management system is intended to decrease movement of water by trucks and it is estimated that there will be fewer trips during the development phases because of this system.

In addition to heavy truck traffic, there will be workers coming into Battlement Mesa and traveling within Battlement Mesa in passenger cars and light trucks. It is estimated that there will be an average of 120-150 workers in Battlement Mesa during the five year development period. Antero intends to house some workers in Battlement Mesa to decrease worker movement into and out of the PUD. Workers exceeding speed limits can put other vehicles and pedestrians at risk for injury and fatality. . Antero management emphasizes safe driving but a formal safe driving program does not exist.

It is expected that the increase in heavy truck volume from negligible to tens or hundreds per day within the PUD may compromise road integrity and needs for increased road maintenance is anticipated. County funds will be needed to maintain haul routes as well as installation of road and pedestrian safety mitigations if needed. Utilization of county funds for roads and road safety may divert funds from other county programs, including health programs, there by potentially impacting public health infrastructure.

4.3.4 Characterization of Traffic Impacts on Safety

The following table summarizes the characterization of impacts from traffic.

Impact	Direction of health effects	Geographic extent of exposure	Vulnerable populations	Duration of exposure	Frequency of exposure	Likelihood of health effects as a result of Project	Magnitude of health effects	Ranked
Traffic and Transportation	Negative (-)	Community-wide	Yes	Long	Frequent	Possible	Low to high	-13.0*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

When considering public health to residents of Battlement Mesa, the increased traffic within the PUD is likely to create **negative** health effects due to increased safety risks. Because the haul routes include the entire circle of the Battlement Mesa Parkway as well as other roads within and on the perimeter of the PUD, the impact of the traffic is likely to be **community-wide**. There will be certain parts of the community that will be greater impacts for the duration of Antero's project (those homes next to CR300/Stone Quarry Road) while others will be impacted by very high volume traffic during the construction of the Phase 3 pads (those along River Bluff Road). Because children often walk and ride bicycles and are not as safety conscious, they are more **vulnerable** than most adults to the impacts of traffic within the PUD. Antero has committed to limit heavy truck traffic during school zone hours which will decrease risk to children traveling to and from school at those times. Children staying after school for sports and other activities may be at risk for traffic incidents related to truck traffic outside of those hours. Furthermore, truck traffic is likely to continue on weekends and holidays and children may be crossing haul routes at those times. The duration of exposure to increased traffic will be **long**, spanning the entire duration of the development of all three phases, at least five years. The traffic will be frequent, in some cases (River Bluff Road), several hundred trucks will be passing a day for several months. Along Stone Quarry road, there will be 45 to 113 trucks passing a day for approximately five years. Increased traffic is known to be associated with increased risk of traffic accidents and it is **possible** that there will be traffic related accident as a result of the Antero project. The magnitude will depend upon how well the traffic is controlled, how well mitigation efforts are adhered to, and to unrelated or perhaps chance factors. Traffic can cause minor to severe/fatal injuries and as such, the magnitude of the impacts will be **low to high**. Using the numerical ranking scheme, traffic impacts are expected to produce a negative rank of -13.0 on a scale of ±6-15.

4.3.5 Findings and Recommendations from Traffic and Transportation Assessment

What we know: An increase in traffic is associated with an increase in risk for motor vehicle accidents that can involve cars, pedestrians, and bicycles. The risk of severe injuries in motor vehicle accidents increases as the speed of traffic increases. Increased traffic also increases air pollution and noise levels.

What we do not know: We do not know if Battlement Mesa has dangerous traffic spots or the normal pedestrian/bicycle patterns.

<u>Recommendations to Reduce Impacts to Public Health from Traffic and Transportation</u>

Based on these findings, the following are some of the suggested ways to reduce the potential impact of traffic and transportation.

1. Require Antero to build water treatment facility and associated pipelines in advance of well development, to immediately remove water hauling traffic from PUD.
2. Require Antero to communicate and coordinate with local school district to develop plan for transportation and safety needs of all children going to and from school by car, bus, bicycle and walking during and outside of school zone hours to prevent injury to school children.
3. Reduce truck speed limits to 20 mph in areas where there is existing pedestrian traffic that is not buffered from haul routes to prevent accidents and to reduce the severity of injury should an accident occur.
4. Consider speed control measures on worker ingress and egress routes (ie decreased speed limits, signage, real time speed measurement signs, photo speed ticket vans, speed bumps or other measures) to prevent workers from speeding.
5. Mark pedestrian/bike high use routes and establish safe crossing zones where they intersect Battlement Mesa Parkway or other haul routes to alert drivers of potential pedestrians and bicyclers.
6. Install safety measures (ie, signaled cross walks, elevated side walks, green space buffers) for pedestrians/bikes where established waking/biking routes overlap/run along haul routes to prevent accidents.
7. Request that the Garfield County Sheriff's Department or other qualified entity to review Antero's Traffic Impact Analysis and request feedback on possible safety mitigations and traffic hot spots to ensure the plan has is protective of public health.
8. Require safe driver training for workers and implement penalty system for unsafe drivers, to encourage safe driving.
9. Require Antero to have a system to identify and remove unsafe drivers to prevent accidents and injuries.
10. Provide Sheriff's Auxiliary Unit with authority to log speeding and unsafe driving incidents and complaints within the PUD, which can be provided to Antero, subcontractors and the Sheriff's department so that problems can be resolved, to identify unsafe conditions.

The recommendations to address information gaps are in Section 5.

4.4 Assessment of Noise, Vibration, and Light Pollution on Health in Battlement Mesa

"I am concerned that noise and vibration will affect my sleep. Will these be addressed?"
June 15 stakeholder meeting

Increased noise, vibration, and light are common concerns for citizens near construction and industrial sites. At natural gas sites noise and vibration can occur in the construction phase, drilling and completion phases, and due to truck traffic. Light pollution can occur due to 24 hour lighting during development and production operations. Because of these sources, noise, vibration, and light concerns have been expressed by Battlement Mesa residents at stakeholder meetings.

COGCC Rule 802[48], based upon the State of Colorado Noise Ordinance[49], states that pad construction operations are considered industrial sites and site noise may not exceed 80 decibels (dB) in the day and 75 dB at night. Residential noise must not exceed 55 dB in the day and 50 dB at night. COGCC Rule 803[50] states "site lighting shall be directed downward and internally so as to avoid glare on public roads and building units within seven (700) hundred feet." COGCC does not have a rule limiting ground vibration, but according to the US Department of Transportation ground vibration is generally not felt below 65 VdB and annoyance can be experienced at 70 VdB[51].

According to EPA research, construction equipment can produce noise ranging from 80-89 dB at a distance of 50 feet and 60-69 dB at 500 feet[52]. Heavy construction equipment can cause vibration of 85 VdB 50 feet from the source[51].

Because there is a potential for noise, light and vibration to exceed COGCC rules and background levels, a review of potential noise, vibration and light impacts is warranted.

4.4.1 Noise, Vibration, Light pollution and Health

Both acute loud noise and chronic lower level noise have been associated with a variety of negative health effects. Hearing loss and impairment are known to occur as a result of exposure to acute, high decibel noise (greater than 85 dB). The odds of hearing loss increase as the decibel level increases. A dose relationship between noise level and hearing loss exists[53].

Studies looking at the relationship between noise and cardiovascular disease, hypertension, psychological symptoms, and respiratory impairment are numerous. Reviews and meta-analysis of these studies conclude that noise has the potential to impact these health outcomes[54-57]. Cardiovascular risk factors have been shown to be impacted by noise levels in the range of 51-70 dB in persons with several years of exposure[58].

Noise annoyance can lead to stress related impacts on health such as feelings of displeasure, interference with thoughts, feelings, and activities and disturbed sleep and can have impacts on mood, performance, fatigue, and cognition[59]. Noise levels that produce these impacts can vary: annoyance can occur at 55dB; school performance can be impacted at 70 dB; and sleep can be impacted by as little as 35-60 dB. Ground vibration and low frequency noise may cause health impacts similar to those associated with noise annoyance.

Establishment of causal relationships between noise/ vibration and health impacts is complicated by the fact that noise annoyance in particular can vary with pitch, frequency, and duration. In addition, individual adaptation to noise can vary and complicates subjective reporting as well as expected outcomes.

Preliminary research suggests that light at night may affect health by disrupting normal circadian rhythms[60-61]. The International Agency for Research on Cancer has listed shift work a Class 2A (probable) carcinogen based on epidemiologic links to breast cancer. Mechanisms for the health effects of light at night are actively being studied and include altered melatonin and other hormone release[62].

4.4.2 Current Noise, Vibration, and Light Conditions

Residences in Battlement Mesa are located one mile or more from Interstate-70 and are not likely to have noise impacts from this source. As such, background noise is likely to be comparable to other non-industrial, rural/semi-rural communities. In 2002, La Plata County, Colorado conducted noise sampling in rural, residential, traffic corridors and light industrial areas[63]. Twenty-four hour residential subdivision noise ranged from 37-53 dB, with an average of 42-45 dB. Traffic corridors ranged from 55-65 dB, with an average of 57 on a state highway and 45 on a collector road. Battlement Mesa neighborhoods are likely to have noise levels similar to those measured in La Plata County. Likewise, night time light is likely to be similar to other residential areas, consisting of municipal street and outdoor home lighting. Baseline lighting measures for Battlement Mesa do not exist.

Some residences in Battlement Mesa, however, may already be proximate to natural gas production sites located outside the PUD and maybe experiencing or have experienced noise and light trespass elevated above background in relation to this development. There not currently any significant sources of vibration within the PUD.

4.4.3 Antero Drilling Plans in Battlement Mesa and Noise/Vibration/Light

Sources of noise will include: large truck traffic; road and well pad construction machinery; diesel engines used during drilling; fracking and completion stages; and drill rig brakes. Antero has stated that they will use electric engines for some drilling operations within the PUD but that diesel engines will be used for all completion activities. Antero indicates that well pads are expected to be at least 500 feet from residences and much well pad noise will be abated by distance. However, without ancillary noise abatement, it is likely that the Antero project will produce noise above background, and possibly above COGCC levels, during the construction and well development phases and during well maintenance (workovers). The topography of the land may play an important role in increasing or decreasing noise emanating from the well pad. Noise is expected to range from intermittent (traffic and drill rig brakes) to continuous (diesel engine use during drilling and fracking) for several weeks to months. Drilling and associated noise will also round the clock. Although specific distances from truck haul routes to schools is not available, rough estimates indicate that schools are roughly 1,000 feet or more from truck routes and may not experience significant noise impacts. Residents living less than 500 feet from truck routes, such as along CR 300 (Saddleback Village) or West Battlement Mesa Parkway (Willow Creek Village), are close enough to experience noise that could be between 65 and 85 dB when trucks are passing, at times 9- 12 times per hour or more. These areas could experience some associated intermittent vibration as well.

Because drilling operations occur round the clock, the well pad is lighted and may contribute to light at night at nearby residences. Elevated light levels would be expected to last throughout the drilling period for each pad. In addition, Antero may choose to light well pads for security reasons.

In community meetings, Antero has described possible noise and light abatement strategies. According to meetings documents and the Surface Use Agreement, Antero is not planning centralized compression (a significant noise source). Well head compression if utilized will be housed with noise suppression equipment. Other noise abatement strategies may include use of hay bale walls around the pad, noise blankets for diesel engines, and electric grid power for drilling. Antero documents also indicated possible use of drill rig placement strategies and sodium vapor lights to decrease light trespass. At this time, it is unclear which of these mitigations will be included in the Major Land Use Impact Review and Comprehensive Drilling Plan permit application. However, because Battlement Mesa currently enjoys very low ambient noise and light levels, the Antero project will likely produce noise and light above ambient levels during construction and well development/workover stages and along haul routes, and may at times exceed COGCC rules.

4.4.4 Characterization of Noise, Vibration and Light Impacts

The impact of noise due to the Antero project in Battlement Mesa on the health of local residents can be characterized as follows:

Impact	Direction of health effects	Geographical Extent of exposure	Vulnerable Populations	Duration of exposure	Frequency of exposure	Likelihood of health effects as a result of Project	Magnitude of health effects	Rank
Noise, Vibration, Light	Negative (-)	Local	No	Long	Frequent	Possible	Low-Medium	-10.5*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

When considering anticipated noise, vibration, and light exposures associated with the Antero development within the Battlement Mesa PUD, noise, vibration and light may produce **negative** health effects. Of the three, noise is likely to be the significant health driver. Distance and light mitigations should decrease light at night to the point where there are not significant health impacts. Vibration may occur as a result of truck traffic but health effects are more likely to be due to noise annoyance in these situations. While all or most parts of the community may be proximate to noise sources at different times, it is not likely that the entire community will be affected by noise during the development of an individual pad or by truck traffic. There are some residents close to haul routes that may experience elevated noise due to truck traffic for five years or more. Noise impacts will therefore be **local** to areas in close proximity to the development areas and areas close to truck traffic routes. There are **no vulnerable populations** in Battlement Mesa, although truck traffic passing by the St. John Elementary School and the Grand Valley Middle School may be disruptive during school hours. The elevated noise is expected to be associated with construction and development phases and with truck traffic on haul routes. The pad development phases will last several months, while nearby truck traffic may last several years for some residents, and so, duration of exposure is expected to be **long** depending on location. Significant noise levels are not expected during normal production phases in the years subsequent to well development. Should reworking of wells be conducted, noise levels are expected to increase, again for several months, during the reworking phase. When noise occurs is expected to occur **frequently** as it will be constant and/or frequently reoccurring. It is unlikely that residential noise will be loud enough to cause noise induced hearing loss or long enough in duration to impact cardiovascular disease. In general, health impacts are likely to result from annoyance due to noise above background and may cause sleep disturbance, displeasure, fatigue, etc. It is not likely that medical attention will be necessary for most people, although some may seek medical assistance. Therefore the health effects are rated as **low-medium magnitude**. It is possible that in some individuals, noise levels will produce significant annoyance and may produce larger health effects. Using the numerical ranking scheme, noise/vibration/light impacts are expected to produce a negative rank of -10.5 on a scale of ±6-15.

4.4.5 Findings and Recommendations from Noise, Vibration, and Light Assessment

What we know: Noise can have negative effects on public health that can vary at the individual level. Background noise levels in Battlement Mesa are low.

What we do not know: The potential noise levels at COGCC and Antero's proposed set backs and along truck haul routes are not known.

<u>Recommendations to Reduce Impacts to Public Health from Noise, Vibration, and Light</u>

Based on these findings, the following are some of the suggested ways to reduce the potential impact of noise, vibration, and light pollution.

1. Reduce speed limits for trucks within the PUD to 20 miles per hour to reduce noise and vibration levels.
2. Require best available noise reduction technology for heavy equipment, including trucks and truck brakes, to reduce noise levels.
3. Require Antero to alert residents of anticipated noise, including time, duration, decibel levels, and machinery to be used to protect public health.

4. Require Antero, in cooperation with Battlement Mesa residents and GCPH, to develop and implement a plan that includes a variety of noise control strategies to address the Battlement Mesa resident's noise concerns to protect public health and to prevent long-term nuisance noise levels.
5. Provide residents the option of requiring Antero to install permanent/semi-permanent noise mitigation structures (sound walls) along haul routes CR300 and other routes where trucks are anticipated to be passing throughout the development period to reduce noise levels.
6. Consider installation of traffic noise barriers near the St. John Elementary School and Grand Valley Middle School to reduce noise levels at schools.

The recommendations to address information gaps are in Section 5.

4.5 Assessment of Impacts on Community Wellness

> Will the development have impacts on education? What will be the mental health impacts? Will there be more or less services in the community?
> *February 3, 2010 stakeholder meeting*

Residents of Battlement Mesa are concerned that the Antero project may affect the well-being of their social and community environment. Current epidemiologic literature cites a myriad of challenges in understanding the specific effects of the community and social environment on individual physical and psychological health. Largely, this is due to the difficulty in analyzing the separate and complex processes through which community and individual factors work together to influence health[64-65]. As such, it is difficult to identify and measure community factors which may influence health and well-being independent of individual level risk factors. Never the less, it is widely accepted that societal factors contribute to the health status of individuals through either the promotion or hindering of healthy choices and behaviors, and it is the collective health of individuals which contribute to the broader sense of community well-being among residents[66-67].

While there is no single determinant or definition of a healthy community, the CSPH team assessed current community wellness conditions through societal-based factors which were expressed as concerns by Battlement Mesa citizens. School enrollment, crime rates, prevalence of substance abuse, prevalence of sexually transmitted infection, and social service availability were assessed as surrogate measures of community health. Other measures of quality of life, such as the availability of and participation in recreational activities and the depth and breadth of active social networks, may also speak to the health status of a community, but these are more difficult to codify with data.

4.5.1 Current Community Wellness Conditions

Primary data on several baseline community health characteristics were collected and are cited and described in detail in Appendix C, including data on school enrollment, criminal activity, mental health and substance abuse, and sexually transmitted infections. The years 2005-2008 appear to be a period of increase for several of the measures observed. During this time, school enrollment in Garfield County's District 16 increased by 37.4%. There was a substantive change in the racial/ethnic distribution of students enrolled during this time, demonstrated by the decrease in the proportion of Caucasian/non-Hispanic students accompanied by a rise in the percentage of Hispanic children. Criminal activity was elevated during 2005-08, with a calculated average of over 300 arrests per year during that time. Chlamydia and gonorrhea counts in Garfield County steadily increased during the 2005-2008 time period. However, counts for Battlement Mesa varied, with a larger number of cases occurring in 2007 and 2008. For the purposes of community health monitoring, is important to review these data prospectively to evaluate future changes and trends.

Longitudinal data on mental health, substance abuse and suicide were not available for similar analysis. Results from a 2006 public health survey conducted by the Garfield GCPH found that upwards of 17% of residents were burdened by at least one of these conditions. Further, in many cases, when respondents reported experiencing mental health problems (defined as experiencing depression or stress), they also reported difficulties coping with substance abuse issues and engaging in physical activity[68]. A 2006 study of hospital discharge data for Garfield County regional hospitals found that 275 persons had been hospitalized for alcohol/substance abuse or suicidal behavior during the period 2003-05. Of those 275, 47 (17.1%) had an alcohol/drug abuse diagnosis and 228 (82.9%) had a diagnosis of suicidal behavior [69].

To meet area community health needs, Garfield County operates a comprehensive Public Health Department (the GCPH) with locations in Rifle and Glenwood Springs[70]. Battlement Mesa residents are eligible for all services provided by the GCPH. Some services relevant to the community health measures discussed include:

- General health education and screenings
- Communicable disease surveillance
- STD/HIV screening
- Crisis support hotlines for domestic violence, suicide and mental health
- Tobacco prevention
- Emergency service and assistance
- Adult education programs
- Human services, including employment, food and housing assistance programs
- Services of a designated environmental health department, including the C.A.R.E.S. project for responding to community concern about environmental health issues

4.5.2 Antero Drilling Plans in Battlement Mesa and Community Wellness

While numerous case studies and assessments have been done around boomtown and industrial effects on psychosocial and community health, very little peer-reviewed research has looked at the relationship between natural gas development and production exposure and social-based health effects, and the existing literature appears to be mixed. While there are several studies providing evidence that exposure to natural gas development and production can have negative psycho-social health implications, there are also studies that find positive effects[71 72-75]. Additionally, there are a few studies that find no association at all between natural gas development and production and social and psychological health[17, 76]. Based on the current state of this literature, it is difficult to estimate social and community health effects related to natural gas development and production.

There is some literature available which discusses the relationship of "boomtown" economies and community health. According to information provided by Antero, the workforce for Antero's project is likely to average 120-150 workers. The impact of the Antero workforce may produce some "boomtown" effects, but the magnitude of these effects will depend a great deal upon the makeup of the workforce (number of single men, number of families, living in or out of Battlement Mesa, etc.). Some commonly recognized social impacts of boomtown economies, many of which can be attributed to rapid increases in population and changes in the economic base, are: stresses on local government support and planning agencies; shortages of permanent housing units; and changing employment and business trends, both positive and negative[77]. The social problems of mental health, criminal activity, divorce, suicide and alcoholism are said to occur at disproportionate rates in boomtown economies compared to non-impacted communities[77]. Boomtown literature also describes disruptions in social cohesion due to population influx and the likely opposition that arises between the "new comers" (both temporary and permanent new residents) and the "old timers"[77]. However, both groups are vulnerable to combination of positive and negative community impacts.

Due to limited availability of readily accessible data measures, only the following topics were assessed to address uncertainty and community concern for community impacts of Antero's project.

Education: Inherent with changes in population come changes to school enrollment; increased population generally leads to an increase in the class size, which may dictate an increase in the ratio of students-to-teachers. Larger class sizes also put a strain on the physical aspects of educational facilities with increased wear-and-tear on furniture, books and equipment and need for more physical space. Influx of a semi-permanent or long-term work force coupled with a booming local economy could increase local school enrollments beyond capacity and expected annual growth rates. Increase school enrollment may also have positive effects in that the schools may qualify for increased funds to improve educational services and options.

Crime: 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[72-75]. Because jobs in natural gas development and production usually attract a transient workforce, residents in affected communities often attribute increasing crime rates to the industry workers. On the other hand, there has also been some literature reporting lower crime rates after the commencement of natural gas development and production [71] and some research arguing that there is no association at all between natural gas development and production and social and psychological health outcomes[17, 76]. Due to the uncertainty and potential for high impact on community residents, it is important to examine and monitor the available crime data for Battlement Mesa.

***Substance Abuse*:** 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 [71, 75, 78]. In some cases, increased illegal substance activity has been associated with seasonal increases in natural gas development and production [79]. At the local level, a 2006 survey of EnCana subcontractors working in Colorado, conducted by White River Counseling, reported that 66.3% of subcontractors were concerned about methamphetamine use among their employees, and 68.9% were concerned about heavy drinking. Concern was rated primarily with respect to productivity and workplace safety, however questions about community impact were also assessed. Notably, the respondents who reported higher levels of concern about the potential impact of employee substance abuse affecting the local community also had stronger feelings about being proactive to prevent alcohol and drug abuse[80]. While not a conclusive study, this indicates that workers may be receptive to substance abuse prevention and intervention efforts presented as part of a community health initiative. For these reasons, it is important to monitor whether drug and alcohol use among community residents shifts with the introduction of gas drilling.

***Mental Health and Suicide*:** Treatment for mental health conditions and suicidal tendencies is conducted predominantly in the outpatient setting. As such, hospital discharge data for these and related conditions generally do not reflect the true burden of these issues in any given community. Additionally, due to their highly sensitive nature, outpatient data for these issues at the local community level is not publicly available. Studies of the community impacts of boomtown industries do not offer clear evidence for direct impacts to mental health, other than to suggest that changes in other measures may add or subtract from the levels stress, worry, and satisfaction experienced by individuals in the community[77, 79].

***Sexually Transmitted Infection*:** In any population, sexually transmitted infections are an important public health prevention priority. Undetected and untreated infection with certain sexually transmitted infections can cause long term health problems. As described by the National Institute of Allergy and Infectious Diseases, some of the health complications that arise from sexually transmitted infections include pelvic inflammatory disease, infertility, tubal or ectopic pregnancy, cervical cancer, and perinatal or congenital infections in infants born to infected mothers[81]. In addition, syphilis and HIV/AIDS cause substantial health problems in all those infected. In addition to long-term health effects of acquired sexually transmitted infection's, there are the daily consequences of pain, discomfort, and often embarrassment. Loss of worker productivity is also a concern with sexually transmitted infection, due to time required away from work to access testing, and received results and treatment, a process which may involve two days off work depending on travel distance to the nearest confidential testing/treatment center[82-83].

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 [82-83]. The same association has not been causally established by research conducted in relation to North American energy-extraction; however, it stands to reason that this is an area which should be monitored. Key factors perceived to increase the spread of sexually transmitted infection with the influx of extraction-industries include the transient nature of the in-migrant worker population who are away from social controls of their home community, the long and difficult work days possibly fostering desire for drug and alcohol binges during time off, and high salaries and disposable income in a young work-force[82-83]. These contributing factors are concerning given the difficulties often experienced in providing sexually transmitted infection prevention and treatment for an itinerant natural gas development and production workforce. In addition to the inherent stigmas often associated with sexually transmitted infection testing/treatment, workers cite lack of access to sexually transmitted infection services due to geographic isolation from sexually transmitted infection services, lack of available walk-in testing and sexually transmitted infection clinic hours overlapping with their own working hours[82-83].

***Lifestyle/Recreation*:** Many residents of Battlement Mesa seek the enjoyment of outdoor recreational activities, and thus expressed concern over potential impediments to participating in activities such as hiking, biking, fishing, hunting, and golfing. Negative effects to community engagement in these activities would likely be due to changes in the surrounding wilderness and public lands that may be caused by natural gas development and production. We were unable to assess whether public access to recreational activities would be altered by this project, and the extent of potential environmental effects are not known at this time. In addition to outdoor recreation, Battlement Mesa offers residents a 53,000 square-foot indoor recreation facility. An increase in local population may raise membership at the activity center, however this is not expected to supersede capacity as the facility was designed and built as part of the planned community of Battlement Mesa[11].

***Social Capital/Social Cohesion*:** Perhaps the biggest contributor to the social cohesion of Battlement Mesa is its status as a "planned community", where business, schools, and facilities and access for recreation are cohesively integrated with residential living[11]. Well-planned combinations of built and natural environments promote social interaction and pride in community living, which are in turn determinants of mental health and well-being[66]. Strong social support and community networks have generally positive effects on physical and mental health of individuals[84]. As such, effects on the social cohesion of Battlement Mesa residents may be determined and intertwined with physical effects to the community itself, such as damaged or neglected roads, neighboring homes and businesses, public lands and parks. There is limited data available to directly assess the functioning level of social capital and cohesion in any community, yet surrogate measures can be monitored. These include many of the issues already discussed, as well as monitoring access and use of public health and social services. As population of an area changes or grows, it is expected that the infrastructure of services rendered to that community may need to adapt to meet increasing or changing demands

4.5.3 Characterization of Community Wellness Impacts

As described above, community wellness is characterized by a compilation of factors such as school enrollment, rates of sexually transmitted infection, incidence of criminal activity, burden of substance abuse, and other immeasurable factors such as quality of life, social cohesion, and social capital. For the purposes of this project, the impact due to the Antero project in Battlement Mesa on the community wellness of local residents was calculated as a single factor as follows:

Impact	**Direction of health effects**	**Geographical Extent of exposure**	**Vulnerable populations**	**Duration of exposure**	**Frequency of exposure**	**Likelihood of health effects as a result of Project**	**Magnitude of health effects**	**Rank**
Community Wellness	Mixed (±)	Community Wide	Yes	Long	Infrequent	Possible	Low to Medium	±11.5*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

Community health effects are expected to be **mixed**, both positive and negative. Positive effects might include less stress over finances if increased demand for local business trickles down through the local economy, and increased access to social resources, services and infrastructure expanded to support a growing and changing population[77]. Negative effects that may be experienced include stresses associated with perceived or real increased threat of crime, heavier industrial traffic and visible impacts to natural environment and recreation areas. Community impacts would be expected to be **community-wide,** affecting the entire geographic extent of the Battlement Mesa PUD equivalently. It is possible that the elderly or youth of the community are more **vulnerable** to impacts of community well-being. Elderly may be more vulnerable to crimes of theft or burglary, and are the likely group most affected by changes in social service availability and accessibility. Children would be most affected by changes in school enrollment and class size. They may also be affected by changes in outdoor areas used for play, which may overlap with areas prone to more industrial activity or along roadsides used more frequently for hauling drilling materials. We expect the community impacts to continue for the duration of Antero's project (five years), and therefore be **long**. Because the Antero project is relatively small, it is expected that exposure to altered community wellness will actually be **infrequent**. The overall magnitude of health effects is **low to medium**. This assessment is made based on the nature of community impacts, which do not often present through acute mechanisms. Given adequate coverage and support offered by social infrastructure, we expect the residents of Battlement Mesa will be able to successfully tolerate and adjust to community well-being impacts. Using the numerical ranking scheme, community wellness impacts are expected to produce a negative rank of -11.5 on a scale of ±6-15.

4.5.4 Findings and Recommendations Related to Community Wellness

What we know: A variety of physical and social factors impact the health of a community. The little information available on these physical and social factors for Battlement Mesa show the community is in good health, as compared to the population of Colorado.

What we do not know: We do not know the actual population count, demographics, physical and social health specific to the Battlement Mesa PUD because information has not been collected at this level. In addition, several physical and social health measurements are not routinely monitored.

Recommendations to Reduce Impacts to Community Wellness

Based on these findings, the following are some of the suggested ways to reduce the potential impact to Community Wellness.

1. Establish a mechanism to facilitate on-going community engagement between Antero, GCPH officials and residents of Battlement Mesa for early identification of impacts to community wellness.
2. Review sexually transmitted infection clinic access, outreach and education, with particular attention to in-migrant workforce to reduce spread of sexually transmitted infections within the community.
3. Identify employers that have implemented drug and alcohol free work-place programs and encourage other employers to do so to reduce drug and alcohol abuse. Provide education to employers regarding benefits of such programs.

The recommendations to address information gaps are in Section 5.

4.6 Assessment of Economic and Employment Impacts on Health in Battlement Mesa

Will a boom and bust cycle occur? We are now in a bust and the food banks drying up.
February 3, 2010 stakeholder meeting

Economic conditions of a region can have significant impact on the health of the population. Employment status can impact individual health and well being and economic uncertainty can impact health by increasing stress. Economic development of poor and rural areas is often credited with bringing resources that support health; however "boom town" growth related to natural gas development in Garfield County and other parts of the West have had mixed economic impacts. Residents of Battlement Mesa have expressed concerns that sudden economic growth within their community may negatively impact the community by causing housing and goods inflation, and impacting services. Others in the community are concerned that gas industry development will decrease the appeal of the community and cause a decrease in home values. A review of economic and employment impacts of the Antero gas project in Battlement Mesa is warranted.

4.6.1 Economy, employment, and health

Income and employment influence many central determinants of health and wellbeing, including quality of housing, education, diet, lifestyle, access to health services, etc. Income sufficient to support these basics is strongly related to life expectancy: internationally, annual per capita income above $5,000- $10,000 translates into decades of increased longitivity for the population[85]. For individuals, employment is directly related to positive health outcomes[86] and stress related to job loss, unemployment, and job instability is strongly correlated with self-report of poor health[87]. In addition, in the Untied States, health insurance access is directly related to employment for those under the age of 65. Loss of insurance can lead to decreased health care access and poorer health.

Increased economic activity of a region can increase tax revenues which in turn can be used to support public services, thereby enhancing community wellness. However, if an economy grows too fast, it can create excessive demands on public services and community wellness can suffer. In addition, housing prices and property taxes can rise in response to growing local economies and stress finances of local residents, particularly those on fixed incomes. Increased wages and growing populations associated with new industry can increase demand for all goods, can also create price inflation, which in turn can impact residents' ability to maintain health.

Furthermore, if economic booms are followed by economic busts, loss of resources and jobs can devastate community and individual wellbeing. Repeated boom/bust cycles, where jobs, wages, and services are recurrently out of balance, can lead to significant community stress.

4.6.2 Current Economic and Employment Conditions

Housing prices in Battlement Mesa have been rising steadily over the last decade and have increased faster than average income. In 2008, the estimated median value for a house or condominium was $201,116, nearly 150% higher than estimated values in 2000 ($136,100). Meanwhile, the estimated median household income in 2008 was $42,882—up 17% from the median income in 2000 ($36,680), but still lower than the estimated 2008 state average

($56,993)[88]. Housing price inflation was for the most part due to the regional natural gas boom. The decline of natural gas development in 2008-09 has relieved some pressure on housing prices and availability.

In 2008, Battlement Mesa had a lower poverty rate than Colorado (6.0% vs 9.3%). Primary industries for males is construction, mining, natural gas development and production, and accommodations, and for females health care, education, and food and beverage stores[88].

Residents in Garfield County generally rate themselves to be in good health. In 2008, the Saccommano Institute conducted a survey of Garfield County residents. The results found that 85% of residents surveyed perceived themselves to be in excellent or good health, and that about 76% of those surveyed reported feeling about the same or better level of health than one year prior. Similar results were recorded for the Battlement Mesa/Parachute zip code, with approximately 83% excellent or good health[23].

4.6.3 Antero Drilling Plans in Battlement Mesa and Economics and Employment

Natural gas development has created boom economies in Wyoming, Colorado and other regions of the West over the last decade, with mixed economic impacts to local residents and workers. Examination of natural gas boomtown economics in three towns in Wyoming, related to approximately 40-60 operating rigs in the county, revealed that itinerant workers in the natural natural gas development and production benefited the most from high industry wages, while local residents and workers experienced negative economic impacts associated with inflation, increased property taxes and decreased services[89-90]. This boomtown model predicts changes for other communities involved in the natural gas development and production. Some local businesses may benefit from an increase in commerce, but some may not be able to expand to meet demand and quality of service declines. Increased commerce may bring “box” stores and other new businesses, putting more strain on longtime local business, and some may end up closing. Local residents not earning high industry wages may not be able to keep up with rising cost of living, housing prices, property taxes, and other signs of inflation. Such a change in the economy can cause psychological stress to local workers and residents, resulting in possible mood disturbance, disturbance of thought, sleep disturbance, and immune system effects[91]. Because the gas well development phase is very labor intensive, boom economics associated with worker population influx predictably cycles to bust economics when the development phase for the area is over and development moves on to other regions.

The number of workers involved in well development can vary widely according to pad site topography and geology, number of wells per pad, characteristics of the gas, etc. Most workers are employees of companies subcontracted to perform very specific development jobs and remain on a given pad only as long as needed, sometimes only days, weeks or a few months. Antero plans to use two rigs to develop approximately 200 wells in the PUD over the course of five years. This kind of serial operation may keep many of the workers working within the PUD for much of that time, moving from one site to the next as development progresses. Influx of workers associated with all stages of development during this period is likely to have the most significant economic impact to the area. Once all the wells in the PUD are developed, the workforce needed to maintain the wells over the 20 years of production is relatively very small.

When comparing the economics of the two rig operation in Battlement Mesa to the 40-60 rig boomtown economics of Wyoming and Colorado it becomes apparent that the Antero project is relatively small and the economic benefits and detriments are expected to be small as well. Furthermore, these impacts are not expected to be restricted to Battlement Mesa, but are more likely to be absorbed into the general Garfield County economy. Some workers may live in Battlement Mesa, thereby creating demand for housing, but many may live outside of the Battlement Mesa community as well. Tax revenues from the Antero project will be realized at a county level. By itself, this operation is not likely to create a significant boom economy

Antero estimates of number of workers needed for well development to be an average of 60-75 workers per rig operation .This number is necessarily an average and an estimate and actual numbers of workers are likely to vary significantly from day to day, and well pad to well pad. Once in production, only a small number of workers are needed for routine maintenance of wells.

Economic benefits of higher wages will be primarily realized by industry itinerant workers. The presence of 120-150 workers in the PUD will provide economic benefits to some local businesses, however, these businesses will also be negatively impacted when the development stages are over and the workers leave. Local residents not employed by the industry or supporting businesses may not benefit from economic growth but may be at risk for negative impacts of housing and goods price inflation, rising property taxes and potentially compromised services.

4.6.4 Characterization of the Economy and Employment Impacts on Health

The impact on the economy and employment due to the Antero project in Battlement Mesa on the health of local residents can be characterized as follows:

Impact	**Direction of health effects**	**Geographic Extent of exposure**	**Vulnerable populations**	**Duration of exposure**	**Frequency of exposure**	**Likelihood of health effects as a result of Project**	**Magnitude of health effects**	**Rank**
Employment and economy	Mixed (±)	Community wide	Yes	Long	Infrequent or constant	Unlikely	Low	±10.5*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

Based upon estimates of 100-200 workers for a 2 rig operation over five years, the health effects of the Antero project on Battlement Mesa citizens is likely to be **mixed** with positive effects of higher wages for some residents and higher inflation and no wage increase for others. Economic impacts are likely to be experienced **community-wide** and those on fixed incomes are more **vulnerable** to the negative effects of inflation. The impacts of increased economic activity are likely to be **long**, lasting at least five years, and the frequency of having a health impact (stress, sleep disturbance) as a result of the economic activity is likely to be either **infrequent or constant**, depending upon the individual circumstances. Given the small economic size of Antero's plan and the probability that the economic impacts will be absorbed into the county, it is **unlikely** that there will be health impacts due to changing economic conditions and the magnitude of any health impacts will be **low**. Using the numerical ranking scheme, economic and employment impacts are expected to produce a mixed rank of ± 10.5 on a scale of ±6-15.

4.6.5 Findings and Recommendations from Economic and Employment Assessment

What we know: Boom and bust industries, such as natural gas development and production, can affect public health through rises and falls in the local economy and employment. However, Antero's project within the PUD is too small to initiate a boom and bust cycle.

What we do not know: We do not know the affect Antero's plan will have on housing prices within the PUD.

Recommendations to Reduce Impacts from Boom and Bust Cycles

Based on these findings, the following are some of the suggested ways to reduce the potential negative aspects and maximize potential positive aspects from economic and employment impacts.

1. Review local tax structure to ensure that revenue from natural gas development and production are used to mitigate impacts in areas most affected by the industry development in order for the community to realize the economic benefits.
2. Continue to consider public health as a high level priority when judging uses of local government revenues derived from the natural gas development and production to maximize protection of public health.
3. Engage in long term planning to maintain affordable housing, education, and public services to protect residents from sudden industry downturns (e.g. the bust).
4. Consider mechanisms for providing property tax relief for residents on fixed income should home values rise rapidly to reduce negative economic impacts.
5. Engage local educational institutions to provide industry related training so that local residents can be employed by the industry.
6. Engage local educational institutions to provide retraining for residents employed by the industry so that they can find future employment when industry development is complete and development jobs are no long available locally to reduce impacts from sudden industry downturns.

The recommendations to address information gaps are in Section 5.

4.7 Assessment of Impacts to Health Infrastructure in Battlement Mesa

"What will be the impacts to health care in Battlement Mesa?
February 3 stakeholder meeting

Health infrastructure can include private and public medical services, hospitals, and emergency transport services. Availability, access and quality of local clinical and public health services can be limited in small communities, due to small populations, low rates of insured patients, and limited public resources. New industry can lead to positive and /or negative impacts on the health care infrastructure. Industrialization of a rural community can increase the insured population and local revenues, which may provide resources for expansion of local clinical and public health care services. On the other hand, without substantial investment in health infrastructure, population and employment changes may increase both clinical and public health care utilization, stretching already limited resources. The citizens in the rural community of Battlement Mesa have expressed concerns that development of natural gas resources in their community may negatively impact available medical resources. Because the Battlement Mesa health infrastructure may be exposed to utilization changes, a review of potential health impacts is needed.

4.7.1 Private and Public Health Services and Health

Availability, access and quality of medical health services can have direct impacts on individual physical health. Research demonstrates that residents of rural communities often have decreased clinical health care services available to them, negatively impacting health [92-95]. Limited availability can be due to a combination of small population and low health insurance coverage, both of which limit the financial viability of both clinical and public services. As a result, residents of rural communities may need to travel long distances for care.

Increased economic activity in a community may bring more patients and insurance coverage which can support increased and diversified clinical medical services. On the other hand, a rapid increase in population, particularly uninsured population, can increase utilization of services beyond capacity and may strain the finances of small medical facilities and decrease incentive to increase services[77].

Public health programs provide services to the general community and can fill some gaps for the un-insured[96-97]. Vaccination programs, health screenings, and communicable disease clinics provide limited clinical health care to uninsured populations. Public health programs that focus on food safety programs and health education programs benefit the community at large. When the local population increases, particularly an uninsured population, local public health services may experience increased utilization while capacity may lag or never catch up. Cyclical economic conditions may also cause intermittent strain on public health programs while making it difficult to adjust capacity to need. On the other hand, local revenues may be able to increase public health services, should tax and royalty structures and community priorities permit it. In some cases, severance taxes from extractive industries are sent to state agencies, with little benefit to the localities where the industrial activity is occurring[77].

4.7.2 Current Health Infrastructure Conditions

Currently, primary clinical health services in Battlement Mesa include a primary care clinic administered by the Grand River Hospital District, staffed five days a week by family medicine providers and visiting specialists. The clinic also provides physical therapy services three days a week. There is also separate chiropractic, orthopedic, and dental services in Battlement Mesa. There are four hospitals within 60 minutes of Battlement Mesa. The closest hospital is Grand River Medical Center in Rifle, 20 minutes away. This is a 12-bed hospital with an emergency room, surgical, acute care facilities, and outpatient clinics. Grand River Medical Center is a Level 4 trauma center; it does not provide have obstetric (baby delivery) services. Valley View Hospital in Glenwood Springs, 46 miles away, has 80 beds, a 24 hour emergency department, and obstetric services. Community Hospital in Grand Junction, 48 mile away, has 78 beds and does not provide obstetric services. St. Mary's Hospital in Grand Junction, 49 miles away, is a Level 2 trauma center and has obstetric services. The closest Level 1 trauma center is 4 hours away in Denver. Patients needing such services may be airlifted. Emergency response and transport is provided by the Grand Valley Fire Protection District. There is an occupational health clinic operated by Grand River Hospital District in Battlement Mesa that sees work related injuries five days a week.

There is a 40 room assisted living facility in Battlement Mesa. The closest skilled nursing facility is in Rifle and there are other nursing facilities in the county. Meals on Wheels is offered in Battlement Mesa and a senior center in Parachute offers lunch daily.

Public Health services for Battlement Mesa citizens are offered by GCPH. Services include vaccination clinics, communicable disease surveillance, health education programs, safety programs, health screening for Medicaid patients, and programs for underinsured children and low income families. The Environmental Health Program serves the public by evaluation and education regarding environmental health risks related to air and water quality, sewage treatment, mosquito control, and environmental sustainability. The GCPH offices are located in Rifle and Glenwood Springs.

Insurance coverage rates for Battlement Mesa residents are not available. According to the Colorado Household survey conducted in 2008-9 by the Colorado Department of Health Care Policy and Financing[98], 14% of Colorado residents were uninsured and in the five county region that included Garfield County, 21% of the population was uninsured (the highest in the state). In

Colorado, 15% of employed adults were uninsured. Insurance status for natural gas industry workers is unavailable.

4.7.3 Antero Drilling Plans in Battlement Mesa and Healthcare Infrastructure

The development of natural gas wells requires several labor intensive phases, which can last several years for large natural gas projects. Most health infrastructure impacts relate to the expanded workforce during the well development phase. Antero estimates an average of 120-150 workers will be working in Battlement Mesa.

Workers associated with natural gas development and production projects can increase utilization of emergency services due to increased work related and transportation related accidents associated with the injury[77]. Insured natural gas workers utilizing the health care system could provide positive support to the system as long as the utilization does not exceed capacity. Should utilization exceed capacity, then the availability of services may be negatively impacted. Uninsured workers strain the health care system. Public health programs may see an increase of utilization as a result of an increase the insured and uninsured population. On the other hand, pubic health programs may benefit from increased local revenues, as long as utilization does not exceed capacity. Should this happen without increased supporting revenue dedicated to public health, then services may be compromised. The cyclical nature of the natural gas development and production, which is dependent upon market influences, technological advances and regulatory forces, can make both clinical and public health infrastructure planning difficult and lead to a mismatch between needs and services.

Workers and their families are expected to utilize clinical and public health services in Battlement Mesa and other local services. According to Antero representatives, Antero workers are offered health insurance; however, information regarding health insurance coverage for subcontracted workers (the majority) is not available. Some clinical services may see a disproportional increase in utilization, including emergency, urgent care and trauma services and services related to pediatric care for young families. Depending on the insurance status of the workers, these services may or may not be directly supported by the industry. Clinical and emergency providers may be negatively impacted by uncompensated care, and public health services may see an increase in local needs without increased funding. Utilization of health services by insured gas workers will support the health system. Revenues to Garfield County could be used to support public health services, depending upon prioritization of needs.

4.7.4 Characterization of Healthcare Infrastructure Impacts

Impact	Direction of health effects	Geographical Extent of exposure	Vulnerable populations	Duration of exposure	Frequency of exposure	Likelihood of health effects as a result of Project	Magnitude of health effects	Rank
Health Infrastructure	Mixed (±)	Community-wide	Yes	Long	Infrequent	Unlikely	Low	±10*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

When considering anticipated impacts to local health infrastructure associated with the Antero development within the Battlement Mesa PUD, the increase in workforce and the associated potential health care utilization could have **mixed** health effects in Battlement Mesa community; however, impacts to the health care system are anticipated to be small given Antero's project only involves 120 to 150 workers, spread into a community of approximately 5,000 in Battlement Mesa and 55,000 in Garfield county. There is a potential for increased utilization of the health care services to strain existing services, however, the extent of such a strain may be small enough that it is unlikely to lead to decreased availability and quality of services. Likewise, insured workers will support local health services but the extent of such support may not be sufficient to lead to increased availability and quality of services. Local tax revenues from the Antero project will contribute to the overall county fund are not likely to be large enough to directly impact public health services in Battlement Mesa. Impacts of uninsured workers are likely to be noted by providers, but it is unclear that this would reach a level that would negatively impact either clinical or public health services. Should health services be impacted in Battlement Mesa, the impacts would affect the **entire community**, although those that utilize health care services most frequently such as the elderly, young children and disabled may be more **vulnerable** to negative impacts such as decreased availability. Likewise, those groups may benefit from expanded health care services. Should health service impacts occur, they are likely to be noted in the first few **years** of Antero's project as the health infrastructure adjusts to new needs. Impacts to the health care infrastructure are not anticipated to last the entire duration of Antero's project. The frequency of both positive and negative on impacts the health care system and therefore on the community are likely to be **sporadic**, given that the relatively small number of workers and families associated with the Antero project. It is possible that large financial strain to local providers, particularly emergency care providers, could occur should expensive emergent care become necessary for an uninsured worker, but this is anticipated to be an infrequent event. Potential impact to vulnerable groups, the community at large and the multiple years of potential exposure drive a high summary statistic, however, it is **unlikely** that Battlement Mesa citizens will experience positive or negative health impacts as a result of changes to the health care infrastructure related to the Antero project. The overall magnitude of health effects due to health infrastructure impacts are expected to be **low**. Using the numerical ranking scheme, healthcare infrastructure impacts are expected to produce a mixed rank of ±10.0 on a scale of ±6-15.

4.7.5 Findings and Recommendations Related to Health Care Infrastructure

What we know: The availability of healthcare facilities and professionals affects public health. The level of health insurance in an area affects health care infrastructure.

What we do not know: The level of health insurance in natural gas development and production is not known.

Recommendations to Prepare for Impacts to Health Care Infrastructure

Based on these findings, the following are some of the suggested ways to prepare for the potential impact to the Health Care infrastructure.

1. Monitor which companies, including Antero and subcontracting companies, provide health insurance to employees to determine direction of impact.
2. Review county tax structure for adequacy of revenues necessary to meet increased county services, including public health services.

The recommendations to address information gaps are in Section 5.

4.8 Assessment of Accidents and Malfunctions Impacts on Health

Is there a plan to prevent pipeline leaks and explosions?
February3, 2010 stakeholders meeting

Accidents and malfunctions can occur as a result of a variety of causes, including equipment failure, human error, and environmental hazards. Identification of potential sources of accidents and malfunctions can lead to effective prevention efforts, while recognition of potential health, community, and environmental effects can direct response strategies which can decrease impacts should an incident occur. COGCC addresses accident prevention (fire, explosion, hazardous materials release, pipeline maintenance) throughout the Rules Document[9]. The 600 series rules address safety regulations. For example, setbacks for pad locations are 150 feet in low population density areas, 350 feet in high population areas and 1000 feet for other facilities such as schools, hospitals, etc. Rule 906 specifies reporting, prevention and clean up requirements for spills and releases. Pipeline regulations are found in Rules 1101-1103, however, there is not a designated setback for pipelines in the COGCC rules.

According to the Denver Post, there were over 1,000 spills statewide and over 230 in Garfield County reported to the COGCC between January 2008 and June 2010[99]. There were 21 fires, loss of well control (including gas kicks), and explosions in Garfield County that were reported to the COGCC from January 1997 to August 2010 (COGCC database). The Battlement Mesa citizens have expressed concerns regarding the potential for accidents and spills and the potential for related health and safety impacts. Because incidents of this nature happen with low, but predictable, regularity, an assessment of potential health impacts is warranted.

4.8.1 Accidents, Malfunctions and Health

Accidents and malfunctions can occur as a result of well installation errors, material failure, construction and operations accidents, equipment accidents and failures, third party activities, and environmental episodes. Incidents can manifest as fires, explosions, hazardous material losses, and/or spills. Fires and explosions may result from well blowouts, gas kicks, pipeline leak or rupture, ignition of flammable materials during storage, transportation or transfer. Hazardous materials spills/loss may be due to transportation accidents or equipment failure, during material transfer, leaking valves, fittings, etc in storage equipment, well blowouts, and improper disposal of hazardous materials. Environmental conditions such as wildfires, tornados, lighting, blizzards, and extreme heat and cold may cause or exacerbate incidents.

These incidents may result in release of contaminants into surface water, ground water, soil, and air. Releases associated with significant accidents and malfunctions are likely to be acute, high level emissions. Releases of produced water into soil and water sources contain salts, metals, VOC/BTEX, drilling fluids, muds and fracking chemicals. Spills of drilling and fracking materials could include a variety of chemicals such as diesel fuel and other hydrocarbons, BTEX, acids, glutaraldehyde, and other proprietary chemicals. Releases of natural gas into water or air contain VOC/BTEX. Combustion products of hydrocarbons released during fires contain PAHs, including naphthalene, sulfur oxides, nitrogen oxides, PM and other chemicals.

Examples of potential health effects of chemicals given sufficient exposure:

Chemical	Acute health effect
VOC	Irritant, neurological
Benzene	Neurological, anemia
Naphthalene	Anemia
Combustion Products	Respiratory, cardiovascular, irritants
Hydrochloric acid	Irritant
Glutaraldehyde	Irritant, allergic reactions

In addition to chemical exposures, accidents and malfunctions can expose nearby persons to injury or death. Although outcomes are potentially severe, these exposures are generally short-term, very rare and only those in close vicinity at the time of the accident are at risk. Employees on the well pad during a fire or explosion are at most risk for injury. Although the likelihood of an explosion involving a pipeline occur is very small, persons in the community may be at risk for injury should such an incident occur. An explosion occurred in a rural area of Johnson County Texas on July 7, 2010 when crews installing a communications pole hit a 36-inch gas transmission line. Newspaper reports indicated that one worker was killed, and seven injured.

The fire was reported to be 400-600 feet in circumference and intense heat was felt 900 feet away. The gas line valves were shut off 1.5 hours after the explosion, and the fire stopped. A more recent explosion of a 30 inch gas distribution line in San Bruno, California on September 9, 2010, destroyed 150 homes and killed four people. The cause of this explosion is still unknown. Other accounts of explosions related to natural gas development, production, and distribution can be found in newspaper accounts throughout the country.

4.8.2 Current Conditions for Accidents and Malfunctions

According to the Denver Post, 236 spills in Garfield County were reported to the COGCC between January 1, 2008 and June 15 2010, involving 66,386 barrels of fluids (primarily drilling liquids and produced water)[99]. During that time, Antero submitted approximately 5 percent of the gas permits in Garfield County, reported 15 spills to the COGCC (6 percent of the spills). Antero's contribution of 1707 barrels of fluids to the total barrels spilled in Garfield is small (2.6 percent). Five of Antero's 15 spills have required remedial action and one resulted in a notice of alleged violation (also known as NOAV) because of failure to report the spill to COGCC per the oil and gas rules.

Antero has received three other Notice of Alleged Violations since January 1, 2008. The latest, on July 14, 2010, was in response to several odor complaints filed during flow back operations on the Watson Ranch well pad. Another Notice of Alleged Violation issued on January 04, 2010, resulted from lack of secondary containment of condensate from fracking tanks and observation of condensate lying on the ground around fracking tanks and separation units. COGCC issued a third Notice of Alleged Violation because Antero spudded a well prior to permit approval in June 2009[100].

Local newspapers and COGCC databases have recorded incidents of well fires, blowouts, tanker spills, condensate tank emissions and pit discharges in Garfield County. These incidents have resulted in contamination of surface and ground water with BTEX, and other chemicals. Residents have reported a variety of health effects, including acute and long term neurological complaints, upper respiratory issues, headaches and fatigue, and nausea. There have been no reported fatal injuries related to accidents or malfunctions in Garfield County reported to COGCC.

4.8.3 Antero Drilling Plans in Battlement Mesa and Accidents and Malfunctions

Applying Antero's spill rate of 15 spills per 252 permit applications (6 percent) and rate of 5 remediations per 15 spills to the 200 wells proposed for Battlement Mesa it is estimated that approximately 12 spills of 5 gallons or more may be expected in Battlement Mesa. It can be expected that at least four of these spills may have some impact to soil, groundwater, or surface water requiring remediation and have the potential to impact public health.

As discussed in the Water and Soil Quality Assessment, Battlement Mesa residents use a municipal water system that draws water from the Colorado River. Secondary water supplies include four shallow ground water wells which were used prior to the establishment of the water treatment plant. These wells are monitored once a year for quality.

The Surface Use Agreement between Antero and The BMC specifies a temporary 50 foot easement for pipeline construction and a permanent 25 foot easement for gas gathering lines. Antero also plans to build a wastewater pipeline system along the same easements. The Surface Use Agreement states that the gas gathering lines will be 48 inches below the surface. The gas gathering lines in Battlement Mesa will be 12 inches in diameter. According to maps provided at community meetings, the pipelines primarily follow haul routes, however, a pipeline there is one pipeline that will cross an open space in a residential area between Valley View Village and Fairways Village. It is unclear from available maps how far this pipeline, or any other pipeline on the map, is from residences, schools and other buildings.

Although the COGCC rules allow for 350 foot well pad setbacks in densely populated areas, the Antero well pads in Battlement Mesa are all at least 500 feet from the nearest residence.

4.8.4 Characterization of the Impact from Accidents and Malfunctions

Impact	Direction of health effects	Geographical Extent of exposure	Vulnerable populations	Duration of exposure	Frequency of exposure	Likelihood of health effects	Magnitude of health effects	Rank
Accidents and malfunctions	Negative (-)	Local or Community wide	Yes	Short	Infrequent	Possible	Low to high	-10*

*For an explanation of the numerical ranking system used, see the chart at the beginning of Section 4.

When considering the possible health impacts due to an accident or malfunction of Antero gas operations in Battlement Mesa, the health effects are likely to be **negative**. Depending upon the size and nature of the incident, health and safety impacts may be felt only in close proximity (**local**) or throughout the PUD (**community-wide**). Again, depending upon the nature of the incident, certain populations may be more **vulnerable** to health impacts. For instance, elderly or frail and those living in the assisted living facility, may have difficulty evacuating an area quickly. Children in school may also be slower to evacuate. Those with underlying medical conditions such as pulmonary or cardiovascular disease, may have negative health effects to fires or air emissions at levels that are may not have significant impact to others. Accidents and malfunctions are likely to be **short in duration** and **infrequent.** Given the 6% rate of incidents in the industry and within Antero's other operations in Garfield County, incidents are likely to occur and it is **possible** that health impacts will occur. The health effects will be **low to high** in magnitude, potentially ranging from minor irritation to more severe exacerbation of underlying health conditions to severe injury or death. Using the numerical ranking scheme, accidents and malfunction impacts are expected to produce a negative rank of -10.0 on a scale of ±6-15.

4.8.5 Findings and Recommendations from Assessment of Accidents and Malfunctions

What we know: A small number of accidents and malfunctions occur on a regular basis in natural gas development and production. These accidents and malfunctions can have minor to catastrophic consequences and can impact air, water, and soil quality. Lack of adherence to rules and regulations, as well as regulatory oversight and enforcement can result in accidents and malfunctions.

What we do not know: We do not know if the current setbacks and placements of pads, pipes, and maintenance stations are sufficient to protect residents from catastrophic malfunctions. We also do not know if there are emergency plans in place that address catastrophic malfunctions.

Recommendations to Reduce Impacts from Accidents and Malfunctions

Based on these findings, the following are some of the suggested ways to reduce the potential public health impact from accidents and malfunctions.

1. Require review of evacuation, shelter in place and air intake plans for all locations with high concentrations of persons, such as the schools, the assisted living facility, and recreation center to protect the public health and reduce injury. Allow these entities an opportunity to comment on Antero and community emergency response plans.
2. Require emergency responders to review evacuation and shelter in place plans for Battlement Mesa community and Antero emergency response plans to protect public health and reduce injury.
3. Periodically test emergency communications systems. Consider siren, reverse 911, or other system of other mass alert to protect the public health and reduce injury.
4. Require periodic maintenance review of water and gas gathering lines to highest industry standards to reduce accidents and malfunctions.
5. Institute mechanism for reporting safety concerns, near-misses, etc to the appropriate designated county agency or department to reduce accidents and malfunctions. Ensure timely follow up of all concerns.
6. Review procedures for utility permissions to dig near line location to reduce accidents and malfunctions.
7. Require permanent gas line markers in the field, and other standard practice safety procedures to reduce accidents and malfunctions.
8. Review pipeline system for routes that avoid proximity to homes, schools or other areas used by residents to protect the public health and reduce injury.

The recommendations to address information gaps are in Section 5.

4.9 Summary of Assessments on Health in Battlement Mesa

The following table summarizes the characterization of stressors and the numerical ranking of impacts on the health in Battlement Mesa. By ranking the stressors we are able to conclude that air quality impacts are likely to produce important negative health impacts to residents throughout the community. Other stressors that may produce relatively important health impacts include traffic, and noise. Compromise of water supplies could produce important effects to health but are not likely to occur. Some stressors may produce both positive and negative impacts (mixed) but health impacts will be of low to medium magnitude. These include stressors to community wellness, the economy and health infrastructure. The driving force for those impacts is primarily the workforce associated with the five year development phase. Accidents and malfunctions may impact health but incidents of this nature are difficult to predict. Recent events demonstrate, that although accidents and malfunctions are infrequent, on rare occasions they can be devastating and significant care should be taken to prevent them.

Assessment	**Direction of health effects**	**Geographical Extent of exposure**	**Vulnerable populations**	**Duration of exposure**	**Frequency of exposure**	**Likelihood of health effects as a result of Project**	**Magnitude of health effects**	**Rank**
Air Quality	Negative (-)	Community-wide	Yes	Long	Frequent	Likely	Moderate to High	-14.5
Water and Soil Quality	Negative (-)	Community-wide	Yes	Long	Infrequent	Unlikely	Moderate to High	-11.5
Traffic	Negative (-)	Community-wide	Yes	Long	Frequent	Possible	Low to high	-13
Noise, Vibration, Light	Negative (-)	Local	No	Long	Frequent	Possible	Low-Medium	-10.5
Community Wellness	Mixed (±)	Community-wide	Yes	Long	Infrequent	Possible	Low to Medium	± 11.5
Employment and economy	Mixed (±)	Community-wide	Yes	Long	Frequent	Unlikely	Low	±10.5
Health Infrastructure	Mixed (±)	Community-wide	Yes	Long	Infrequent	Unlikely	Low	±-10
Accidents and malfunctions	Negative (-)	Local or Community-wide	Yes	Short	Infrequent	Possible	Low to high	-10

5 Next Steps

This HIA used the compiled baseline health characteristics of Battlement Mesa, current ambient environmental conditions in Garfield County and Antero's proposed gas development and production plans to evaluate probable and possible health impacts of Antero's project to the residents of Battlement Mesa. Through this process the CSPH has attempted to address the concerns of the citizens outlined in the BCC petition.

At the end of each assessment recommendations aimed at decreasing potential negative health impacts are provided. However, CSPH identified numerous gaps in information that limited this evaluation and may limit future evaluations of health in Battlement Mesa.

In order to fill the information gaps identified in this HIA, investigation is needed in the following areas. The immediate next step will be development of an environmental and health monitoring study (EHMS) that addresses some but not all, of these issues.

AIR

1. Conduct baseline measurement of ambient air concentrations for air toxics within the Battlement Mesa PUD. Continue ambient air monitoring through out the development of Antero's natural gas project. Detection limits should be at or below EPA Regional Screening Levels and air quality standards, when available and technically possible.
2. Conduct air sampling at COGCC setbacks (150 feet, 300 feet), Antero setback (500 feet) and set back requested by citizens (1000 feet) during well installation, completion, and production operations and at the proposed water storage facility.
3. Further characterize constituents of odors during odor events.
4. Determine how to enhance public health response should emission levels exceed health based standards.

WATER

1. Establish hydrogeological characterisics of the four back up groundwater wells and the well pads, the proposed central water storage facility in Battlement Mesa and in other areas of gas development in Garfield County.
2. Develop estimates of environmental fate and transport of chemicals used in natural gas development

TRAFFIC

1. Use Geographical Information System technology to overlay proposed truck routes on a map of Battlement Mesa with location of schools, school zones, school bus routes, bike and walking paths to determine if alternative truck routes will improve community safety.
2. Conduct baseline pedestrian/bike route survey to establish current use and to identify where these routes overlap with haul routes. Monitor use through out the five year development phase.
3. Identify existing traffic "hot spots" within the PUD and along the haul routes that will be susceptible to increased traffic.

NOISE

1. Conduct background noise monitoring for Battlement Mesa residential areas, schools, and along main traffic routes.
2. Conduct noise monitoring at COGCC setbacks (150 feet, 300 feet), Antero setback (500 feet), and set back requested by citizens(1000 feet) during well installation, completion, and production operations and at the proposed water storage facility.

COMMUNITY WELLNESS

1. Determine number of workers needed for various development operations, including operator and subcontractor employees.
2. Establish methods to monitor measures of community well-being (i.e., mental health, suicide, substance abuse, crime, educational opportunities) specific to Battlement Mesa/Garfield County.
3. Monitor access and use of public health and social services.

ECONOMY

1. Monitor economic effects of natural gas development in Battlement Mesa/Garfield County.

HEALTH CARE INFRASTRUCTURE

1. Convene county level health care forum with private and public health providers to assess health care services and anticipated needs related to the natural gas development and production.

ACCIDENTS AND MALFUNCTIONS

1. Use Geographical Information System technology to overlay pipelines, pigging stations, well locations within Battlement Mesa community to determine relationship to residences, schools, assisted living facility, etc.

2. Determine if standards of practice for gas line placement within residential communities exists.

The Antero project described in this HIA involves approximately 200 wells, which is only a fraction of the natural gas development that is occurring in Garfield County. Furthermore, natural gas development is and will continue to grow in other parts of the region and state, as well as other parts of the country. The results of the EHMS will likely have application beyond the study area and will contribute to filling some of the knowledge gaps about natural gas development and production and health.

6 Conclusions

In May, 2010, the Garfield County BOCC engaged the CSPH to perform a HIA to respond to citizen concerns about natural gas drilling in Battlement Mesa, Colorado. The CSPH has worked closely with the GCPH to ensure the scope of the HIA addressed the concerns outlined by the citizens in their letter to the BOCC as well as those voiced in citizen meetings. Along with the GCPH, the CSPH also met with the COGCC, the CDPHE, Antero, and the Colorado Hospital Association to ensure that all stakeholders with pertinent data and information had an opportunity to be involved in the HIA process.

To provide a scientific basis for the HIA we conducted a longitudinal review of multiple Garfield County air and water monitoring studies as well as COGCC reports of water contamination in the county. This information was used to conduct a Human Health Risk Assessment. We also obtained demographic, physical and social health outcome data and used it in a comprehensive review described in the Battlement Mesa Baseline Health Profile. We also reviewed all publicly available information on Antero's plans to drill in Battlement Mesa, as well information made available to us by request from Antero.

With this data we determined that natural gas development and production has the potential to create a variety of stressors that can impact health. Using the medical and social health literature, we reviewed the links between these stressors and health and then applied current conditions and Antero's natural gas development and production plans to assess the potential future impacts of these physical, psychological and social stressors. The HIA considers the mitigations that Antero has disclosed to decrease impacts, so the HIA is based on anticipated effects to current and future residents. These stressors include air emissions, water and soil contamination, traffic, noise/vibration/light, community wellness, economic/employment changes, health infrastructure stress, and industrial accidents/malfunctions.

Using this scientifically based, methodological approach we found that air emissions are likely to occur at levels that can cause human health impacts, especially to vulnerable populations. Increased traffic, particularly increased truck traffic, will be a safety risk to Battlement Mesa residents and contribute to increased air and noise pollution. Increased noise may annoy some residents, but at current and anticipated future levels it is not likely to cause health impacts. Should water contamination and industrial accidents/malfunctions occur they could also cause important health impacts to Battlement Mesa residents, but these events are not likely to occur.

Some stressors may have positive as well as negative social impacts. The Antero project may provide jobs for some Battlement Mesa residents and may provide increased economic activity for some local businesses, including health clinics. As long as these businesses are able to maintain services in the face of increased business, this increased economic activity can be positive for the community. If the quality of services, including medical services, diminishes, then negative physical and/or social health impacts could occur. Other aspects of community wellness may be negatively impacted, and increased levels of substance abuse, crime, and sexually transmitted infections may occur, while opportunities for recreation and social cohesion could decrease. Both the positive and the negative effects of changing economics/employment, health care infrastructure, and community wellness will likely be small given the relatively small size of the Antero project and the likelihood that these affects will be generally absorbed into the County as a whole rather than affecting Battlement Mesa alone.

At the end of each assessment and Section 5, the CSPH investigators have provided several recommendations aimed at decreasing negative impacts or improving positive impacts. Central to decreasing the primary health stressor, air pollution, is continued efforts to decrease all possible emission sources. To bring emissions to the lowest possible level, it is important that the best available current technology be utilized, and new technologies be developed and adopted. To provide an adequate margin of safety, current COGCC emissions rules need to be strictly enforced. Ambient and well pad monitoring should be conducted to characterize emissions and their impacts on local air sheds and determine if further regulation is needed to protect public health. Likewise, because of the potential for important health impacts due to water contamination from accidents and/or malfunctions, effort should be focused on prevention of such events, the best available technologies required, new technologies adapted, and strict monitoring maintained. Traffic mitigation should also be a priority in order to reduce the inherent safety risk associated with large truck traffic in residential areas. Noise associated with Antero's project should be monitored and efforts to decrease noise due to drilling activities as well as truck traffic undertaken. Finally, efforts should be made to use economic benefits from Antero's project to mitigate the potential negative impacts of change in social structure. Planning should take place to provide services needed for increased population, as well as planning for the loss of the economic activity in five years when the development phase ends.

The CSPH investigators and the BOCC recognize that implementation of recommended impact mitigations may be insufficient to protect public health. To that end, the BOCC has provided funding to CSPH to design a long term EHMS in Battlement Mesa and/or Garfield County to address some of these issues. This long term study will: 1) further characterize air emissions associated with natural gas production; 2) characterize air emission exposure levels for persons living in close proximity to natural gas production; 3) further characterize emission sources during development and production phases; 4) develop methods to characterize surface and ground drinking water contamination; 5) conduct health surveillance of residents in areas impacted by natural gas and in similar comparison populations not affected by natural gas development and production; 6) conduct social and community health surveillance of areas impacted by natural gas development and production.

Because there are natural gas plays in other parts of the United States undergoing similar development as that occurring in the Piceance Basin, this HIA and future studies are likely to be broadly applicable. Communities in Texas and Wyoming have reported health and social impacts associated with natural gas development and production, while communities in

Pennsylvania, New York and other places are trying to anticipate and forestall impacts before drilling occurs. Use of this or other HIAs as a tool to summarize potential impacts can help communities prioritize mitigations and local resources. Local environmental and health monitoring can provide communities with information necessary to protect public health. This information can also contribute to the growing body of knowledge on chemical and psychosocial stressors and health impacts associated with natural gas development and production.

In Colorado, recent legislation will compel Front Range coal fired electrical plants to switch to cleaner fuels and alternative energies, thus enhancing the natural gas market. In Grand Junction, two fueling stations for natural gas vehicles are slated to be built in the next few years. These and other market enhancing projects and policies will mean Colorado natural gas development and production projects will continue to grow. The recently updated COGCC rules included provisions to protect health and environment. These rules should undergo regular review and update in order to reflect new understanding and technologies as they emerge.

Because development of domestic natural gas resource is part of the national policy to increase domestic energy production and reduce greenhouse gas emissions, a high level discussion of the health implications of this policy needs to take place. While municipal, county and state governments have begun to respond to citizen concerns, a national discussion of the benefits and risks associated with this policy is due. As outlined in this HIA, local economic benefits of energy development may not outweigh the negative local impacts to physical and social health of the community. Without understanding public health implications in the context of national priorities for domestic energy production, continued disagreements about the impact of drilling and its effects on local health are bound to continue.

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Part Two: Supporting Documentation

TABLES

Table 1: Identified Stakeholders

Table 2: Stakeholder Meetings

Table 3: Stakeholder Concerns and Questions

Table 1: Identified Stakeholders		
Stakeholder	**Acronym**	**Stakeholder Role**
Antero Resources Corporation	Antero	Natural gas operator, proposes development within the planned urban development of Battlement Mesa
Battlement Mesa Concerned Citizens	BMCC	Grassroots citizen group formed in response to the Antero gas project.
Battlement Mesa Company	BMC	Owner of mineral and surface rights in Battlement Mesa.
Battlement Mesa Service Association	BMSA	Home owners association for Battlement Mesa residential communities.
Colorado Department of Public Health and Environment	CDPHE	State health department; has consultative responsibility to the state permitting agency for comment health and environmental concerns, but has no regulatory responsibilities.
Colorado Oil and Gas Conservation Commission	COGCC	Colorado regulatory and permitting agency. Maintains databases for water quality, spills, and well locations Databases include federal and tribal lease owners as well as state lease owners. Provides permitting for state lease owners only.
Garfield County Board of County Commissioners	BOCC	Requested county environmental health to develop proposals to respond to citizens health concerns. Have indicated that HIA and health study proposals will satisfy this request.
Garfield County Oil and Gas Department	GCOG	County office that oversees county relationships with oil and gas operators.
Garfield County Oil and Gas Operators	GCOGO	Natural gas companies operating in Garfield County but not involved in the development within the Battlement Mesa PUD (Encana, Williams, Bill Barrett, Noble).
Garfield County Public Health	GCPH	County health agency with environmental health program. Environmental health program directed to respond to citizen concerns and has strong ties to all stakeholder groups. Environmental health program considered a regional leader in health and gas exploration and production.
Grand River Hospital District	GRHD	Primary hospital and Emergency department provider in Rifle, Colorado (28 miles east of Battlement Mesa) and operator of a primary care clinic in Battlement Mesa.
Grand Valley Citizens Alliance	GVCA	Grassroots community group, loosely tied to the Battlement Concerned Citizens.

Table 2: Stakeholder Meetings		
Date	**Location**	**Groups represented**
January 13, 2010	CDPHE, Denver	CDPHE
January 27, 2010	COGCC, Denver	COGCC
February 3, 2010	GCPH, Rifle	BMCC, BMC, BMSA, BOCC, CDPHE, COGCC, GCPH, GVCA, Encana Corporation, Williams Corporation
February 16, 2010	GC Board Chambers, Glenwood Springs	BOCC
April 22, 2010	Antero Field Office, Rifle	Antero Resources
June 15, 2010	Battlement Mesa Fire Station, Battlement Mesa	BMCC, BMC, BMSA, BOCC, CDPHE, COGCC, GCPH, GVCA, Antero Resources, EnCana Corp., Williams Corp
June 24, 2010	CDPHE, Denver	CDPHE

Table 3: Stakeholder Concerns and Questions	
Meeting Date	**Concern or Question**
	Air Pollution/Quality
February 3, 2010	Will PM10, VOC monitoring be included?
February 3, 2010	Parachute= Battlement Mesa when it comes to air monitoring?
February 3, 2010	Is PM2.5 a greater hazard?
February 3, 2010	Will the air quality assessment include all processes of the well development?
February 3, 2010	Do hydrocarbons evaporate from produced water ponds?
February 3, 2010	Are there BTEX emissions from trucks?
February 3, 2010	Will gathering pipelines with leaks be accounted for?
June 15, 2010	Is there enough water and air baseline data for Battlement Mesa?
June 15, 2010	Have air quality exposures in the summer when swamp coolers are being used? Will air pollution be concentrated indoors?
	Water Quality
February 3, 2010	Is there adequate monitoring of water?
February 3, 2010	How will impacts to the water supply (CO river, surface and spring) be assessed?
February 3, 2010	What if domestic supply is ½ mile from well pad, is it safe?
February 3, 2010	Will emergency wells within the PUD be impacted, are the pads close to the emergency wells?
February 3, 2010	Should the intake on the CO river have gates (like Rifle)?
February 3, 2010	Should real time monitoring instead of 3 month turn around for sampling results be implemented?
February 3, 2010	Can there be a quicker response to water issues?
February 3, 2010	Is there enough water for all needs, including fires?
February 3, 2010	Should there be a drill for potential water shut-down?
June 15, 2010	Will the effect of chemicals on the water supply be included in the study?
June 15, 2010	Will possible contamination of the Colorado River from upstream contamination be considered?
June 15, 2010	Is there enough water and air baseline data for Battlement Mesa?
	Drilling and Fracking Chemicals
June 15, 2010	Will fracking chemicals be considered?
June 15, 2010	How will chemical spills be considered?
June 15, 2010	Why can't Colorado require public release of fracking chemicals like Wyoming?
June 15, 2010	Will you be working with physicians and Grand River Hospital to obtain local data?
	Pipeline Safety
February 3, 2010	Is there a plan to prevent pipeline leaks/ explosions?
February 3, 2010	Does pipeline proximity to buried high voltage power lines pose a risk?
Occupational Hazards	
February 3, 2010	How will the development have social impacts: will it increase domestic abuse? Will workers have health insurance?

Table 3: Stakeholder Concerns and Questions	
Meeting Date	**Concern or Question**
Occupational Hazards Continued	
February 3, 2010	How does worker schedules impact families?
February 3, 2010	Will the health of workers on rigs be included?
February 3, 2010	What are the mental health impacts?
February 3, 2010	If economic security is tied to gas jobs, will fear of loosing a job prevent workers from speaking up about health problems? Grand Valley Citizens Alliance gets input from workers that wish to remain anonymous.
Concerns of Industry	
February 3, 2010	There is misinformation that drives fear. The health study will relieve the misinformation.
February 3, 2010	The industry will partner with local fire department.
February 3, 2010	Industry hopes to make Battlement Mesa to be a better place.
Concerns about Research and the HIA	
February 3, 2010	Hope that HIA will not be "inconclusive"
February 3, 2010	What is the difference between probability vs. predictability: What does probability mean?
February 3, 2010	How are acute vs. chronic diseases defined? This needs to be communicated.
February 3, 2010	Will the HIA include information on healthy individuals? Balanced picture of the community
June 15, 2010	Is there a formula that will tell us that the hazards are too high?
June 15, 2010	Will analysis be comparing results to other areas in Colorado such as Denver and Grand Junction?
June 15, 2010	Will illnesses be captured even if a resident goes to a hospital outside of Garfield County?
June 15, 2010	How will gaps in health outcomes be addressed?
June 15, 2010	Will there be another public meeting prior to the release of the draft report?
June 15, 2010	Be aware that the population has been trending to younger age groups during the 2000-2010 time period.
Community Concerns	
February 3, 2010	What will the impacts on county services be? Will there be more or less services? services Will there be an increase in STD's and other "social" diseases
February 3, 2010	Will the development impacts on education? Will class size be affected?

Table 3: Stakeholder Concerns and Questions	
Meeting Date	**Concern or Question**
February 3, 2010	Will there be adequate affordable housing? Sometimes there is not enough, sometimes too much.
	Additional Exposures/Impacts
February 3, 2010	Will decreased property value be included in the assessment?
	Additional Exposures/Impacts Continued
February 3, 2010	Will decreased aesthetics of the community be included?
February 3, 2010	Are set backs adequate to protect health?
February 3, 2010	Will other stressors including light, noise, traffic be considered?
February 3, 2010	Will concern include skin, respiratory, vertigo?
February 3, 2010	Will there be motor vehicle accidents and related injury and death?
February 3, 2010	What kind of impacts will fracking have?
February 3, 2010	Will remote frac'ing with high pressure pipelines be dangerous?
February 3, 2010	How will changing landscape and changing resident demographics be included?
February 3, 2010	Will a boom and bust cycle occur? We are now in a bust and the food banks drying up.
February 3, 2010	What are the impacts to health services and other community services in BM?
February 3, 2010	How will post drilling, post spill reclamation be handled?
February 3, 2010	What will be done with cuttings? Will they be buried onsite?
February 3, 2010	Will the sites be contaminated and be unsuitable for future use?
June 15, 2010	Will vibration be considered along with noise?
June 15, 2010	Have exposures to herbicides and dust been considered?
June 15, 2010	Will fires on the well pad be considered?
June 15, 2010	Will you consider all O&G activity in close proximity to the PUD? The project should expand beyond the PUD.
June 15, 2010	Mental health and social issues are important impacts.
	Outside Agencies
June 15, 2010	Does EPA have any interest in the work being done? What other studies have been done or are being conducted?
June 15, 2010	What role does Pew Charitable Trust play in the HIA?

APPENDICES

APPENDIX A: SUMMARY OF THE NATURAL GAS DRILLING PROCESS

To transport natural gas that is diffusely embedded in sediment thousands of feet below the earth's surface to a commercial gas pipeline and into a household's gas stove is a complex process involving many different operations. While the description included in this HIA is far from complete, to understand the HIA and its recommendations requires some familiarity with natural gas drilling. For additional reading about the natural gas drilling process, please refer to the following documents:

- *Community Guide to Understanding Natural Gas Development*, written by the Garfield County Energy Advisory Board[101] and
- *Comprehensive Safety Recommendations for Land-Based Oil and Gas Well Drilling*[102]

Natural gas drilling involves the following processes.

Site Selection

A geological survey team collects information on the geology of potential sites to drill. The geological survey team and business managers discuss the benefits and risks of each potential site. Eventually, the business managers and geologists select a site or a group of sites to develop into well pads.

Site Preparation

Before drilling can begin, an operator must prepare the site. The operator typically contracts this task to earth moving companies that create a level surface on which to work. In addition to creating a level platform for drilling activities, site preparation companies often dig and dike any required reservoirs and excavate the cellar. The cellar is, essentially, a pit that collects fluids and accommodates the **blowout preventer** and other equipment. During the site preparation, contractors often transport heavy machinery to the site for earth moving operations and gravel/soil to create a level well pad. Site preparation also may include building roads to access the well pad and installation of pipes to transport natural gas and water.

Drilling

A subcontractor delivers and erects a load-bearing structure to support the weight of the **drill**, the **drill string** and other relevant equipment. Historically, contractors used a structure called a **derrick**. While many contractors still use derricks, contractors also use a different type of structure called a **mast**. Whereas derricks must be constructed on site, masts do not require as much assembly once they are delivered to the site. Masts are simply hoisted and secured into place.

When the load-bearing structure is secure, the drill creates an initial hole by a process commonly called "**spudding in**". As soon as "spudding in" is complete, the contractor inserts a section of metal pipe, called **conductor casing**, into the hole to prevent blowouts and ensure the well's integrity. The contractor secures the conductor casing into place by injecting cement between the sediment and the casing.

Once the conductor casing is securely cemented into place, the drill bores to a depth of approximately 900 feet below ground surface (bgs). This "surface hole" is also lined with casing (called **surface casing**), which like the conductor casing is cemented into place. Surface casing is the barrier between the well bore and groundwater reserves.

After surface casing is securely in place, the contractor continues to drill, meanwhile installing the subsequent layer of casing, called **production casing**. Production casing, like other forms of casing, is manufactured, transported and installed in thirty-foot sections. Eventually, the production casing runs thousands of feet deep to reach the hydrocarbon formations – as much as 10,000 feet bgs but in the Piceance Basin, more likely around 6,000 feet bgs. The production casing, as with the other sections of casing, is cemented into place.

During the drilling process, contractors transport the drill rig, casing, materials for drilling mud, water and other equipment to the well pad. After the production casing is securely in place, the drill rig is disassembled and the well completion process begins.

A couple of additional terms to be aware of include (but are not limited to):

Drilling Mud – Drilling contractors use drilling mud to lubricate the drill bit, carry cuttings (i.e. sediment) to the surface, and provide downward pressure in the well bore. Drilling mud is usually a complex mixture of liquids, reactive solids and inert solids. Mud often includes bentonite, a heavy clay material. The liquid might be comprised of freshwater, diesel oil, crude oil and/or "conditioners." The category of "conditioners" actually includes a wide variety of chemical compounds that serve various purposes in the drilling process[103]. Some conditioners stabilize the geologic formation as the operator drills deeper. Other conditioners lubricate the drill. Some conditioners make the drilling mud thicker. Others make the mud thinner. Characterizing the precise chemical composition of all of the conditioners available for Antero's use is beyond the scope of this HIA.

Directional Drilling – Drilling contractors now have the ability to drill at angles other than directly downward. The angle of the well bore relative to the surface can change during the drilling process. Sometimes, wells are started at an angle and drill practically horizontally. Other times, contractors drill straight down and change the angle of the well bore after the production casing is in place.

Well Stimulation

At the depth of the hydrocarbon formation, the production casing is pierced with explosive charges or bullets. Perforating the production casing itself and the surrounding layer of cement creates channels through which natural gas can pass. Well perforation is not the same as hydraulic fracturing, although it is a necessary precursor.

Natural gas contractors use **well stimulation** methods to increase the rate at which natural gas flows to the surface. One prominent stimulation method is **hydraulic fracturing**, whereby a contractor injects liquids under high pressure to create fissures in the sediment surrounding the well bore. By creating fissures in the sediment, hydraulic fracturing releases natural gas that was embedded in the tightly packed sediment. The gas enters the well bore through the perforated production casing and flows up to the surface. The liquids used in the hydraulic fracturing process are composed of water and various chemicals – some of which may be protected by trade secrets. Hydraulic fracturing fluids also may be called fracking or frac'ing fluid or water.

Well Completion

The pressure of the geologic formation and its heterogeneous contents necessitate the process called **well completion**. After a formation is hydraulically fractured, the natural gas operator must collect water, hydraulic fracturing fluids, sediment, condensate, oil and natural gas that is generated in the process. Well completion is a process by which the channels of the well are cleared so that natural gas can pass freely to the surface. The contents are typically collected into tanks and shipped off-site.

Well Production

After the well has been completed, the well pad shifts into production mode, whereby the recently-drilled well releases natural gas into the commercial line. However, to ensure the safety and the quality of the gas, the well production phase requires additional technologies. For instance, tanks collect water and additional condensate that the well may produce.

Reclamation

After a well is no longer producing gas, it is plugged and abandoned. According to the Colorado Oil and Gas Conservation Commission's regulations pertaining to well reclamation, the land surrounding the wellhead must be restored as closely as possible to its original condition. If the well pad is on cropland, the operator has three months to begin the reclamation process. Operators have 12 months to begin reclamation on non-crop land. To reclaim the well-pad, the operator needs to remove all of the equipment and waste from the site. They need to re-fill the hole in which the wellhead was located. Land needs to be re-graded and re-vegetated to its original condition, as do access roads. Prior to deeming the land "reclaimed" a COGCC inspector must investigate the land to ensure it has been properly re-graded and re-vegetated and that all of the waste and debris have been cleared.

APPENDIX B: NATURAL GAS DEVELOPMENT IN THE PICEANCE BASIN

B1 Geology

This brief summary of the area's geology provides additional context for understanding the potential drilling plan, in particular how the geology of the region relates to proposed drilling methods.

The Battlement Mesa PUD rests on top of a geologic formation known as the Piceance Basin. The Piceance Basin stretches underneath seven Colorado counties, including Garfield County, where Battlement Mesa is located. The Piceance Basin is a part of the larger Uinta-Piceance Province, which is 40,000 square miles in area. Of the larger Uinta-Piceance Province, the Piceance Basin is approximately 100 miles long and 40-50 miles wide. The Axial Uplift forms the Piceance's northeastern border and the White River Uplift forms the eastern border. The Douglas Creek Arch forms the Piceance Basin's western border. The southern border is roughly parallel with and north of the Uncompahgre Uplift axis.

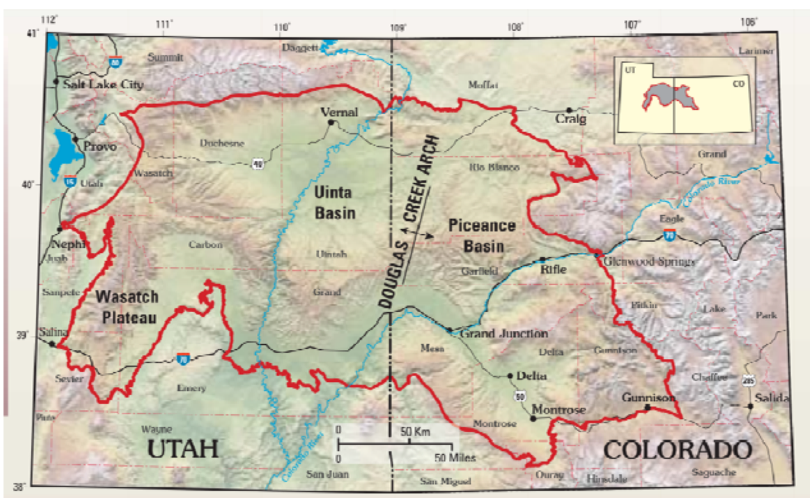


Figure 1. Uinta-Piceance Province located in northwestern Colorado and northeastern Utah. The Douglas Creek arch separates Piceance Basin from Uinta Basin. The Wasatch Plateau is included in this province. [104]

The Piceance Basin, however, is not simply an area of land, the Piceance Basin refers to the geology underlying the area previously described. Therefore, it is useful to consider the Basin as being “deep” as well as “wide.” At its deepest section, the Phanerozoic sedimentary rock[*] of the Piceance Basin extends 20,000 feet below the Earth’s surface.

The Piceance Basin was formed during a period geologists call the Tertiary Period[105] – which ranges from approximately 65 million years ago to 1.8 million years ago[106]. The layers of rock and sediment that comprise the Piceance Basin include significant deposits of petroleum, much of which geologists term “unconventional” petroleum. As opposed to “conventional” reserves of hydrocarbons, that can be accessed using oil well technology from the 1800’s, unconventional reserves such as tight sands, shale gas, coal bed methane and oil shale require more technologically advanced extraction methods. While all of the types of unconventional reserves previously listed are embedded in the Piceance Basin[105], the type of unconventional reserve that relates most directly to Antero’s proposed drilling plan in Battlement Mesa are tight sands.

<u>Tight Sands</u>

Tight sands are deposits of compacted sediment or hard rock that are saturated with natural gas (also known as methane or methane gas). Operators require advanced technologies - particularly hydraulic fracturing and/or acidizing – to access the methane gas permeating tight sand formations.

According to a United States Geological Survey (USGS) assessment of the Uinta-Piceance Province, “Major resources of tight gas are present in the province.”[105] The same USGS assessment highlights two notable tight gas plays in the Piceance Basin. Both tight sands plays are in the Mesaverde Group, and the USGS differentiates them from each other by the quality of the reservoirs, their respective depths and other geological characteristics (i.e. stratigraphy).

Williams Fork Play
Rivers and streams deposited the sediment in the Williams Fork Play. The play’s thickness ranges between 1,500 feet and 4,500 feet. To access methane gas embedded in the Williams Fork Play, natural gas companies need to drill anywhere from 5,500 feet to more than 9,800 feet. The average drill depth for the Williams Fork Play in the Piceance Basin is 7,500 feet.

At the time the USGS assessment was performed, geologists from USGS and industry were “attempting to determine why water is being recovered from horizontal wells; whereas, vertical wells in the same areas do not produce significant amounts of water.” The author hypothesized that the water was from open natural fractures. One implication of the recovered water, noted the assessment’s author, is that “operators may need to attempt to dewater the wells through sustained production.” Although Antero has indicated that their natural gas drilling within the PUD will primarily involve the Williams Fork Play they have also indicated that they are also going to explore the Mancos shale beneath the Williams Fork.

[*] I.e. sedimentary rock from the Phanerozoic Eon – the current eon of the geologic timescale – which covers the previous 542 million years

Iles Play

The Iles Play lies directly beneath the Williams Fork Play. Sediment in the Iles Play is marine and marginal marine (i.e. deposits from oceans, as opposed to rivers and streams). The Iles Play is approximately 500-1,500 feet thick. To access the Iles Play, natural gas companies would need to drill between 5,800 feet, in excess of 10,000 feet. On average, the drill depth in the Iles Play is 7,700 feet.

Mancos Shale[107]

In addition to the Williams Fork Play and the Iles Play, it's important to mention a shale formation commonly called the "Mancos Shale" formation. The Mancos Shale is comprised of mudrock (i.e. hardened mud) that was deposited by the Cretaceous Interior seaway between 90 and 85 million years ago. The Mancos Shale is interconnected with the Williams Fork Play and the Iles Play.

B2 Energy Development in the Piceance Basin: Past

The 1973 Organization of the Petroleum Exporting Countries (OPEC) oil embargo and subsequent fluctuations in the price of crude oil created strong financial incentives for the United States to reconsider its dependence on foreign oil. The United States' Government invested in programs, such as the Synthetic Fuels Corporation, to support research and development of alternative fuel sources (such as oil shale and coal gasification)[108]. Private energy companies also invested in what seemed to be a growing market for domestically produced fuels. In 1980, the Exxon Corporation announced its Colony Oil Shale Project, which involved developing the oil shale resource within Garfield County. They began building the Battlement Mesa Planned Urban Development (PUD) shortly thereafter. The Battlement Mesa PUD was originally created as a company town for Colony Project workers[3]. However, when crude oil prices dropped in the early 1980's, the economic viability of oil shale collapsed. On May 2, 1982, the Colony Project was shut down, thereby eliminating 2,200 jobs[3]. Following the oil shale bust and subsequent exodus of oil shale workers, Exxon marketed the Battlement Mesa PUD as a retirement community until December 1989 when it sold the PUD's surface rights and mineral rights to the Battlement Mesa Company (BMC)[3]. Though the BMC continues to operate rental properties (primarily town homes and mobile homes) for local workers and their families, the BMC continued to market Battlement Mesa as a retirement community. By 1998, more than two-thirds of Battlement Mesa's residents were retirees[109].

B3 Energy Development in the Piceance Basin: Present

The United States' dependence on fossil fuels has re-emerged as in issue of national political significance. As in the 1970's, policymakers in Federal and State agencies have been considering incentives to promote "alternative" sources of energy (i.e. energy sources that are neither conventional petroleum reserves nor coal reserves). One such energy source, which is abundantly infused into the geology of Western Colorado's Piceance Basin[105], is methane – commonly referred to as "natural gas."

In April, 2010, Colorado House Bill 1365, referred to as the "Clean Air – Clean Jobs" initiative, became law. The new law is to provide resources to reduce emissions of air pollutants through retiring, retrofitting, or reprocessing Front Range coal-fired power plants by replacing them with facilities fueled by natural gas or other lower or non-emission sources. This action "will jumpstart our natural gas sector the same way we are driving Colorado's solar and wind industries, according to Governor Bill Ritter,"[110].The Governor went on to say that the "Clean Air-Clean Jobs" law will bring "economic, energy and environmental benefits together in one package."[110] Even before House Bill 1365 was signed into law, though, Colorado's natural gas industry had been expanding rapidly, in Garfield County, as well as other parts of the state. High oil prices and technological advances such as hydraulic fracturing and directional drilling were making Colorado's vast "unconventional" natural gas reserves increasingly viable economically. In Garfield County, Colorado, the increased demand for extraction of natural gas was most apparent between 2003 and 2008. As a rapid influx of new workers arrived in Garfield County, some of them bringing families, hotels and motels filled quickly. Temporary housing facilities, commonly referred to as "man camps" were established. The pace of development stressed local infrastructure, creating concerns at the local and state levels of government. In 2009, the Colorado State Legislature implemented revised regulations governing oil and gas development, in part, to minimize development's impact on public health and the environment[111]. Continued, and possibly accelerated expansion of the natural gas industry within Garfield County is expected with the passage of House Bill 1365.

B4 Antero's Plan in Battlement Mesa

This section of Appendix B gives a brief overview of what information Antero has shared with the community as to it Plan to drill for natural gas in the PUD. A review of the natural gas drilling process is presented in Appendix A.

In the Spring of 2009, Antero announced plans to purchase surface rights and mineral rights from the BMC. Along with this, Antero indicated its intent to drill for natural gas within the Battlement Mesa PUD. It is important to keep in mind that Antero's drilling plans have not and will not be determined entirely by Antero. In addition to the federal, state and local regulations, drilling activities in the PUD are subject to three separate Surface Use Agreements (which are legally binding agreements for the parties entering into them). This section briefly summarizes the Surface Use Agreements determining how and where drilling activities will occur in the PUD:

Surface Use Agreement #1: Exxon and BMC – December 12, 1989
This Surface Use Agreement will always be effective as a condition of BMC's purchase of the PUD. It requires that before mineral resources within the PUD are developed, a formal Surface

Use Agreement must be executed. This initial Surface Use Agreement also established "general" locations for 16 well pads – 15 of which are within the PUD. BMC agreed to accommodate necessary changes to the locations. This Surface Use Agreement also required that in the event that surface development and mineral resource development were in conflict, there needed to be alternate locations for the drill sites.

Surface Use Agreement #2: Barrett Resources and BMC – August 6, 1990
This Surface Use Agreement is only binding for the natural gas operator Williams (which is Barrett Resources' successor in the Surface Use Agreement). Various restrictive provisions exist within the Surface Use Agreement to dictate how Williams can develop resources in the PUD. Among them is a provision that wells be set back at least two hundred feet from existing structures.

Surface Use Agreement #3: Antero Resources and BMC
According to the Surface Use Agreement (Surface Use Agreement) entered into between Antero and the BMC, the Battlement Mesa PUD development project will utilize horizontal drilling techniques and hydraulic fracturing stimulation to develop approximately 200 gas wells on 10 pads distributed throughout the residential community. The full Surface Use Agreement is included in [Attachment 2].

While the Surface Use Agreement is a worthwhile basis for understanding Antero's plans, it is not a legally binding agreement with BOCC. Only the Major Land Use Impact Review will represent a contract between BOCC and Antero. The Surface Use Agreement includes provisions (in addition to compliance with existing regulations) that are intended to reduce any potential impacts on the Battlement Mesa community's health and quality of life.

This is a summary of some, but not all, provisions in the Surface Use Agreement # 3 between Antero and the BMC[7]:

Wellsite Locations
The Surface Use Agreement identifies ten locations where Antero will erect drilling rigs and one site where Antero will build a covered water handling facility.

Access Roads
Access roads Antero builds to and from its well pads must be 20 feet wide and gated. Antero agreed to keep the access roads clean and suppress dust generated on the access roads.

Pipelines
The pipelines that gather gas must be at least 48 inches deep except where BMC and Antero agree that the pipelines need to accommodate existing infrastructure (in particular, gravity-dependent facilities including but not limited to sewer lines). Antero was granted 25 foot easements to install, operate maintain and repair permanent pipelines. They were also granted 50 foot easements for pipelines during construction.

Power/Telephone/Transformers
The only situation in which power lines, transformers and data transmission lines can be installed at a pre-identified well location is when they are necessary for the operation of production equipment.

Hours of Operation
BMC does not restrict the times of day when Antero can be engaged in drilling, completing, re-completing, well workover or reservoir stimulation operations. For routine maintenance, development and production, the Surface Use Agreement requires Antero to work between 7 AM and 8 PM, except in the event of an emergency.

Noise Abatement
Antero needs to be in compliance with COGCC standards that relate to noise (e.g. COGCC Series 802 Noise Abatement Rule[48]). There will be no centralized compression stations, which could be sources of constant noise, in the PUD. Hospital-grade mufflers will be installed on high noise output machinery.

Lighting Abatement
Rigs will be oriented to direct light away from closest homes. Antero "shall use appropriate technology to minimize light pollution emanating from the Property, including, but not limited to, utilization of low density sodium vapor lighting."

Air Emissions and Odor Abatement
Antero will use mats, soil tack and/or liquid dust suppressants as necessary to suppress dust. Antero can not flare wells within 2,000 feet of an occupied dwelling, unless they take the measures specified in the COGCC rules to contain the flare or unless there is an emergency. Antero will comply with Colorado Department of Public Health and Environment (CDPHE)Air Quality Control Commission Regulations. At the "F" pad, there will be a centralized water handling facility that will be lined and covered.

Noxious Weed Management
Antero will implement a noxious weed management plan in accordance with Garfield County and COGCC requirements. While it is expected the weed management plan will be similar to weed management plans currently in place within the PUD, the plan was not available for review at the time of this HIA report.

Visual Impact Mitigation and Reclamation of Wellsite Locations
Antero will construct well pads that mitigate the visual impact using berms and trees to shield the pad from view. Some drill rigs will be shrouded.

Environment and Safety

Antero will comply with all applicable COGCC, CDPHE, United States Environmental Protection Agency (EPA), Comprehensive Environmental Response Compensation and Liability Act (also known as CERCLA), Resource Conservation and Recovery Act (also known as RCRA), Oil Pollution Act, and Clean Water Act regulations. These include, but are not limited to, stipulations pertaining to sanitary facilities; refuse, trash and solid waste disposal; hazardous materials; spills of oil, gas and other hazardous chemicals; spill prevention and control plans; employee training; and employee housing.

Emergency Communications
Antero will comply with local, state and federal reporting requirements in all emergency situations.

Operator's Sole Risk: Insurance
Antero assumes all risk and liability of "any natural incident to, occasioned by or resulting in any manner, directly or indirectly, from (Antero's) operations hereunder."

Owners' Utilities
If Antero requires any utility lines to service any of the well site locations, Antero will pay to locate the lines underground.

The Surface Use Agreement does not address environmental monitoring.

Antero has described a three-phase development plan for the Battlement Mesa project. (Battlement Mesa Website)

- Phase 1 will develop the Stierberger Pad, Pad E, Pad G and the water storage facility (Pad F) on the south side of the PUD.
- Phase 2 will develop the Parks and Rec Pad, Pad A, Pad B and Pad D on the north side of the PUD.
- Phase 3 will develop the L and M pads on the northeast side of the PUD.

Each phase will involve access road, pad and pipeline construction needed to develop the wells and tie them to the water movement system and the gas gathering lines at the eastern edge of the PUD. At this time, Antero anticipates that all three phases will be completed in five years. A slower development scenario is possible and could depend upon the natural gas economy, internal Antero priorities, regulatory impacts, etc. This HIA is based upon the five-year development concept currently favored by Antero.

APPENDIX C: BATTLEMENT MESA BASELINE HEALTH PROFILE

C1 Physical Determinants of Health

In order to describe the baseline of physical health for the residents of Battlement Mesa, the CSPH team obtained information regarding cancer, inpatient hospital diagnoses, mortality and births. By comparing Battlement Mesa data to the same data for Colorado, we were able to provide a relative picture of health for the time period 1998-2008.

C1.1 Methods

Public health practitioners often compare the number of observed events (i.e. disease, death, hospitalizations) to the number of expected events. This allows practitioners to determine if a certain group of people is experiencing an increased (or decreased) amount of disease. A Standardized Incidence Ratio is one method used to measure excess or decreased amount of disease, or when mortality is examined, a Standardized Mortality Ratio (SMR). These methods were used to describe disease incidence and deaths in the Battlement Mesa/Parachute zip codes (81635, 81636).

C1.1.1 Cancer Data Methods

The Colorado Central Cancer Registry at the Colorado Department of Public Health and Environment is mandated by state statute to collect all diagnosed cancers among state residents. This registry provided the CSPH HIA team with aggregated counts of cancer for residents living within the two zip codes and age adjusted standardized incidence ratios for selected cancers diagnosed during the time period of 1998-2008.

Standardized incidence ratios were calculated using the numbers of cancers diagnosed in the Battlement Mesa/Parachute zip code compared to an expected number of cancer cases based on statewide Colorado cancer rates. Colorado rates were obtained from the Colorado Central Cancer Registry for men and women of comparable race and age and were used to calculate expected number of cancers for the Battlement Mesa/Parachute zip code. Adjusting for age, sex, and race/ethnicity assures that any difference found is not due to differences in demographics. The state of Colorado was used as a comparison to provide a large population base to generate stable, reliable rates.

Cancers studied included those based on known association between a specific type or types of cancer and the exposures of concern, common cancers, and those for which community members voiced concerns. Cancers selected for these analyses included:

- Hodgkin Lymphoma

- Non-Hodgkin Lymphomas
- Multiple Myeloma
- Leukemias
- Melanoma
- Breast cancer
- Prostate cancer
- Bladder cancer
- Colorectal cancer
- Cancer of the adrenal gland

When the number of events is less than 3 the data are not reported to preserve confidentiality, this is a policy of the Health Statistics and Vital Record Division at CDPHE. Leukemias were originally requested by type: acute lymphoblastic leukemia, acute myeloid leukemia, chronic lymphocytic leukemia, and chronic myelogenous leukemia., Because fewer than 3 cases of each type of leukemia were diagnosed over the 10 year period, the Leukemias were grouped together for the analysis.

When interpreting an standardized incidence ratio/SMR, size and stability need to be taken into consideration. Standardized incidence ratios based on greater numbers of events produce estimates that are more stable, meaning that there is greater confidence in the conclusions being drawn from the information. Because the population of Battlement Mesa/Parachute is small and the number of diseases is small, determining the *statistical significance* is extremely important. Confidence intervals (CIs) were calculated, in order to determine if the number of observed cases is significantly different from the number of expected cases or whether the difference may be due to chance alone. For these analyses, a 95% confidence interval (CI) was calculated for each standardized incidence ratio.

The following table describes how the standardized incidence ratio/SMRs are interpreted and deemed statistically significant or statistically insignificant.

Interpretation of Statistical Measures

Ratio (SIR/SMR)	Interpretation	95% Confidence Interval	Significance
< 1.00	The number of events observed is less than expected	The lower and upper limits of the interval are < 1.00	Ratio is considered statistically significant.
		The upper limit of the interval is > 1.00	Ratio is not considered statistically significant.
= 1.00	The number of events observed is equal to the number of events expected for the population.		
> 1.00	The number of events observed is greater than expected	The lower limit of the interval is < 1.00	Ratio is not considered statistically significant.
		The lower limit of the interval is > 1.00	Ratio is considered statistically significant.

C1.1.2 Inpatient Hospital Diagnoses Data Methods

Inpatient hospitalization diagnoses data from the Colorado Hospital Association were analyzed by the Health Statistics Section at the Colorado Department of Public Health and Environment and provided to the CSPH. The Colorado Department of Public Health and Environment provided aggregated inpatient hospitalization counts and standardized incidence ratios of select diagnoses using the International Classification of Diseases, ninth revision or ICD-9 codes for the time period of 1998-2008. The ICD-9 is the official system in the United States of assigning codes to diagnoses and procedures associated with hospital admissions during the 1998-2008 time period.

The Colorado Hospital Association collects discharge data for inpatient hospitalizations from participating hospitals throughout the state of Colorado. Each hospital discharge record collected can contain up to 15 diagnoses. For purposes of this analysis, the total hospitalizations were counted by including ICD-9 codes listed in any of the 15 diagnoses fields.

The Colorado Department of Public Health and Environment provided the CSPH team with aggregated numbers of hospitalizations by major category as well as standardized incidence ratios computed using indirect adjustment of age based on the 2000 Census populations for the zip codes 81635 and 81636.

Major categories of ICD-9 codes included those based on known association between disease and the exposures of concern, and those for which community members voiced concerns of elevated occurrence of disease. Major diagnosis categories analyzed included:

- Depression
- Nervous system

- Ear nose and throat (ENT)
- Vascular system
- Pulmonary

Similar to the cancer analyses, a 95% CI was calculated for each standardized incidence ratio to determine statistical significance and data are suppressed when less than 3 cases were recorded for the time period.

C1.1.3 Mortality Data Methods

Mortality data were analyzed by the Health Statistics Section at the Colorado Department of Public Health and Environment and provided to the CSPH.

The Colorado Department of Public Health and Environment provided aggregated mortality counts and standardized ratios of select underlying causes using the International Classification of Disease, tenth revision or ICD-10 codes for determining diagnoses. Mortality data were provided for the time period of 1999-2008. Data for the year 1998 were not included due to a switch from ICD-9 codes in 1998 to ICD-10 codes in 1999.

Mortality data were presented as number of deaths by primary underlying cause as well as SMRs computed using indirect adjustment of age based on the 2000 Census populations for the zip codes 81635 and 81636.

Major categories of ICD-10 codes were chosen based on diseases of interest. Major mortality categories included seven major categories:

- Suicide
- Nervous system diseases
- Major cardiovascular diseases
- Chronic lower respiratory diseases
- SIDS
- Cancers
- Leukemias

Similar to the cancer and inpatient hospitalization analyses described above, a 95% CI was calculated for each SMR to determine statistical significance. Also, data are suppressed when less than 3 deaths were recorded for the time period.

C1.1.4 Birth Outcomes Data Methods

The Colorado Department of Public Health and Environment provided CSPH data from the Colorado Birth Registry for the analyses of birth outcomes.

CSPH analyzed data from 1998 to 2008 for incidences of negative birth outcomes in zip codes 81635 and 81636 based on total births. Incidences of negative birth outcomes in the remainder of Colorado were used to determine expected incidences.

Birth outcome data are presented as the number of observed and expected birth outcomes, as well as standardized incidence ratios adjusted for maternal age and race.

Two negative birth outcomes were analyzed:

- Preterm birth (Gestational age less than 37 weeks)
- Low Birth weight (Gestational age 37 weeks or greater and birth weight less than 5.51 pounds)

Birth defects were not analyzed because the birth registry may not accurately reflect the number of birth defects. Birth detects will be evaluated at the later date using data from the Colorado birth defects registry, given that more than three events exist for the recorded time period.

Similar to the cancer and inpatient hospitalization analyses, a 95% CI was calculated for each standardized incidence ratio to determine statistical significance. Data suppression was not necessary because greater than three events were recorded for the time period.

C1.2 Population/Demographics

For all analyses listed within the physical health outcomes section, the population of Battlement Mesa Planned Urban Development (PUD) was defined as the population living within one of two zip codes: 81635 and 81636. The zip code 81635 denotes physical addresses in both the Battlement Mesa PUD and the town of Parachute, which is just north of the Battlement Mesa PUD. The zip code 81636 is used for Post Office (PO) boxes and therefore the 81635 zip code was used for population counts. Because the town of Parachute shares zip codes with Battlement Mesa, we included the Parachute population in our analyses.

The 2000 U.S. census was used to obtain the most accurate population counts as well as information on age, gender, and racial composition for the Battlement Mesa/Parachute zip code. According to the 2000 U.S. census estimates, 49.3 percent of the Battlement Mesa/Parachute population was female and 50.7 percent male. The median age was 37.5 years. Twenty-six percent of the population were under 18 years of age, 7.2 percent under five years, and 19.8 percent were 65 years and older. For people reporting race in Battlement Mesa/Parachute, 98.0 percent reported a single race: 93.4 percent identified as White, 0.5 percent as Black or African American, 0.9 percent as American Indian and Alaska Native, 0.2 percent as Asian, 0.2 percent as Native Hawaiian and Other Pacific Islanders and 2.8 percent as another race. Two percent of the population reported two or more races and 9.7 percent of the population identified as Hispanic or Latino (of any race). (Table 1) The most dramatic difference between the population for the 81635 zip code and the state of Colorado as a whole is in the over 65 age group. In Colorado in 2000, 9.7 percent of the population was 65 years and over compared to 19.8 percent of the population in the Battlement Mesa/Parachute zip code. Demographic/Population information for the zip code 81635 is provided in the table below.

Demographic/Population information for the zip code 81635

Subject	Number	Percent
Total population	**5,041**	**100**
SEX		
Male	2,487	49.3
Female	2,554	50.7
AGE		
Under 5 years	361	7.2
5 to 9 years	407	8.1
10 to 14 years	347	6.9
15 to 19 years	310	6.1
20 to 24 years	252	5
25 to 34 years	661	13.1
35 to 44 years	690	13.7
45 to 54 years	510	10.1
55 to 59 years	245	4.9
60 to 64 years	258	5.1
65 to 74 years	613	12.2
75 to 84 years	333	6.6
85 years and over	54	1.1
Median age (years)	37.5	(X)
18 years and over	3,730	74
Male	1,833	36.4
Female	1,897	37.6
65 years and over	1,000	19.8
Male	479	9.5
Female	521	10.3
RACE		
One race	4,939	98
White	4,709	93.4
Black or African American	23	0.5
American Indian and Alaska Native	43	0.9
Asian	11	0.2
Asian Indian	0	0
Chinese	1	0

Subject	Number	Percent
Filipino	2	0
Japanese	8	0.2
Korean	0	0
Vietnamese	0	0
Other Asian	0	0
Native Hawaiian and Other Pacific Islander	11	0.2
Some other race	142	2.8
Two or more races	102	2
Race alone or in combination with one or more other races		
White	4,808	95.4
Black or African American	37	0.7
American Indian and Alaska Native	94	1.9
Asian	18	0.4
Native Hawaiian and Other Pacific Islander	13	0.3
Some other race	181	3.6
HISPANIC OR LATINO AND RACE		
Total population	**5,041**	**100**
Hispanic or Latino (of any race)	488	9.7
Mexican	372	7.4
Puerto Rican	17	0.3
Cuban	4	0.1
Other Hispanic or Latino	95	1.9
Not Hispanic or Latino	4,553	90.3
White alone	4,413	87.5

Source: U.S. Census Data, 2000.

C1.3 Vulnerable populations

It is important to note that within a population there are individuals and groups of individuals which are at increased risk or more Vulnerable to disease. Increased Vulnerability is dependent upon a number of factors that can be categorized as demographic factors, genetic factors, and acquired factors.

Demographic factors include age, sex, race and ethnicity. Age is an important factor in determining Vulnerability. As noted in the population/demographics section, the U.S. Census data for the 81635 zip code indicate that greater than 45% of the population, in the year 2000, may be considered to be more Vulnerable to certain exposures, based on age (26 % under the age of 18 and 19.8 % over the age of 65).

Acquired factors (pre-existing disease, and behaviors such as smoking history, alcohol use, pregnancy, and nutrition) and genetic factors require a more in-depth analysis of individual history, including detailed information such as lifestyle behaviors, occupation, and residential history. Although these factors can contribute significantly to a person's Vulnerability to disease, such information is not available to the HIA team.

C1.4 Cancer, Death, Birth, Hospital Inpatient Data

Data for Cancer, Inpatient Hospital Diagnoses, Mortality and Birth data are reported below.

C1.4.1 Cancer Data

The counts listed in the tables below provide a summary of disease frequency. The incidence analyses determine whether a certain number of diagnosed cancers is greater or less than expected, and whether that difference is statistically significant. The results do not allow conclusions to be made about causal relationships between exposure and any cancer.

Tables 2-4 display the number of diagnosed cancers (types) in the Battlement Mesa/Parachute zip codes, the expected number of cases based on the population of male and female residents, stratified by race and age, and the calculated standardized incidence ratios with 95% CIs.

Male/Female Cancers Combined- As displayed in Table 2, the five most common cancers diagnosed in the Battlement Mesa/Parachute zip code during the 1998-2008 time period were prostate, breast, lung, colorectal, and melanoma. (Table 2) The only statistically significant difference between the number of diagnosed cancers and the number of expected cancers was shown for prostate cancer. Over the 10-year period, 79 cases of prostate cancer were diagnosed, compared to the calculated 61.897 expected cases, which yielded a ratio of 1.28 and a confidence interval of 1.01-1.59. However, caution should be exercised when interpreting standardized incidence ratios based on a small number of cases. In this case, if 2 fewer cases of prostate cancer were diagnosed over the 10-year period, the standardized incidence ratio would not have been significant. In addition, when multiple independent tests are compared, there is a statistical chance that 5 % of the tests will be abnormal by chance alone.

Table 2- Number of Males and Females Diagnosed with Selected Cancers Compared to the Expected Number in Battlement Mesa/Parachute Zip Codes 81635 and 81636 by Cancer Site, 1998-2008

Cancer Site	Cancers Diagnosed	Cancers Expected	SIR	95% C.I.
Hodgkin Lymphoma	+	0.880	NC	NC
Non-Hodgkin Lymphoma	8	7.645	1.05	0.45-2.06
Multiple Myeloma	5	2.442	2.05	0.66-4.79
Leukemia	5	6.017	0.83	0.27-1.94
Lung	29	23.958	1.21	0.81-1.74
Melanoma	17	14.190	1.20	0.70-1.92
Prostate	79	61.897	1.28*	1.01-1.59
Bladder	13	13.200	0.99	0.52-1.68
Colorectal	20	19.954	1.00	0.61-1.55
Adrenal Gland	+	0.120	NC	NC
Hodgkin Lymphoma	+	0.880	NC	NC

+= Data are not reported when the value for the time period is fewer than 3.
NC = Not calculated.
Note: diagnosed/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
* = ratio is statistically higher than expected
Source: Colorado Central Cancer Registry, Colorado Dept. of Public Health & Environment, July, 2010

Cancers (Male Group) – As displayed in Table 3, the five most common cancers diagnosed in **males** Battlement Mesa/Parachute zip code during the 1998-2008 time period were prostate, lung, colorectal, melanoma, and bladder. The only statistically significant difference between the number of diagnosed cancers and the number of expected cancers when adjusted for age, and race was calculated for prostate cancer.

Table 3 – Number of Males Diagnosed with Selected Cancers Compared to the Expected Number in Battlement Mesa/Parachute Zip Codes 81635 and 81636 by Cancer Site, 1998-2008

Cancer Site	Cancers Diagnosed	Cancers Expected	SIR	95% C.I.
Hodgkin Lymphoma	+	0.880	NC	NC
Non-Hodgkin Lymphoma	8	7.645	1.05	0.45-2.06
Multiple Myeloma	5	2.442	2.05	0.66-4.79
Leukemia	5	6.017	0.83	0.27-1.94
Lung	29	23.958	1.21	0.81-1.74
Melanoma	17	14.190	1.20	0.70-1.92
Prostate	79	61.897	1.28*	1.01-1.59
Bladder	13	13.200	0.99	0.52-1.68
Colorectal	20	19.954	1.00	0.61-1.55
Adrenal Gland	+	0.120	NC	NC

+= Data are not reported when the value for the time period is fewer than 3.
NC = Not calculated.
Note: diagnosed/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
* = ratio is statistically higher than expected
Source: Colorado Central Cancer Registry, Colorado Dept. of Public Health & Environment, July, 2010

Cancers (Female Group) - As displayed in Table 4, the five most common cancers diagnosed in **females** Battlement Mesa/Parachute zip code during the 1998-2008 time period were breast, lung, colorectal, melanoma, and bladder. No statistically significant differences were observed between the number of diagnosed cancers and the number of expected cancers when adjusted for age and race.

Table 4 - Number of Females Diagnosed with Selected Cancers Compared to the Expected Number in Battlement Mesa/Parachute Zip Codes 81635 and 81636 by Cancer Site, 1998-2008

Cancer Site	Cancers Diagnosed	Cancers Expected	SIR	95% C.I.
Hodgkin Lymphoma	+	0.693	NC	NC
Non-Hodgkin Lymphoma	4	6.215	0.64	0.18-1.65
Multiple Myeloma	+	1.562	NC	NC
Leukemia	+	3.773	NC	NC
Lung	19	18.656	1.02	0.61-1.59
Melanoma	7	9.218	0.76	0.31-1.57
Breast	56	56.452	0.99	0.75-1.29
Bladder	6	3.663	1.64	0.60-3.57
Colorectal	14	16.335	0.86	0.47-1.44
Adrenal Gland	+	0.088	NC	NC

+= Data are not reported when the value for the time period is fewer than 3.
NC = Not calculated.
Note: diagnosed/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
* = ratio is statistically higher than expected
Source: Colorado Central Cancer Registry, Colorado Dept. of Public Health & Environment, July, 2010

C1.4.2 Inpatient Hospital Diagnoses Data

The counts listed in the tables below provide a summary of inpatient hospital diagnoses data. The results provide a summary of diagnoses given patients while in the hospital. The results determine whether diagnoses are greater or less than expected, and whether that difference is statistically significant. The results do not allow conclusions to be made about causal relationships between exposure and any hospital diagnoses.

Tables 5-7 display the number of diagnoses in the Battlement Mesa/Parachute zip code, the expected number of diagnoses per category based on the population of male and female residents, stratified by race and age, and the calculated standardized incidence ratios with 95% CIs

Inpatient Hospital Diagnoses (Male/Female Group) - As displayed in Table 5, there are no inpatient ICD-9 code groups in which the standardized incidence ratio is >1.00 and statistically significant. Table 5 does show ICD-9 groups with fewer diagnoses than expected that are statistically significant, those groups include:

- Depression
- Nervous system
  - brain and CNS
  - dizziness
  - vertigo
- Ear, nose, and throat (ENT)
- Vascular (blood vessel related)
  - cardiovascular
  - cardiac dysrhythmia (abnormal heart rhythm)
  - heart failure
  - hypertension (high blood pressure)
  - stroke
- Pulmonary
  - bronchospasm-airway obstruction
  - asthma
  - other diseases with symptoms of the lung

Table 5- Inpatient Hospital Diagnoses (male/female combine group) compared to expected number in Battlement Mesa/Parachute zip codes 81635 and 81636 by sex and selected diagnoses: Colorado residents, 1998-2008.

Disease	Hospitalizations	Expected	SIR	95% CI
Depression	491	569.16	0.86	0.79-0.94
Nervous system	377	427.229	0.88	0.8-0.98
Brain and Central Nervous System (CNS)	44	60.189	0.73	0.53-0.98
Peripheral Nervous System (PNS)	99	101.571	0.97	0.79-1.19
Headaches	47	49.115	0.96	0.7-1.27
Seizure, epilepsy	167	184.211	0.91	0.77-1.05
Dizziness, vertigo	40	60.106	0.67	0.48-0.91
Ear, Nose and Throat (ENT)	224	272.762	0.82	0.72-0.94
Vascular	2,454	2,897.65	0.85	0.81-0.88
Cardiovascular disease	891	1,120.45	0.8	0.74-0.85
Cardiac dysrhythmia	669	846.962	0.79	0.73-0.85
Heart failure	539	723.47	0.75	0.68-0.81
Hypertension	1,688	1,914.51	0.88	0.84-0.92
Stroke	202	234.681	0.86	0.75-0.99
Arterial disease	90	85.952	1.05	0.84-1.29
Pulmonary	1,184	1,402.48	0.84	0.8-0.89
Bronchospasm, airway obstruction	894	1,068.22	0.84	0.78-0.89
Chronic bronchitis	172	191.802	0.9	0.77-1.04
Asthma	307	348.671	0.88	0.78-0.98
Reactions to external agents	+	0.941	NC	NC
Other diseases, symptoms of the lung	384	494.032	0.78	0.7-0.86

+= Data are not reported when the value for the time period is fewer than 3.

NC = Not calculated.
Note: Expected counts computed by applying age-and sex-specific statewide mortality rates to 2000 based study population
Note: Hospitalizations/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
Note: A single hospitalization event may be represented in more than one diagnosis category.
Source: Hospital Discharge Data, Colorado Hospital Association
Prepared by: Health Statistics Section, Colorado Dept. of Public Health & Environment, July, 2010

Inpatient Hospital Diagnoses (Male Group) - As displayed in Table 6, there are no inpatient ICD-9 code groups in which the standardized incidence ratio is >1.00 and statistically significant. Table 6 does show ICD-9 groups with fewer diagnoses than expected that are statistically significant, those groups include:

- Depression
- Vascular disease
    - cardiovascular
    - heart failure
    - hypertension (high blood pressure)
- Pulmonary
    - bronchospasm-airway obstruction
    - chronic bronchitis
    - asthma
    - other diseases with symptoms of the lung

Table 6- Inpatient Hospital Diagnoses (male) compared to expected number in Battlement Mesa/Parachute zip codes 81635 and 81636 by sex and selected diagnoses: Colorado residents, 1998-2008.

Disease	Hospitalizations	Expected	SIR	95% CI
Depression	146	199.205	0.73	0.62-0.86
Nervous system	178	192.663	0.92	0.79-1.07
Brain and CNS	19	29.116	0.65	0.39-1.02
PNS	55	48.653	1.13	0.85-1.47
Headaches	13	9.316	1.4	0.74-2.39
Seizure, epilepsy	86	95.26	0.9	0.72-1.11
Dizziness, vertigo	15	22.243	0.67	0.38-1.11
ENT	112	123.6	0.91	0.75-1.09
Vascular	1,112	1,456.82	0.76	0.72-0.81
Cardiovascular disease	531	710.133	0.75	0.69-0.81
Cardiac dysrhythmia	336	466.968	0.72	0.64-0.8
Heart failure	233	368.404	0.63	0.55-0.72
Hypertension	696	867.24	0.8	0.74-0.86
Stroke	112	118.67	0.94	0.78-1.14
Arterial disease	47	50.935	0.92	0.68-1.23
Pulmonary	527	700.505	0.75	0.69-0.82
Bronchospasm, airway obstruction	376	536.028	0.7	0.63-0.78
Chronic bronchitis	72	104.377	0.69	0.54-0.87
Asthma	97	122.566	0.79	0.64-0.97
Reactions to external agents	+	0.541	NC	NC
Other diseases, symptoms of the lung	178	247.538	0.72	0.62-0.83

+= Data are not reported when the value for the time period is fewer than 3.
NC = Not calculated.
Note: Expected counts computed by applying age-and sex-specific statewide mortality rates to 2000 based study population

Note: Hospitalizations/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
Note: A single hospitalization event may be represented in more than one diagnosis category.
Source: Hospital Discharge Data, Colorado Hospital Association
Prepared by: Health Statistics Section, Colorado Dept. of Public Health & Environment, July, 2010

Inpatient Hospital Diagnoses (Female Group) - As displayed in Table 7, there are no inpatient ICD-9 code groups in which the standardized incidence ratio is >1.00 and statistically significant. Table 7 does show ICD-9 groups with fewer diagnoses than expected that are statistically significant, those groups include:

- Nervous system diseases
- ENT
- Vascular disease
    - cardiovascular disease
    - cardiac dysrhythmia
    - heart failure
    - stroke

- Pulmonary disease

Table 7- Inpatient Hospital Diagnoses (female) compared to expected number, in Battlement Mesa/Parachute zip codes 81635 and 81636 by sex and selected diagnoses: Colorado residents, 1998-2008.

Disease	Hospitalizations	Expected	SIR	95% CI
Depression	345	365.566	0.94	0.85-1.05
Nervous system	199	235.072	0.85	0.73-0.97
Brain and CNS	25	31.015	0.81	0.52-1.19
PNS	44	52.968	0.83	0.6-1.12
Headaches	34	40.1	0.85	0.59-1.18
Seizure, epilepsy	81	90.114	0.9	0.71-1.12
Dizziness, vertigo	25	36.953	0.68	0.44-1
Ear, Nose, and Throat (ENT)	112	149.617	0.75	0.62-0.9
Vascular	1,342	1,448.91	0.93	0.88-0.98
Cardiovascular disease	360	436.398	0.82	0.74-0.91
Cardiac dysrhythmia	333	390.491	0.85	0.76-0.95
Heart failure	306	358.627	0.85	0.76-0.95
Hypertension	992	1,033.64	0.96	0.9-1.02
Stroke	90	117.158	0.77	0.62-0.94
Arterial disease	43	36.563	1.18	0.85-1.58
Pulmonary	657	717.134	0.92	0.85-0.99
Bronchospasm, airway obstruction	518	547.509	0.95	0.87-1.03
Chronic bronchitis	100	91.099	1.1	0.89-1.34
Asthma	210	225.193	0.93	0.81-1.07
Reactions to external agents	+	0.409	NC	NC
Other diseases, symptoms of the lung	206	248.615	0.83	0.72-0.95

+= Data are not reported when the value for the time period is fewer than 3.
NC: Not calculated.
Note: Expected counts computed by applying age-and sex-specific statewide mortality rates to 2000 based study population

Note: Hospitalizations/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
Note: A single hospitalization event may be represented in more than one diagnosis category.
Source: Hospital Discharge Data, Colorado Hospital Association
Prepared by: Health Statistics Section, Colorado Dept. of Public Health & Environment, July, 2010

C1.4.3 Mortality Data

The counts listed in the tables below provide a summary of mortality data. The results determine whether deaths categorized by underlying disease are greater or less than expected, and whether that difference is statistical significant. The results do not allow conclusions to be made about causal relationships between exposure and any cancer.

Tables 8-10 display the number of deaths by underlying disease in the Battlement Mesa/Parachute zip code, the expected number of deaths based on the population of male and female residents, stratified by race and age, and the calculated SMRs with 95% CIs.

Mortality (Male/Female group combined) - As displayed in Table 5, there are no groups of underlying cause of death in which the SMR was >1.00 and was statistically significant. However, Table 5 does show two categories of underlying disease where there were fewer deaths than expected. The following categories were less than expected (statistically significant):

- Nervous system diseases
- Major cardiovascular disease

Table 8- Deaths (Males/Females) compared to expected number in Battlement Mesa/Parachute zip codes 81635 and 81636, by sex and selected underlying causes: Colorado residents, 1999-2009.

Disease	Deaths Observed	Expected Deaths	SMR	95% CI
Total deaths	381	499.799	0.76	0.69-0.84
Suicide	11	7.81	1.41	0.7-2.52
Nervous system diseases	18	30.724	0.59	0.35-0.93
Major cardiovascular diseases	114	162.546	0.7	0.58-0.84
Chronic lower respiratory diseases	27	37.062	0.73	0.48-1.06
Sudden Infant Death Syndrome (SIDS)	+	0.501	NC	NC
Cancers				
Breast	7	7.843	0.89	0.36-1.84
Prostate	7	7.12	0.98	0.4-2.03
Lung and bronchus	30	28.094	1.07	0.72-1.52
Colon/rectum	7	11.359	0.62	0.25-1.27
Melanoma	3	1.943	1.54	0.32-4/51
Bladder	+	2.712	NC	NC
Adrenal gland	+	0.1	NC	NC
Non-Hodgkin's lymphoma	4	4.654	0.86	0.23-2.2
Hodgkin's lymphoma	+	0.255	NC	NC
Multiple myeloma	3	2.446	1.23	0.25-3.58
Leukemia	4	4.68	0.85	0.23-2.19
Acute lymphocytic leukemia	0	0.261	NC	NC
Chronic lymphocytic leukemia	3	1.024	2.93	0.6-8.56
Acute myeloid leukemia	+	1.846	0.54	0.01-3.02
Chronic myeloid leukemia	+	0.277	NC	NC

+= Data are not reported when the value for the time period is fewer than 3.
NC = Not calculated.

Note: Expected counts computed by applying age-and sex-specific statewide mortality rates to 2000 based study population
Note: Deaths/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
ICD-10 codes used to identify selected diagnoses[112], Table C
Source: Health Statistics Section, Colorado Dept. of Public Health & Environment, July, 2010

Mortality (Male Group) - As displayed in Table 9, there were no groups of underlying cause of death in which the SMR was >1.00 and was statistically significant. There were also no groups of underlying disease in which the SMR was <1.00 and statistically significant.

Table 9- Deaths (Males) compared to expected number in Battlement Mesa/Parachute zip codes 81635 and 81636, by sex and selected underlying causes: Colorado residents, 1999-2008

Disease	Deaths Observed	Expected Deaths	SMR	95% CI
Total deaths	223	272.783	0.82	0.71-0.93
Suicide	9	6.295	1.43	0.65-2.71
Nervous system diseases	9	14.17	0.64	0.29-1.21
Major cardiovascular diseases	71	86.902	0.82	0.64-1.03
Chronic lower respiratory diseases	13	21.324	0.61	0.32-1.04
Sudden Infant Death Syndrome (SIDS)	+	NC	NC	NC
Cancers				
Breast	+	NC	NC	NC
Prostate	7	8.377	0.84	0.34-1.72
Lung and bronchus	21	16.728	1.26	0.78-1.92
Colon/rectum	4	6.355	0.63	0.17-1.61
Melanoma	+	1.373	NC	NC
Bladder	+	2.187	NC	NC
Adrenal gland	+	0.051	NC	NC
Non-Hodgkin's lymphoma	3	2.8	1.07	0.22-3.13
Hodgkin's lymphoma	+	0.165	NC	NC
Multiple myeloma	3	1.479	2.03	0.42-5.93
Leukemia	+	2.997	NC	NC
Acute lymphocytic leukemia	+	0.159	NC	NC
Chronic lymphocytic leukemia	+	NC	1.47	NC
Acute myeloid leukemia	+	NC	0.87	NC
Chronic myeloid leukemia	+	0.173	NC	NC

+= Data are not reported when the value for the time period is fewer than 3.
NC = Not calculated.

Note: Expected counts computed by applying age-and sex-specific statewide mortality rates to 2000 based study population
Note: Deaths/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
ICD-10 codes used to identify selected diagnoses[112], Table C
Source: Health Statistics Section, Colorado Dept. of Public Health & Environment, July, 2010

Mortality (Female Group) - As displayed in Table 10, there are no groups of underlying cause of death in which the SMR was >1.00 and was statistically significant. Table 10 shows that there were fewer total deaths and deaths due to cardiovascular disease than expected and this was statistically significant.

Table 10- Deaths (Female) compared to expected number in Battlement Mesa/Parachute zip codes 81635 and 81636, by sex and selected underlying causes: Colorado residents, 1999-2008

Disease	Deaths Observed	Expected Deaths	SMR	95% CI
Total deaths	158	231.569	0.68	0.58-0.8
Suicide	+	1.642	NC	NC
Nervous system diseases	9	16.36	0.55	0.25-1.04
Major cardiovascular diseases	43	76.496	0.56	0.41-0.76
Chronic lower respiratory diseases	14	16.667	0.84	0.46-1.41
Sudden Infant Death Syndrome (SIDS)	+	0.189	NC	NC
Cancers				
Breast	7	7.329	0.96	0.38-1.97
Prostate	+	0	NC	NC
Lung and bronchus	9	12.083	0.74	0.34-1.41
Colon/rectum	3	5.139	0.58	0.12-1.71
Melanoma	+	0.636	NC	NC
Bladder	+	0.73	NC	NC
Adrenal gland	+	0.049	NC	NC
Non-Hodgkin's lymphoma	+	1.97	NC	NC
Hodgkin's lymphoma	+	0.096	NC	NC
Multiple myeloma	+	1.03	NC	NC
Leukemia	+	1.857	NC	NC
Acute lymphocytic leukemia	+	0.113	NC	NC
Chronic lymphocytic leukemia	+	0.38	NC	NC
Acute myeloid leukemia	+	0.759	NC	NC
Chronic myeloid leukemia	+	0.112	NC	NC

+= Data are not reported when the value for the time period is fewer than 3.

NC = Not calculated.
Note: Expected counts computed by applying age-and sex-specific statewide mortality rates to 2000 based study population
Note: Deaths/expected ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
ICD-10 codes used to identify selected diagnoses[112], Table C
Source: Health Statistics Section, Colorado Dept. of Public Health & Environment, July, 2010

C1.1.4 Birth Outcome Data

The counts listed in the tables below provide a summary of birth outcome data. The results determine whether birth outcomes are greater or less than expected, and whether that difference is statistically significant. The results do not allow conclusions to be made about causal relationships between exposure and any birth outcome.

Table 11 presents a comparison of maternal age and race between the Battlement Mesa/Parachute zip code and the rest of Colorado.

Table 11- Maternal demographics in Battlement Mesa/Parachute zip codes 81635 and 81636 compared to Colorado, 1998-2008.

Race	Battlement Mesa/Parachute	Colorado
Hispanic	240 (23.98)	213842 (28.84)
White	727 (72.63)	455285 (61.41)
Other Race	34 (3.4)	72245 (9.74)
< 20 years	154 (15.38)	77679 (10.48)
20-40 years	833 (83.22)	643619 (86.81)
> 40 years	14 (1.4)	20074 (2.71)

Table 12 displays the number of a particular birth outcome observed in the Battlement Mesa/Parachute zip code, the expected number of birth outcomes, based on the number of total births in the Battlement Mesa/Parachute zip code, stratified by maternal race and age, and the calculated standardized incidence ratios with 95% CIs

As displayed in Table 12, there are no birth outcomes for which the standardized incidence ratio is >1.00 or <1.00 and statistically significant. There is no statistical difference between the number of negative birth outcomes observed and the number expected.

Table 12- Negative birth outcomes compared to expected number in Battlement Mesa/Parachute zip codes 81635 and 81636 to Colorado residents, 1998-2008.

Outcome	Observed	Expected	SIR	95% CI
Preterm Birth	92	93	0.99	0.68 – 1.4
Low Birth Weight	30	34	0.88	0.43-1.6

Note: Expected counts computed by applying age-and race-specific statewide incidence rates to births in zip codes 81635 and 81636 between 1998 and 2008
Note: standardized incidence ratios that have a 95% confidence interval that brackets the value 1.00 are not considered statistically high or low.
Source: Data from Colorado Birth Registry provided by: Health Statistics Section, Colorado Dept. of Public Health & Environment, July, 2010

C.1.5 Health Data Gaps/Limitations

In determining baseline health for the Battlement Mesa/parachute area, it was not possible to obtain some important information regarding physical health. This missing information is referred to as *Data Gaps.*

Some medical conditions are routinely treated on an outpatient basis, with rare hospital admissions. Asthma, hypertension, diabetes, mental health disorders and other conditions are such examples. While the CSPH team made several attempts to obtain outpatient and emergency department information, it was not possible to do so in the time frame of this report. Therefore, this information is not included in the baseline health assessment. In addition, the CSPH team was unable to include injury information in the baseline health assessment. Injury information is best found in emergency room data, outpatient and occupational health clinics.

All data sets have important limitations. It is important to understand the limitations of the data that was used for this baseline health assessment. Understanding the limitations helps researchers and readers interpret the data correctly.

C1.5.1 Cancer data

Cancers may sometimes be associated with residential history, lifestyle behaviors, occupation, or genetics. Cancers are typically diseases of long latency, often years to decades, therefore current incidence is not necessarily indicative of current exposure. We did not have information regarding individual residential history, lifestyle behaviors, occupation, or genetics.

C1.5.2 Inpatient hospitalization data

Hospital discharge records do not capture information about personal risk factors, such as weight, smoking, family medical history, which are all important in considerations when assessing health. Hospital discharge records often contain detailed information for each patient discharge record, such as demographic information, however, the CSPH team did not have access to hospital discharge records, and therefore no demographic information was obtained.

Some diseases may take years to be actively reflected hospital diagnoses numbers. As mentioned above these diseases may be treated primarily on an outpatient basis and are therefore not captured by hospital diagnoses. In addition, like cancer, some diseases have long latency and are not captured in hospital discharge records until years after pertinent exposures.

Medical practice patterns and payment mechanisms may affect decisions by healthcare providers to hospitalize patients, to correctly diagnose disease, and/or to list the condition as a discharge diagnoses.

The ICD-9 codes abstracted from the discharge records include all diagnoses made during that particular hospital stay. As a consequence of this method, the sum of the diagnoses across a series of diagnosis subcategories (i.e. stroke, cardiovascular disease) may be greater than the total count for a parent category (i.e. vascular disease) because a single hospitalization record may have provided more than one subcategory when containing multiple diagnoses. It should also be noted, that it is possible that a patient was admitted more than once during our time frame and therefore the diagnoses associated with that patient would have been counted more than once. Diagnoses, therefore, may be higher than prevalence of disease.

C1.5.3 Mortality Data

Mortality data provide information on fatal illness only, not on current rate of disease. In addition, there are often multiple causes that act synergistically to cause death, or the cause of death is not clear. For this analysis, only the primary cause of death was considered.

C1.5.4 Birth Data

Birth data provide information from birth certificate, which may not have been verified and are not always consistently recorded. They do reflect the current rate of disease. In addition, there are often multiple causes that act synergistically to cause negative birth outcome.

C1.6 Conclusions for Physical Health

In order to provide the residents of Battlement Mesa with a baseline picture of physical health, the CSPH obtained analyzed data from state and hospital databases, as well as birth outcomes data, from CDPHE.

For the time period of 1998-2008 the Battlement Mesa/Parachute residents were found to be in better health than people of similar age, race and gender elsewhere in the state of Colorado. The slightly higher than expected rate of prostate cancer is felt to be a chance occurrence. The residents of Battlement Mesa had the same number or fewer as expected of other common cancers and leukemia; the same number or fewer than expected hospital discharge diagnoses related to depression, nervous system conditions, ear/nose/throat conditions, vascular conditions, and pulmonary conditions. These residents also had the same as expected or fewer than expected total deaths and deaths related to suicide, nervous system diseases, cardiovascular diseases, chronic lower respiratory diseases, and sudden infant death syndrome, as well as common cancers. Finally, the negative birth outcomes preterm birth, low birth weight, and congenital malformations all occurred at rates no higher or lower than those elsewhere in Colorado.

Data gaps and limitations make this baseline profile incomplete. Future investigations should focus on establishing data sharing agreements with local hospitals to obtain emergency room and outpatient data. Furthermore, collection of primary data, through surveys, medical record review and reanalysis of existing databases would also yield a more complete picture of physical health in Battlement Mesa.

C2 Social Determinants of Health

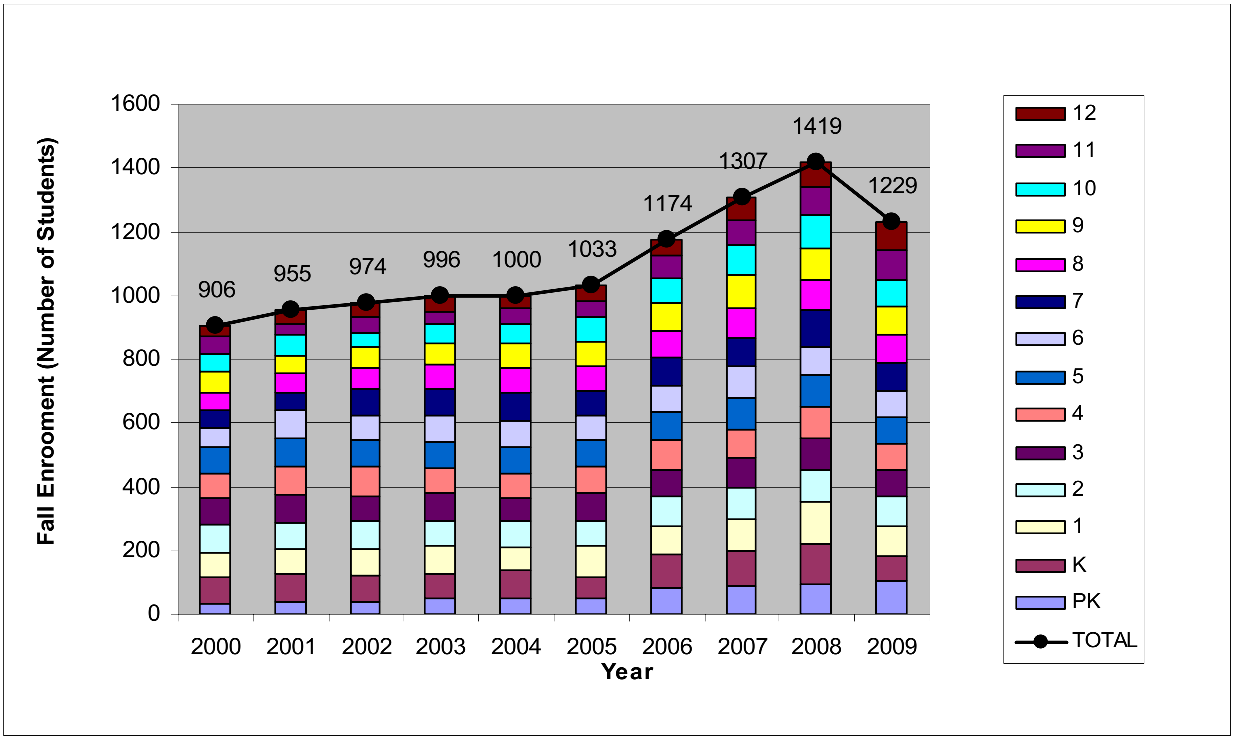
The following sections summarize key data evaluations conducted as part of the Community Wellness Assessment.

C2.1 Education/School Enrollment

Education for children in the towns of Battlement Mesa and Parachute is provided by Garfield County School District 16. Currently, the district is comprised of four schools, Grand Valley High School (9^{th}-12^{th}), Grand Valley Middle School (6^{th}-8^{th}), St. John Elementary School (4^{th}-5^{th}), and Bea Underwood Elementary School (1^{st}-3^{rd}). Additionally, the Grand Valley Center for Family Learning hosts the districts Head Start, Pre-Kindergarten and Kindergarten programs[113].

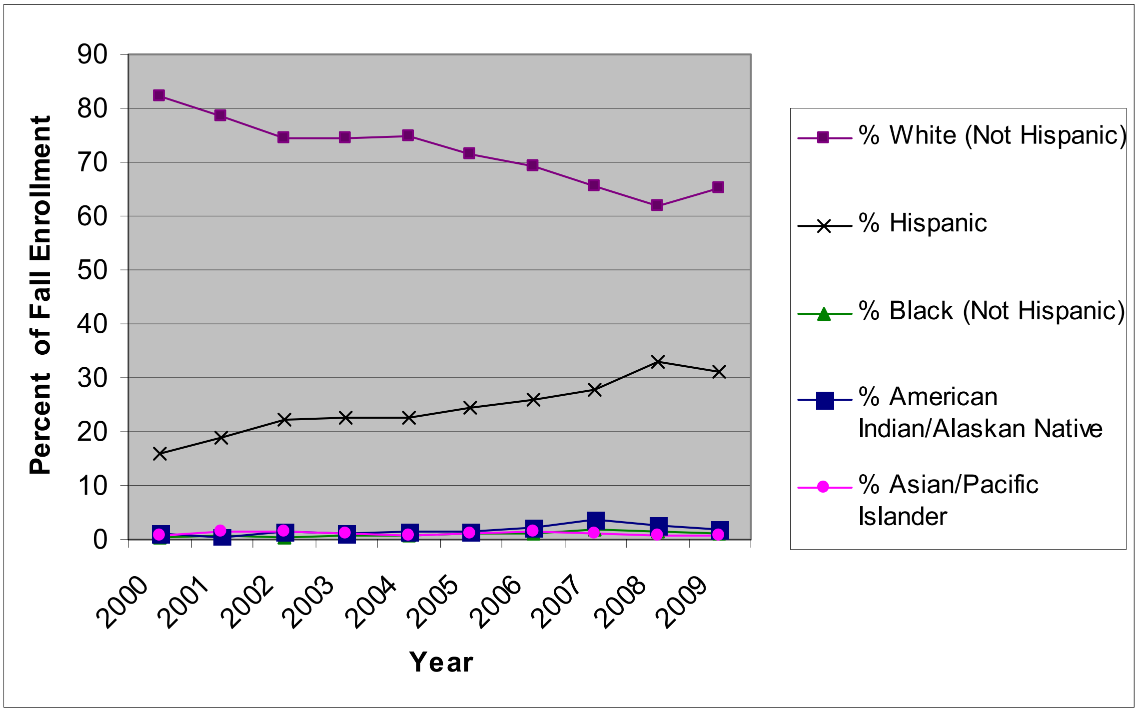
Data on school enrollment was collected from the Colorado Department of Education (http://www.cde.state.co.us/ index_stats.htm). In 2009, there were 1,229 students enrolled in the district, an increase of 19.0% since 2005 and 35.7% since 2000. Figure 1 displays annual district enrollment stratified by grade. While total enrollment has increased significantly, with an increase of nearly 400 students during the period 2005-2008, proportional enrollment by grade appears to have remained relatively stable.

Figure 1: Garfield County District 16, School Enrollment by Grade 2000-2009



Since 2000, there has been a change in the racial and ethnic profile of students enrolled in the district schools (Figure 2). The percentage of Hispanic children has doubled from approximately 15% in 2000 to 30% in 2009. At the same time, the percentage of White children has decreased from 82% to 65%. Proportions of African American, American Indian, and Asian children have remained relatively stable.

Figure 2: Garfield County School District 16, Enrollment by Race/Ethnicity 2000-2009



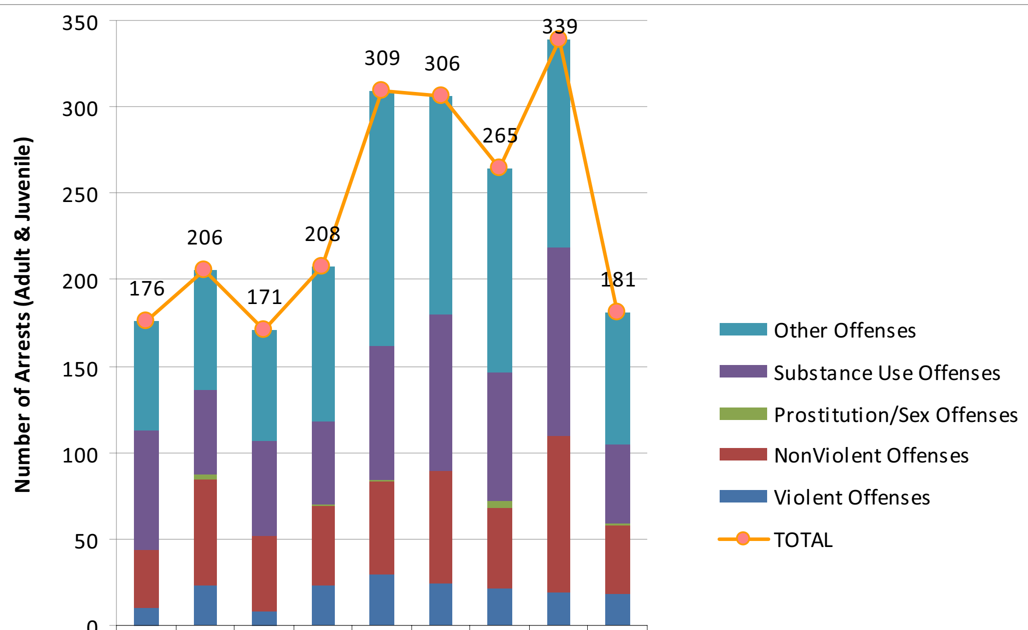
C2.2 Crime

Data on criminal activity is publically available through the Colorado Bureau of Investigation (CBI) in the annual Crime in Colorado report. All Colorado law enforcement agencies are required to submit crime and arrest data to the CBI through the federally mandated Uniform Crime Reporting (UCR) Program. Incident data follow the national UCR Summary Hierarchy Rules and the National Incident-Based Reporting System (NIBRS) reporting and counting guidelines, broadly interpreted to mean the arrest for the most serious charge is counted[114].

Due to its unincorporated status and lack of a designated police force, criminal investigation for events in the Battlement Mesa PUD is under the jurisdiction of the Garfield County Sheriff's Office (GCSO). Statistics for crimes occurring in Battlement Mesa are reported to CBI by the GCSO and thus become part of the larger pool of data reported to the NIBRS database by that agency. For this HIA report, the GCSO was contacted and agreed to attempt retrieval of crime statistics specific to Battlement Mesa. These attempts were not successful due to recent changes in their internal electronic systems and also restrictions on mechanisms for agencies to retrieve data from the NIBRS system. The neighboring town of Parachute, which shares a zip-code with Battlement Mesa, operates a stand-alone police department and maintains NIBRS reporting separate from the GCSO. Due to its close proximity and similar community composition, CBI data from the Parachute PD was analyzed as a surrogate for criminal activity in Battlement Mesa. These data may also include crime occurring in Battlement Mesa which the Parachute Police force responded to and resolved. Adult and juvenile arrests were included.

In Figure 3 below, violent arrests consisted of crimes such as assault and forcible rape, nonviolent arrests included crimes like burglary, theft and vandalism, substance use offenses included DUI and drug violations. The category of other arrests was not well-characterized in the source data, but includes various and numerous other crimes such as weapons offenses, fraud and forgery. There is no consistent trend apparent across the entire period of 2000-2009; however crime rates appear somewhat elevated during the period 2005-2008, then decreased to baseline frequency in 2009. This includes clear increases in the categories of substance abuse and other offences. While these data are not sufficient to establish a causal relationship between the boom of drilling activity in 2003 and crime rates, the higher crime numbers over the 2005-2008 period suggest additional monitoring in this area is warranted during times of high industry activity and in-migration of workers and other population shifts. Though not possible to do with publically available data, evaluation of crime rates by season or month may facilitate better understanding of whether criminal activity is correlated with increased drilling activity and workforce numbers.

Figure 3: Arrests Recorded by the Parachute Police Department, 2000-2009*



	2000	2002	2003	2004	2005	2006	2007	2008	2009
Other Offenses	63	70	64	90	147	126	118	120	76
Substance Use Offenses	69	49	55	48	78	90	75	109	46
Prostitution/Sex Offenses	0	3	0	1	1	0	4	0	1
NonViolent Offenses	34	61	44	46	53	66	47	91	40
Violent Offenses	10	23	8	23	30	24	21	19	18
TOTAL	176	206	171	208	309	306	265	339	181

Year

*2001 data not available

C2.3 Mental Health, Substance Abuse and Suicide:

Significant efforts were made to obtain data on mental health, substance abuse and suicide specific to residents of Battlement Mesa. We identified the Colorado West Regional Mental Health, Inc. as a potential source of this information due to their wide-reach in the region with numerous local outpatient clinics, including Rifle and Glenwood Springs[115]. Outpatient services offered by Colorado West include key treatment approaches for mental health such as, emergency and critical incident consultation, counseling for families, children & adults, psychiatric evaluation and medication management, as well as being a major provider of Employee Assistance Programs. While data on clinical usage and outpatient visits is maintained centrally across all clinics in the Colorado West system, they were unable to provide data for analysis requested for this project due to recent changes in their electronic system rendering retrospective data inaccessible in the time-frame required for this report. Colorado West and the authors of this report are also aware of the highly sensitive nature of data on mental health measures, and were prepared to implement information sharing agreements as necessary to safe-guard any identifying protected health information.

As primary data from Colorado West was not available, nor does Colorado West track visit data specific to substance abuse, Community Health Initiative (CHI) was identified as a potential source of baseline data on this topic[116]. CHI is a public service organization with locations in Glenwood Springs and Carbondale. Working with partners from area agencies and organizations, such as Garfield County's Public Health Department and School District, its primary mission involves reducing substance abuse by sponsoring workplace and community prevention programs and providing outpatient treatment services for youth. While primary data were not available from CHI, several reports are publically available which detail recent projects in community prevention and provide summary statistics for measures pertaining to these issues.

One of these reports is the Garfield County Public Health Department's 2006 assessment on community needs[68]. Through their Health and Quality of Life Survey, conducted during the period of September-October 2005, the GCPH identified four types of health/quality-of-life problems most common to survey respondents. One of these common issues was the challenge associated with mental health and substance abuse. This topic was identified to be widespread across households of Garfield County, affecting a greater number of households than issues pertaining to medical/dental service access or environmental risk. Further, the survey found that when respondents reported mental health problems (defined as experiencing depression or stress), they also reported issues with substance abuse in the home and difficulties/restrictions to engaging in physical activity. Within the mental health and substance abuse domains, depression, anxiety and stress along with tobacco smoking and alcohol abuse were the top indicators of the burden of these conditions (Table 13).

Table 13: Data from the Garfield County Public Health Department 2006 Community Needs Survey

Health/Quality of Life Domain Assessed	Three Most Prevalent Conditions Reported	% All Respondents (n=740)
Household with member(s) affected by mental health issues	a) Depression/anxiety	17.2%
	b) Stress	15.4%
	c) Eating disorders	3.0%
Household with member(s) affected by substances abuse issues	a) Smoking using tobacco	10.4%
	b) Alcohol abuse	6.9%
	c) Drug abuse	1.5%

It is important to note that the survey respondents were self-selected through survey distribution at libraries, city halls, community centers, health clinics, and mailings to some randomly selected homes. Thus, the respondents did not represent a statistically chosen sample of Garfield County, however the authors noted that response came from a wide-range of individuals and were probably the "most valid information available on residents' health and quality-of-life experiences."

Another study available through CHI provides an analysis of discharge data from four Garfield County regional hospitals during the period 2003-2005 for persons whose diagnoses included either alcohol/drug abuse or suicidal behavior[69]. This study showed that of the 275 persons attributed to these discharge diagnoses during this period, 47 (17.1%) had an alcohol/drug abuse diagnosis and 228 (82.9%) had a diagnosis of suicidal behavior. (Table 14) This study only looked at count data of hospital admissions, so we cannot assess trends or compare rates of these conditions to expected rates or rates of other discharge diagnoses. While these data cannot be attributed directly to residents of Battlement Mesa, they suggest that substance abuse and suicidal ideation exist in the surrounding community. As such, they should be monitored and prevention measures should be implemented where possible.

Table 14: Data from the Garfield County Colorado Prevention Partners 2006 Local Needs Assessment Report on Alcohol./Drug Abuse and Suicidal Behavior

Hospital	Diagnostic Group		Total
	Alcohol/Drug Abuse	Suicidal Behavior	
Aspen Valley Hospital	12	32	44
Grand River Medical Center	0	8	8
Vail Valley Medical Center	17	133	150
Valley View Hospital	18	55	73
Total	**47** (17.1%)	**228** (82.9%)	**275**

Further analysis in this report showed fewer admissions for alcohol/substance abuse and suicidal behavior treatment during the summer months, with the highest numbers occurring in December and the late winter months. Also seen in this data were that significantly more men were treated for substance abuse and significantly more women for suicidal behavior; the mean ages of the two diagnoses groups were 41 and 39 respectively.

C2.4 Sexually Transmitted Infections

In Colorado, several sexually transmitted infections (STIs) are reportable to the state health department, including Chlamydia, Gonorrhea, Syphilis and HIV. De-identified sexually transmitted infection data were available by request from the Colorado Department of Public Health and Environment (CDPHE). Incident sexually transmitted infection cases were obtained for the years 2005-2009 for all zip codes in Garfield County.

Table 15 displays frequency of cases for the two sexually transmitted infection's of greatest prevalence in Battlement Mesa and Garfield County. Due to small numbers, it is difficult to draw conclusions about proportion or distribution of cases among Battlement Mesa residents, or make valid comparisons to a larger cohort such as Garfield County. However, these data show that Chlamydia is more prevalent in the female population, with between 70-85% of the Garfield County cases and 60-100% of the Battlement Mesa cases occurring in females. During the period 2005-2007, between 46-60% of Gonorrhea case occurred in Garfield County females, yet that proportion has decreased to around 20% in recent years. A similar assessment of Battlement Mesa cases cannot be made due to low numbers.

Table 15: Chlamydia and Gonorrhea Cases by Gender, Garfield County and Battlement Mesa, 2005-2009

sexually transmitted infection	Year	Garfield County N (% of Total)			Battlement Mesa N (% of Total)		
		Male	Female	Total N	Male	Female	Total N
Chlamydia	2005	13 (25.0)	39 (75.0)	52	2 (33.3)	4 (66.7)	6
	2006	12 (16.7)	60 (83.3)	72	0 (0.0)	6 (100.0)	6
	2007	25 (28.1)	64 (71.9)	89	7 (36.8)	12 (63.2)	19
	2008	27 (22.5)	93 (77.5)	120	0 (0.0)	10 (100.0)	10
	2009	21 (29.2)	51 (70.8)	72	1 (10.0)	9 (90.0)	10
Gonorrhea	2005	2 (50.0)	2 (50.0)	4	1 (100)	0 (0)	1
	2006	4 (40.0)	6 (60.0)	10	0 (0)	1 (100)	1
	2007	7 (53.9)	6 (46.1)	13	0 (n/a)	0 (n/a)	0
	2008	4 (80.0)	1 (20.0)	5	0 (n/a)	0 (n/a)	0
	2009	3 (75.0)	1 (25.0)	4	1 (100)	0 (0)	1

Using epidemiologic methods described below, we calculated rates of sexually transmitted infection for Battlement Mesa residents (defined as zip codes 81635 and 81636) as well rates for all residents of Garfield County combined.

Rather than assess only a count of the number of cases, evaluating a rate provides perspective on the measure of the frequency with which a disease occurs in a population over a specified period of time. Population incidence rates can be calculated using the number of new cases observed in the numerator and the mid-year population as the denominator. Using this method, sexually transmitted infection rates for Garfield County were calculated using population estimates from the U.S. Census Bureau, which produces annual mid-year estimates of total population for states, counties and other sub-county units (Table 16) [4]. For the period 2005-2009, these population estimates were derived from 2000 U.S. Census base data.

Within the Garfield County sexually transmitted infection dataset, Battlement Mesas cases were defined as occurring for residents of zip codes 81635 and 81636. Zip code 81635 denotes physical addresses in both the Battlement Mesa and the town of Parachute, while 81636 is used solely for Post Office (PO) boxes. Because the town of Parachute shares a zip code with Battlement Mesa, we were not able to exclude the population from these analyses. Because U.S. Census Bureau mid-year population estimates are not available for unincorporated places, such as the Battlement Mesa PUD, the population for 2005-2009 was calculated using the equivalent percentage changes as provided for Garfield County, described above and in Table 16.

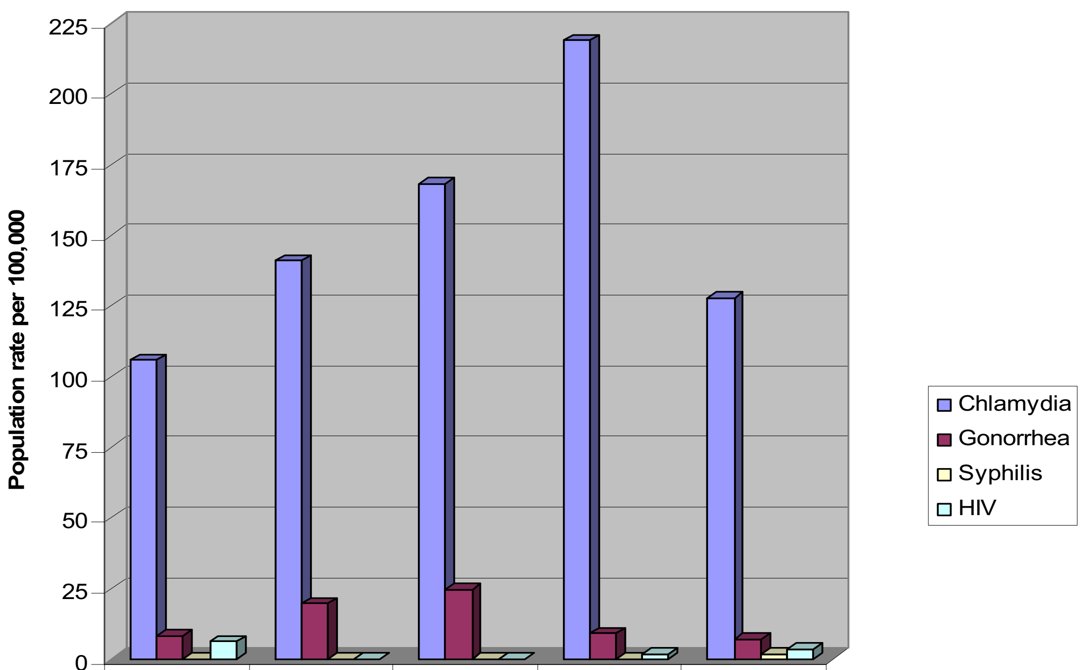
Table 4: Population Estimates for Garfield County and the Battlement Mesa PUD, 2005-2009

	2000 U.S. Census Population Estimate	2005	2006	2007	2008	2009
Garfield County Population Est. Provided by the US Census	43,791	49,177	51,111	52,965	54,838	56,298
Percent Change in Garfield County Population, Calculated & Applied to Battlement Mesa	(Baseline)	12.3 %	3.93 %	3.63 %	3.54 %	2.66 %
Battlement Mesa PUD Population Est.	5,041	5,661	5,884	6,097	6,313	6,481

Because the oil & gas industry boom occurred in 2003, in-migrant populations who have since remained in Garfield County and Battlement Mesas were not counted in the 2000 Census data. As such, these mid-year population estimates may be underestimate of the true population levels and may potentially inflate the observed the rates. Additionally, these population estimates for are not age adjusted. Never-the-less, this method represents the most accurate estimate available to assess trends in sexually transmitted infection incidence rates over time.

Garfield County experienced a steady increase in Chlamydia rates for the period 2005-2008, yet there was a noticeable decline in incidence in 2009. (Figure 4) In comparison, Battlement Mesa residents experienced stable rates of Chlamydia in 2005-06, yet saw a sharp increase in the case rate in 2007, which then decreased and remained stable in 2008-09. (Figure 5) In tandem with the increase of Chlamydia, rates of new Gonorrhea also increased significantly in Garfield County from 8 cases/100,00 population in 2005 to 25 cases/100,000 population in 2007, but declined and have remained stable since 2008. (Figure 4) The Gonorrhea case rate for Battlement Mesa did not experience the same trend, and has not increased over 18 cases per 100,000 population since 2005, the equivalent of < 1 case per 5,000 people. (Figure 5) It is worth noting that the numbers of cases for Battlement Mesa are very small, making it difficult to assess population trends and comparison with the larger cohort of Garfield County. Rates of Syphilis and HIV are extremely low for both Garfield County and Battlement Mesa. In fact, there were no cases of either recorded for residents of Battlement Mesa during this evaluation period.

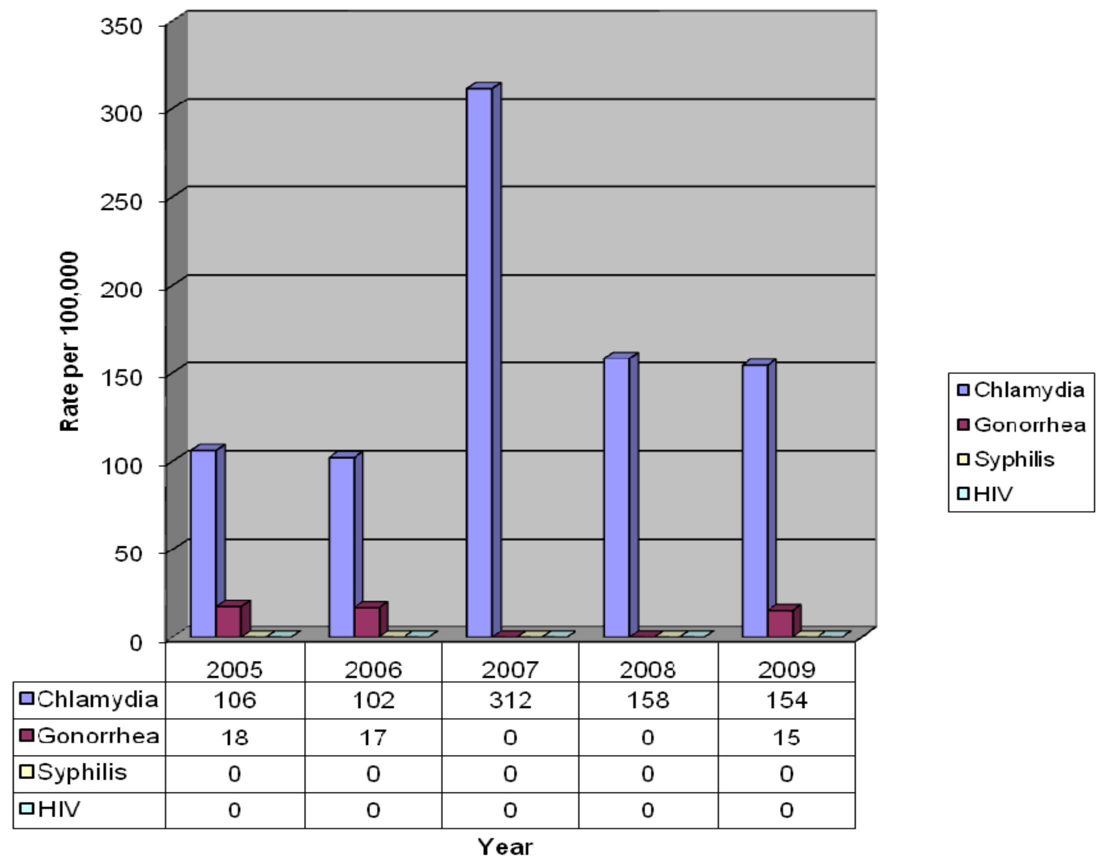
Figure 4: Rates of Sexually Transmitted Infection, Garfield County, 2005-2009



	2005	2006	2007	2008	2009
Chlamydia	106	141	168	219	128
Gonorrhea	8	20	25	9	7
Syphilis	0	0	0	0	2
HIV	6	0	0	2	4

Year

Figure 5: Rates of Sexually Transmitted Infection, Battlement Mesa Zip Codes 81635 & 81636, 2005-2009



	2005	2006	2007	2008	2009
Chlamydia	106	102	312	158	154
Gonorrhea	18	17	0	0	15
Syphilis	0	0	0	0	0
HIV	0	0	0	0	0

C2.5 Limitations of Social Determinants of Health

Data on measures of community well-being are rife with limitations, with the repeating theme being lack of primary data available for systematic review and analysis, especially at the level of a small community such as Battlement Mesa. For many key-indicators of community health, aggregate data may very well be available at the county, state or national level, yet these may not be representative of the local community due to local customs, culture and social structure in place in microcosms of a bigger community. In this case report, data sources were mostly limited to Garfield County and we were unable to locate data specific to the residents and the localized area of the Battlement Mesa PUD. Some additional limitations are as follows:

- U.S. Census and other types of nationally complied statistics are not available to the level of unincorporated areas, such as the Battlement Mesa PUD. Incorporating the Battlement Mesa PUD may increase access to health statistics collected and disseminated by the federal government.

- Data on student-teacher ratios for the local school district are not publically available beyond 2004, and so are not included as part of this baseline assessment. This information is crucial in order to fully characterize impact of the project on the local education system.

- While crime statistics from the Parachute Police Department represent a reasonable surrogate for the Battlement Mesa PUD, it is not possible to assess data only on crimes specifically occurring in Battlement Mesa. With publically available data, it is also not possible to evaluate criminal conduct on the basis of residence location or length of residence.

- Community level data on outpatient treatment for mental health, substance abuse and suicide are not readily available for public access. Analysis of hospital discharge data (in-patient) may provide additional perspective on the burden of these conditions.

- While local data on sexually transmitted infections was available, incidence rates were calculated using population estimates, which may not accurately reflect the true population at any given time. It is also difficult to assess statistical significance of the sexually transmitted infection data due to very low numbers.

C2.6 Summary and Conclusions for Social Determinants of Health

Of all the potential indicators of community health, only certain data were publically available and readily accessible in the time frame of this project to evaluate the health of resident of the Battlement Mesa PUD. As such, we were able to analyze data on education, criminal activity and sexually transmitted infections, obtained through web-based reports or by request of local agencies. The years 2005-2008 appear to be a period of increase for all three of these indicators, with apparent rises in local school enrollment as well as criminal activity. Incidence rates of sexually transmitted infection in Garfield County (Chlamydia and Gonorrhea) also increased during this period, accompanied by a noteworthy increase in the rate of Chlamydia observed in the Battlement Mesa population in 2007. Numbers in all categories appear to decrease in 2009. The mechanisms for obtaining and reviewing the community health indicators of education, crime and sexually transmitted infection are adequate for timely and prospective monitoring. Comparative review of these data should continue in a similar fashion to evaluate any changes and trends. Future analysis should focus on potential causal associations correlated with shifts in population or community environment that may be brought about by nearby industrial development.

Longitudinal source data for mental health, substance abuse and suicide were not available for analysis, however the 2006 survey data indicates upwards of 17% of residents were burdened by one of these conditions. Additional efforts to evaluate these issues should focus on pursuit of a relevant data source for outpatient visits or investigation of another source for surrogate data that are representative of these measures.

APPENDIX D: HUMAN HEALTH RISK ASSESSMENT

Attachments

Attachment 1: BCC letter
Attachment 2: Surface Use Agreement

Human Health Risk Assessment for Battlement Mesa Health Impact Assessment

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Disclaimer

The research team that performed this work has no conflicts of interest to report, financial or otherwise. The statements made in the Health Impact Assessment and Human Health Risk Assessment are the work product of the authors and do not represent the position of any university, private company, government agency, community group or any other organization.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

AI air intake
AIQ Air Quality Standard
Antero Antero Resources Corporation
APCD Air Pollution Control Division
AT averaging time
ATSDR Agency for Toxic Substances and Disease Registry
bgs below ground surface
BMC Battlement Mesa Company
BTEX benzene, toluene, ethylbenzene, and xylene
BTV background threshold value
BW body weight
CDPHE Colorado Department of Public Health and Environment
cm^2 square centimeters
COGCC Colorado Oil and Gas Conservation Commission
COPC contaminant of potential concern
CSM conceptual site model
DNPH 2,4-dinitrophenylhydrazine
ED exposure duration
EF exposure frequency
ET exposure time
EPA United States Environmental Protection Agency
EPC exposure point concentration
ERG Eastern Research Group
GCPHD Garfield County Public Health Department
HHRA Human Health Risk Assessment
HI hazard index
HIA Health Impact Assessement
HQ hazard quotient
IRIS Integrated Risk Information System
kg kilogram
IUR inhalation unit risk
L liter
MEI maximum exposed individual
MRL method reporting limit
NIOSH
PAH polycyclic aromatic hydrocarbon
PAR population attributable risk
PM particulate matter
$PM_{2.5}$ particulate matter of 2.5 microns or less
PM_{10} particulate matter of ten microns or less
ppb parts per billion
ppm parts per million
PPRTVs Provisional Peer-Reviewed Toxicity Values
PRG preliminary remediation goal

PUD Planned urban development
RAGs EPA Risk Assessment Guidance for Superfund
RfC reference concentration
RfD reference dose
RSL regional screening level
SNMOC speciated non-methane organic compound
TWA time weighted average
UCL upper confidence limit
VOC volatile organic compound
$\mu g/m^3$ micrograms per cubic meter

1 Introduction

This human health risk assessment (HHRA) was conducted in support of the Battlement Mesa health impact assessment (HIA). The HIA seeks to evaluate the potential health impacts of Antero Resources Corporation's (Antero) proposed natural gas production operations within the Battlement Mesa planned urban development (PUD). This HHRA specifically addresses potential impacts to the health of Battlement Mesa residents that may be exposed to chemicals released from natural gas production operations to ambient air, surface water, groundwater, and soil. The resident receptor refers to both an adults and children. The child resident receptor refers to children. Three exposure scenarios were evaluated:

(1) A long-term chronic exposure scenario for all Battlement Mesa residents
(2) A long-term chronic exposure scenario for Battlement Mesa residents living adjacent to a well pad.
(3) An acute exposure scenario for Battlement Mesa child residents living adjacent to a well pad

The risk assessment was conducted according to standard United States Environmental Protection Agency (EPA) methodology, including:

(1) EPA Risk Assessment Guidance for Superfund (RAGS) Part Volume 1 Human Health Evaluation Manual (Part A) Interim Final (EPA 1989)
(2) Residual Risk Report to Congress and the EPA Risk Assessment Reference Library (EPA 2004)
(3) ProUCL Version 4.00.05 Technical Guide (Draft). EPA/600/R-07/041 (EPA 2010).

This HHRA is organized as follows:

- Introduction
- Chemical Data Evaluation and Selection of contaminants of potential concern (COPCs)
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Uncertainty Analysis
- Summary and Conclusion
- Data Gaps
- References

1.1 Site Description

The Battlement Mesa Planned Urban Development (PUD) is a 3,200-acre unincorporated jurisdiction divided into several neighborhoods, the names of which are:

- The Reserve
- Battlement Creek Village
- Willow Creek Village
- Willow Ridge Apartments
- Willow Park Apartments
- Eagles Point
- Valley View Village
- Fairway Villas
- Stone Ridge Village
- Monument Creek Village
- Canyon View Village
- Mesa Ridge
- Mesa Vista
- Tamarisk Village
- Tamarisk Meadows
- Saddleback Village

The community sits on a 500 foot mesa approximately to the south of Colorado River and mesas continue to rise above the community for another 500-1000 feet.

1.1.1 Geology

Appendix B of the HIA provides a description of the sites geology.

1.1.2 Population

The most reliable estimates of Battlement Mesa PUD residents' demographic characteristics come from the 2000 US Census. It is important to keep in mind that the demographics of the PUD have likely changed since 2000, though without the most-recent census data it is difficult to tell how or by how much the community makeup has changed.

The 2000 United States census was used to obtain the most accurate population counts as well as information on age, gender, and racial composition for the Battlement Mesa/Parachute zip code 81635 (Zip code 81636 is used for post office boxes and there fore is not included in the demographic data). According to the 2000 United States census estimates, there total population of the Battlement Mesa/Parachute zip code was 5,041; 49.3 percent of the Battlement Mesa/Parachute population was female and 50.7 percent male. The median age was 37.5 years. 26.0 percent of the population were under 18 years of age, 7.2 percent under 5 years, and 19.8 percent were 65 years and older. For people reporting race in Battlement Mesa/Parachute, 93.4 percent identified as White, 0.5

percent as Black or African American; 9.7 percent of the population identified as Hispanic or Latino (of any race).

The Battlement Mesa PUD is often described as a "retirement community" (Miller et al. 2005). While it is difficult to precisely define what is and what is not a "retirement community," several objective measures reflect characteristics of Battlement Mesa's population. In Colorado in 2000, 9.7 percent of the population was 65 years and over compared to 19.8 percent of the population in the Battlement Mesa/Parachute zip code. Furthermore, whereas 63.9% of the United States population (16 and over) was participating in the labor force, only 48.9% of Battlement Mesa residents were either working or looking for work in 2000. There is a 40-unit nursing home in the Battlement Mesa PUD serving seniors of low to moderate income (Miller et al. 2005).

While the lower labor force participation rate of Battlement Mesa residents and the higher proportion of people 65 and over are likely indicators of a high retiree population in the PUD, almost half of the PUD residents 16 and over were either working or looking for work. More than a quarter of the family households in Battlement Mesa had children under the age of 18 (27.2%). While the Battlement Mesa PUD is home to higher proportions of people 65 and over than the US as a whole, the community is not homogeneously "retired."

1.1.3 Economy

Currently, the Battlement Mesa community is entirely residential. The only businesses in the PUD support the local residents. While there has been extensive natural gas drilling in the area surrounding the PUD, there is currently no industrial activity within the PUD itself. Several natural gas operators operate wells in the area surrounding Battlement Mesa. The businesses with in the PUD include:

- A grocery store
- Gas stations
- Several medical facilities
- A public golf course
- Banks
- A café
- A recreation center (paid for by homeowner association dues)
- A local newspaper

In addition to the local businesses, the PUD is home to two churches and two schools – Underwood Elementary (grades K-5) and St. John Middle School (grades 6-8). Battlement Mesa students attend Grand Valley High School in Parachute for grades 9-12.

1.1.4 Antero's Proposed Plan

In the Fall of 2009, Antero announced plans to purchase surface rights and mineral rights from the BMC. Along with this, Antero indicated their intent to drill for natural gas within the Battlement Mesa PUD. Antero plans to drill approximately 200 natural gas wells on ten well pads (approximately 20 wells per pad) in three phases spanning a total of 5 years. Each well is currently estimated to produce natural gas for 20 to 30 years, after which the well would be abandoned. The possibility exists for some wells to be re-developed.

1.2 Previous Risk Assessments

Four risk assessments have been conducted in Garfield County over the past 8 years to determine if air borne emissions from natural gas production operations have an impact on public health. As described in the following sections, each of these risk assessments evaluated one specific set of data. This HHRA incorporated several of the data sets used in previous risk assessments to provide a more comprehensive evaluation of the potential risks to human health from natural gas production operations.

1.2.1 2002 Community-based Short-term Ambient Air Screening Study in Garfield County for Oil and Gas Related Activities (CDPHE 2002)

The Colorado Department of Public Health and Environment (CDPHE) first conducted a limited screening level risk assessment using ambient air data from 20 samples collected in 2002 by the EPA in response to a request of the Grand Valley Citizen's Alliance. Samples were collected over 24- and 8-hour intervals at wells and residences located in the Parachute valley. The samples were analyzed for 42 volatile organic compounds (VOCs) by EPA method TO-14. Maximum concentrations of acetone, methyl ethyl ketone, benzene, toluene, and xylenes (the only contaminants detected in the samples) were compared to EPA region 9 preliminary remediation goals (PRGs) for residential ambient air. PRGs are protective risk-based levels below which chronic health effects are not expected to occur. Benzene, a known human carcinogen, was the only contaminant, at a concentration of 6.5 $\mu g/m^3$, that exceeded its PRG of 0.23 $\mu g/m^3$. None of the non-carcinogenic VOCs were detected at concentrations that would pose a significant health risk to area residents. While the cancer risk from benzene was within EPA's generally acceptable range of 1E-06 to 1E-04, it was greater than the 1E-06 (l cancer in a million). The report concluded benzene may warrant further review pertaining to exposure scenario assumptions and typical exposure concentrations.

1.2.2 2005-2007 Garfield County Air Toxics Inhalation: Screening Level Human Health Risk Assessment (CDPHE 2007)

CDPHE conducted a second more rigorous screening level HHRA in accordance with Tier-1 of EPA's Air Toxic Risk Assessment Library (EPA, 2004) in 2007. The data for risk assessment was collected from 14 fixed air monitoring sites for 24-hour intervals on a once per month or once per quarter basis. The 14 sites were divided into three categories: Oil and Gas Development (eight sites); Urban (four sites); and Rural

Background (two sites). In addition, grab samples were also collected at 27 locations based on odor complaints. All samples were analyzed for VOCs by EPA method TO-14a/15.

This HHRA concluded that, the non-cancer hazards on either a chronic or short-term basis do not exceed the acceptable health based standard and the cancer risk estimates are at, or slightly above, the upper-end of EPA's acceptable risk range (1 to 100 excess cancers per 1 million individuals). However, the HHRA identified the need for continued air monitoring and source apportionment and strongly supported the need to manage the risk posed by potential exposure of residents of the Garfield County to air toxics as a result of the dramatic increase in oil and gas development for the following reasons:

(1) The estimated cancer risks and the non-cancer hazards across the rural background areas were significantly lower than those across the oil and gas development and urban areas.
(2) Although total cancer risks were slightly higher in the urban areas than those in the oil and gas areas, the major contributors of cancer risk were different between the two areas. Benzene, a known human carcinogen, was the major contributor of risk across the oil and gas development areas, while trichloroethene and 1,4-dichlorobenzene were the major contributors in the urban areas.
(3) The cancer risk estimates for benzene across the oil and gas development areas were significantly higher than those across the urban and rural background areas.
(4) The high-end, short-term, non-cancer hazard estimates across the oil and gas development area exceed an acceptable value of one for benzene (e.g., Hazard Quotient [HQs] of 2 or 3) showing the potential for adverse health effects in areas of oil and gas development.
(5) The high-end acute non-cancer hazard estimates for benzene across the oil and gas development area, as represented by several grab sampling sites collected during observed odor events, exceed an acceptable value of one (e.g., HQs of 2 to 6) showing the potential for adverse health effects associated with odor events.
(6) Exposures may be underestimated because increases in air concentrations of VOCs over time were not evaluated and several important air toxics, such as polycyclic aromatic hydrocarbons (PAHs) were not evaluated.

1.2.3 2008 Community Health Risk Analysis of Oil and Gas Industry Impacts in Garfield County, Colorado (Coons and Walker, 2008)

The Saccomanno Research Institute sought to evaluate the risk associated air, water, and soil contaminants associated with natural gas operations. A lack of data on pollutant concentrations in water and soil limited the quantitative evaluation to contaminants in air. Air concentrations were estimated with a Gaussian plume model, based on meteorological conditions specific to Garfield County (measured at the Rifle Airport) and "typical" emission rates of benzene, toluene, and m&p-xylene from natural gas and condensate to predict air contaminant concentrations that may occur during natural gas operations. It should be noted that these concentrations were not based on actual data collected in Garfield County. Contaminant concentrations for five specific natural gas operations were modeled: flow back with no recovery of natural gas, flow back with 93% recovery of natural gas, wellhead glycol dehydration, uncontrolled emissions from condensate tanks, and condensate emissions controlled by a combustion device. Risks to human health were calculated from the modeled air concentrations according to EPA's RAGS Volume 1 (EPA 1989).

The results of the risk assessment indicate that the cancer risk from benzene for 70 years of exposure in air exceeds EPA's generally accepted range of 1E-06 to 1E-04 for flow back with no gas recovery for distances up to 500 meters (1640 feet) downwind of the well; flow back with 93% gas recovery for distances up to 75 meters (246 feet) downwind of the well; wellhead glycol dehydration for distances up to 50 meters (164 feet) downwind of the well; and uncontrolled condensate emissions for distances up to 100 meters (328 feet) downwind of the tank.

The results of the risk assessment also indicated that acute (1-<14 day exposure) reference concentrations (RfCs) for non-cancer hazards from benzene and m&p-xylene may be exceeded for flow back with no gas recovery for distances up to 250 meters (820 feet) downwind of the well and uncontrolled condensate emissions for distances, up to 55 meters (180 feet) downwind of the tank.

The risk assessment concluded that benzene emissions during uncontrolled flow back present the greatest threat of cancer risk and non-cancer hazard and that these effects may occur in people who spend one or more days within 250 meters (820 feet) downwind of the natural gas well during flow back operations with no gas recovery. This observation has been sited as a rationale for moving Antero's proposed set back from 500 feet to 1000 feet. Whether or not this finding would apply to Antero's proposed wells, depends on the extent to which Antero intends to control flow back emissions. In addition, the exposure concentrations in this risk assessment were modeled using "typical" emission rates rather than site specific emission rates and meteorological data from the Rifle airport. Actual emission rates and meteorological conditions in the PUD could be different than those used in the model. Therefore, the modeled exposure concentrations may not be applicable to Antero's natural gas production operations within the PUD.

1.2.4 2010 Garfield County Air Toxics Inhalation: Screening Level Human Health Risk Assessment Inhalation of Volatile Organic Compounds Measured in 2008 Air Quality Monitoring Study (CDPHE 2010).

CDPHE conducted a rigorous screening level HHRA in accordance with Tier-1 of EPA's Air Toxic Risk Assessment Library (EPA, 2004) using data for speciated non-methane organic compounds (SNMOCs) and carbonyls collected by the Garfield County Public Health Department (GCPHD) during the 2008 air quality monitoring study. GCPHD collected 24-hour air samples from four fixed monitoring sites on a weekly (SNMOCs) or bi-weekly (carbonyls) basis over the course of 12 months. The four monitoring sites, Bell-Melton Ranch, Brock, Parachute, and Rifle, were located in close proximity (<1.5 mile) to oil and gas production operations in the rural and urban oil and gas development areas.

The HHRA concluded that there is a potential for public health impacts across the oil and gas development areas in Garfield County for the following reasons.

- The estimated cumulative lifetime cancer risks for the crotonaldehyde, benzene, formaldehyde, ethylbenzene, 1,3-butadiene, and acetylaldehyde are at or slightly above the high-end of EPA’s acceptable cancer risk range of 1 to 100 excess cancers in a million (1E-06 to 1E-04) across all monitoring sites.
- Each of the 20 individual air toxics assessed at any monitoring site have a chronic non-cancer hazard estimate well below an acceptable value of one. However, when accounting for the cumulative chronic non-cancer hazards for all of these 20 air toxics the chronic non-cancer hazard estimate is just below the acceptable level of one and the non-cancer hazards are most likely underestimated because non-cancer toxicity values were not available for 65 contaminants. The major contributing chemicals to the cumulative hazard estimate are acetaldehyde, formaldehyde, trimethylbenzenes, and benzene.
- The cumulative health impacts of 86 detected ambient air toxics cannot be determined due to the absence of EPA-reviewed toxicity values for 65 air toxics.

2 Data Evaluation and Selection of COPCs

2.1 Sources of data

Several sources of data collected in Garfield County between 2005 and 2010 were used for this HHRA.

2.1.1 2005 to 2007 Garfield County Ambient Air Quality Study

Garfield County contracted Colorado Mountain College (CMC) to collect ambient air samples from June 2005 through May 2007 for analyses of VOCs and particulate matter of ten microns or less (PM_{10}). The samples for VOC analyses were collected over 24-hours interval into Summa-polished stainless steel canisters (Summa canisters) either monthly or quarterly from 14 monitoring stations. In addition, 28 15-second grab samples were collected into Summa canisters by residents when they observed odors. Columbia Analytical Services analyzed the samples for 43 VOCs by EPA Method TO-14/15a. CDPHE provided some support for equipment and installations as well as data processing and analysis support. CDPHE performed a screening level risk assessment for ambient air with this data (CDPHE 2007).

The VOC data from 29 samples collected from the rural oil and gas impacted Bell-Melton Ranch monitoring station, and 18 samples collected from the rural Silt-Daley and Silt-Cox monitoring stations were employed in this HHRA. The PM_{10} data is discussed in the Uncertainty Section.

2.1.2 2008 Garfield County Air Toxics Study

The GCPHD, in conjunction with the CPDHE's Air Pollution Control Division (APCD), and the aid of a Regional Geographic Initiatives Grant administered by the EPA conducted a study of air toxics associated with natural gas production operations in the summer of 2008. Ambient air samples were collected over 24-hour intervals into Summa canisters and sent to Eastern Research Group (ERG) for analyses of 78 SNMOCs by EPA method TO-12. The samples were collected at each cardinal direction from the perimeter of eight well pads during drilling and well completion activities (four locations for each activity). In addition, one background sample was collected for each location. The well completion and background data was employed in this HHRA.

Data also was collected for particulate matter of 2.5 microns or less ($PM_{2.5}$), real time VOCs, and meteorology during the 2008 air toxics study. This data is discussed in Uncertainty Section.

2.1.3 2008 to 2010 Garfield County Ambient Air Study

The GCPHD collected ambient air samples from five monitoring stations over 24-hour intervals and shipped the samples to ERG for analyses of 78 SNMOCs by EPA method TO-12 and 11 carbonyls by EPA method TO-11a. Samples for SNMOC analysis were collected into Summa canisters every 6 days. Samples for carbonyl analysis were collected onto pre-treated 2,4-dinitrophenylhydrazine (DNPH) cartridges every 12 days. CDPHE performed an annual screening level risk assessment for ambient air with the data collected in 2008 (CDPHE 2010)

The data from 188 samples collected from the Bell-Melton Ranch monitoring station from January 2008 through March 2010 were employed in this HHRA. Ozone, PM_{10}, and $PM_{2.5}$ data collected at the Rifle and Parachute monitoring stations will be discussed in the Uncertainty Section.

2.1.4 2010 annual groundwater quality results – Battlement Mesa Water treatment plant

The Battlement Water Treatment Plant collected one groundwater sample from one of the back-up groundwater wells in July 2010 and submitted the sample to Accutest Laboratories in Wheat Ridge Colorado for analysis of VOCs by EPA method 524.2, endothall by EPA method 548.1, 1,2-dibromo-3-chloropropane and 1,2-dibromoethane by EPA method 504.1, herbicides by EPA method 515.4, carbamates by EPA method 531.1, and pesticides by EPA method 508. This data was used to evaluate baseline groundwater conditions.

2.2 Sample Quantitation Limit Evaluation

Method reporting limits (MRLs) were adjusted for sample characteristics, sample preparation, and analytical adjustments. Therefore, the MRL are equivalent to the sample quantitation limit. Chemicals reported as not detected are considered to have a concentration less than the MRL for the purposes of the HHRA.

The MRLs were compared to EPA regional screening levels (RSLs) (EPA 2010) to determine if they were adequate for the purposes of the HHRA. RSLs are protective health-based levels below which chronic health effects are not expected to occur. If the RSL is greater than the MRL, the MRL is adequate for determining the chemical is not present at a concentration that may impact health. If the RSL is less than the MRL, the MRL is not adequate to determine whether the chemical is present at a concentration which may impact health.

2.2.1 2005 to 2007 VOC data

Table 2-1 summarizes the MRLs for chemicals with a detection frequency less than five percent for the VOC data collected between 2005 and 2007. For the following 15 VOCs with a detection frequency of less than five percent, the EPA RSL was less than the minimum MRL:

- 1,2-Dibromoethane
- 1,1,2,2-tetrachloroethane
- Bromodichloromethane
- 1,2-Dichloroethane
- Chloroform
- 1,1,2-Trichloroethane
- Vinyl Chloride
- 1,4-Dichlorobenzene
- 1,2-Dichloropropane
- Carbon Tetrachloride
- Tetrachloroethene
- cis-1,3-Dichloropropene
- Trans-1,3-Dichloropropene
- Trichloroethene
- Dibromochloromethane

The data for these chemicals is not adequate to determine if the chemical is present at a concentration that may impact health, which contributes to the uncertainty of the HHRA, as discussed in Section 6.1.1.

2.2.2 2008 to 2010 data

Table 2-2 summarizes MRLs for chemicals with a detection frequency less than five percent for the SNOMC and carbonyl data collected between 2008 and 2010. EPA RSLs are not available for the six chemicals with detection frequencies less than five percent and the MRLs were not further evaluated.

2.2.3 Groundwater data

No contaminants were detected in the groundwater sampled by the Battlement Mesa Water Treatment Plant. Table 2-3 compares the MRLs to EPA RSLs for tap water. Out of 98 contaminants, 29 MRLs were greater than the EPA RSL. The data for these contaminants is not adequate to determine if the contaminant is present at a concentration that may impact health, which contributes to the uncertainty of the HHRA, as discussed in Section 6.1.1.

2.3 Data Reduction, Summary Statistics

The data was modified (reduced) as described in this section, for use in the HHRA. The section also discusses the summary statistics that were generated from the reduced data.

2.3.1 Duplicate Analyses

Duplicate analyses were reduced as follows:

1. For duplicate pairs, for which each sample had detectable quantities of a contaminant in question, the higher of the two concentrations was used in the HHRA, per RAGS (EPA 1989).
2. For duplicate pairs, for which neither sample had detectable quantities of a contaminant, the lower of the two MRLs was used in the HHRA.
3. For duplicate pairs, for which one sample contained a detectable quantity of contaminant in question and the other sample does not, the detectable quantity was used in the HHRA.

2.3.2 Summary Statistics of Sample Data

Data from samples collected at the Bell-Melton Ranch monitoring station from 2005 to 2007 was combined with data from samples collected at the Bell-Melton Ranch monitoring station from 2008 through March 2010 for evaluation of the long-term chronic exposure scenario for all Battlement Mesa residents. Table 2-4 contains summary statistics (number of samples, detection frequency, maximum detected concentrations, and mean) for the Bell-Melton Ranch monitoring station.

Table 2-5 contains summary statistics for the data from samples collected from the well completion sites, during the 2008 Air Toxics Study. This data was used with the Bell-Melton Ranch data described in the preceding paragraph to calculate a time-weighted average for residents living adjacent to a well pad and to evaluate acute exposures for the child resident living adjacent to a well pad.

Table 2-6 contains summary statistics for data from the grab samples collected during odor events in the 2005 to 2007 air monitoring study. This data was used to evaluate potential acute exposures for the child resident living adjacent to a well pad.

No contaminants were detected in the groundwater and summary statistics were not performed.

2.4 Background

The VOC data from the samples collected at the rural Silt-Daley and Silt-Cox monitoring sites during the 2005 to 2007 air monitoring study was combined with the SNMOC data from the samples collected during the 2008 air toxics study to compile a background dataset. Samples have not been collected for carbonyls from background locations. Table 2-7 summarizes summary statistics for the background data set.

Table 2-7 also presents background threshold values (BTVs) computed per EPA guidance (EPA 2010). BTVs are background contaminant concentrations computed based upon the sampled data collected from the site- specific background locations. Site observations can be compared to BTVs. A site observation exceeding a BTV can be viewed as coming from a contaminated area of the site under study. For most of the SNMOCs, only seven samples were available for the background dataset. EPA recommends that the background data set contain greater than 8-10 observations for statistical computation of the BTV (EPA 2010). Therefore, the maximum detected concentration was selected as the BTV for chemicals with seven samples in the background dataset. EPA also recommends that the background data set contain at least 4-6 detected concentrations for statistical computation of the BTV (EPA 2010). Therefore, for chemicals with 18 or 25 samples but less than 4 detected concentrations in the background data set, the maximum detected concentration was assigned as the BTV. The maximum MRL was assigned as the BTV for chemicals that were not detected in the background dataset. For the remaining chemicals, BTVs were calculated using EPA’s proUCL version 4.00.05 statistical software (EPA 2010).

These BTVs were not used in the selection of COPCs for the HHRA. Rather, they were used in the qualitative assessments and uncertainty assessment to evaluate COPCs without toxicity values and to add prospective for the calculated risk for COPCs with toxicity values.

2.5 Selection of Contaminants of Potential Concern and Exposure Point Concentrations

The EPA RSL is the level at which health effects are not expected to occur for a given contaminant and exposure route. To account for possible additive effects of multiple contaminants and exposure routes, the maximum detected concentration of each contaminant detected in each of the data sets described in Section 2.3.2 was compared to 1/10 EPA’s RSL. If the maximum detected concentration exceeded 1/10 EPA’s RSL, the contaminant was retained as a COPC in the HHRA. If the maximum concentration of the contaminant did not exceed 1/10 EPA RSL, the contaminant was not considered further in the HHRA. If EPA did not have an RSL for a contaminant, the contaminant was retained as COPC if its detection frequency was five percent or greater. Contaminants without an EPA RSL and with a detection frequency of less than five percent were not considered further in the HHRA.

2.5.1 Bell-Melton Ranch Monitoring Station

Table 2-4 summarizes the selection of COPCs from samples collected at the Bell-Melton Ranch monitoring station for the all Battlement Mesa residential chronic exposure scenario described in Section 3. 74 out of 126 chemicals were selected as COPCs. The following nine chemicals were retained as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL:

- Acetaldehyde
- Formaldehyde
- 1,2,4-Trimethylbenzene
- 1,4-Dichlorobenzene
- Methylene chloride
- Benzene
- Ethylbenzene
- 1,3-Butadiene
- 2-Hexanone

There was no EPA RSL for the remaining 65 COPCs. They were retained because they were detected in 5 percent or more of the samples.

The EPA recommends that the 95 percent upper confidence limit (UCL) of the arithmetic mean concentration be used as the Exposure Point Concentration (EPC) in calculating exposure and risk for contaminants with 10 or more detections. The 95 percent UCL was calculated for COPCs with 10 or more detections using the EPA ProUCL version 4.00.05 software (EPA 2010). Per current EPA guidance, all non-detect sample results were assigned a value at the MRL (EPA 2010). If the 95 percent UCL was greater than the maximum detected concentration, the maximum detected concentration was assigned as the EPC. For COPCs with less than 10 detections, the maximum detected concentration was assigned as the EPC. The EPC values for COPCs from the Bell-Melton monitoring station are summarized in Table 2-8. Also included in Table 2-8 are 95% UCLs and EPCs from the Bell-Melton Ranch Monitoring stations that were identified as COPCs in the well completion data.

2.5.2 Contaminants of Potential Concern Well Completion

Table 2-5 summarizes the selection of COPCs from samples collected in the 2008 air toxics study during well completion activities. In addition, COPCs identified from the Bell-Melton Ranch data set that were not measured in the 2008 air toxics study were identified as COPCs. 73 contaminants were selected as COPCs. The following 13 contaminants were retained as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL or they were identified as COPCs in the Bell-Melton Ranch data set.

- 1,2,4-Trimethylbenzene
- 1,3-Butadiene
- Benzene
- Ethylbenzene
- m&p-Xylene

- n-Hexane
- n-Nonane
- n-Pentane
- Acetaldehyde
- Formaldehyde
- 1,4-Dichlorobenzene
- Methylene chloride
- 2-Hexanone

There was no EPA RSL for the remaining 61 COPCs, which were retained because their detection frequency was 5 percent or greater.

The maximum detected concentrations were observed in the sample collected downwind of an Antero well during flow back operations. Because flow back is one of the operations with the greatest potential for emissions of contaminants, this maximum concentration assigned as the EPC. In addition, samples were collected over a 24-hour interval which may have diluted out peak emissions during flow back operations.

2.5.3 Chemicals of Potential Concern Odor events

Table 2-6 summarizes the selection of COPCs from grab samples collected when odors were observed in the 2005 -2007 ambient air monitoring study. In addition, COPCs identified from the Bell-Melton Ranch data set or 2008 air toxics study that were not measured in the 2005-2007 study were identified as COPCs. The following 14 contaminants were selected as COPCs because the maximum detected concentration exceeded 1/10 the EPA RSL or they were identified as COPCs in the Bell-Melton Ranch or well completion data set.

- Benzene
- Ethylbenzene
- m&p-Xylene
- o-Xylene
- Toluene
- Chloroform
- 1,2,4-Trimethylbenzene
- 1,3-Butadiene
- n-Hexane
- 2-Hexanone
- n-Nonane
- n-Pentane
- Acetaldehyde
- Formaldehyde

The maximum concentration assigned as the EPC because the maximum possible exposure was desirable in the evaluation of acute exposure for the maximum exposed individual (MEI).

2.6 Observed Trends for Select COPCs

Temporal trends were evaluated for select COPCs from the five year of data that have been collected in Garfield County.

Figure 2-1 illustrates temporal trends for BTEX at the Bell-Melton Ranch monitoring station from 2005 to 2010. There is a consistent seasonal pattern for BTEX with higher concentrations in the winter than the summer, with the exception of one high concentration measured in August 2008. Overall, it does not appear that BTEX concentrations are increasing at the Bell-Melton Ranch monitoring site.

Figure 2-2 illustrates temporal trends for formaldehyde, crotonaldehyde, and acetylaldehyde at the Bell Melton Ranch monitoring station from 2008 to 2010. A consistent seasonal pattern for crotonaldehyde is apparent, with the highest concentrations observed in the summer months. The seasonal pattern is not as apparent for formaldehyde or acetylaldehyde. Overall, it does not appear that carbonyl concentrations are increasing at the Bell-Melton Ranch monitoring site.

Figure 2-2 also show a formaldehyde outlier in the sample collected in January 2009. The 95% UCL for formaldehyde was calculated with and without the outlier. The outlier was retained and not treated separately because the difference between the two 95% UCLs was less than 10 percent.

3 Exposure Assessment

This section presents and discusses potentially exposed populations; the conceptual site model (CSM); exposure assumptions; and estimated intakes of COPCs potentially resulting from natural gas production operations in the Battlement Mesa PUD.

3.1 Potentially Exposed Populations

Current land use within the PUD at Battlement Mesa is primarily residential. It is likely that Battlement Mesa will remain residential in the future. Three populations of residents were evaluated as potential receptors for COPCs resulting from natural gas production operations within the Battlement Mesa PUD. The first population is residents living within the PUD at residence not adjacent to a well pad. The second population is residents living within the PUD at a residence adjacent to a well pad. The third population is child residents aged 3 to 6 living at a residence adjacent to a well pad. The third population represents the MEI.

3.2 Conceptual Site Model

The CSM for human exposure to COPCs resulting from natural gas production operations is shown in Figure 3-1. A CSM is a schematic representation of the chemical sources and release mechanisms, environmental transport media, potential exposure routes, and potential receptors. The purpose of the CSM is to represent chemical sources and exposure pathways that may result in human health risks.

Only potentially complete exposure pathways were evaluated in the risk assessment. A complete exposure pathway includes all of the following elements:

- A source and mechanism of contaminant release
- A transport or contact medium (e.g., air or water)
- An exposure point where receptors can contact the contaminated medium
- An exposure (intake) route such as inhalation or ingestion

The absence of any of these elements results in an incomplete exposure pathway. Where there is no potential exposure, there is no potential risk. The CSM shows (1) incomplete pathways – no evaluation necessary (represented by an “I”); (2) pathways that may be or complete, but for which risk is likely low and only qualitative evaluation is needed (“P”); (3) pathways that are complete and may be significant – quantitative evaluation was performed if there was environmental data available. (“C”). The sources and exposure pathways for each scenario are described in the following sections. Surface soil is defined as 0 to 2 feet below ground surface (bgs) and subsurface soil is defined as greater than 2 feet bgs.

3.3 Sources of potential contamination

The extraction of the natural gas resource from tight sands includes several processes, including transporting materials to and from well pads (trucking), well pad preparation, well drilling, well completion (plug pull out, fracturing, and flow back), collection of salable gas from producing well, maintenance of wells, installation and maintenance of well pads, and abandonment of wells. There is the potential for the release of contaminants during all these processes. Sources of contaminants include the natural gas resource itself, chemicals used in well production activities, wastes from well production activities, and exhaust from machinery used in well production and maintenance.

Well completion activities, trucking, well installation errors, and uncontrolled well development (kick backs, blow outs, and well fires) can result in emissions of contaminants to ambient air, groundwater, subsurface soil, surface soil and surface water. Spills of fracturing fluids, drilling muds, condensate, and diesel can result in contamination of surface soil and ambient air. Run-off and infiltration then can result in subsequent contamination of surface waters and of groundwater and subsurface soil, respectively. Wind erosion, run-off, and infiltration from drilling cuttings and produced water stored on well pads or off-site locations can result in contamination of ambient air, surface soil, surface water, groundwater, and subsurface soil. Exhaust from diesel engines can contaminate ambient air and surface soils (through deposition). Fugitive emission of natural gas through pneumatic pumps and devices, pipe lines, and values and venting of condensers and glycol dehydrators can result in emissions of contaminants to ambient air.

VOC contaminants released to the subsurface (groundwater and soil) have the potential to contaminate air inside buildings (indoor air) through infiltration.

3.4 Exposure Pathways

This section discusses exposure pathways that are quantified, evaluated qualitatively, and those than are not evaluated in the HHRA.

3.4.1. Complete Pathways

Complete pathways for residents to contaminants from natural gas production operations include:

- Inhalation of ambient air
- Incidental ingestion of surface soil
- Dermal contact with surface soil
- Inhalation of particulates from surface soil.
- Dermal contact with surface water

Of these, the inhalation of ambient air pathway and surface water pathways were quantitatively evaluated. Surface soil pathways were not evaluated because no surface soil data is available.

3.4.2 Potentially Complete Pathways

Potentially complete pathways for residents to contaminants from natural gas production operations include:

- Ingestion of surface water
- Ingestion of groundwater
- Dermal contact with groundwater
- Inhalation of VOCs from groundwater
- Inhalation of indoor air

The primary source of drinking and domestic water in Battlement Mesa is the Colorado River. The Battlement Mesa Water Treatment Plant draws water from two intakes located in the middle of the river for treatment, as shown in Figure 3-2. Moument Creek, one of the major drainages off of Battlement Mesa discharges to the river downstream of these intakes. It still is possible that surface run-off could introduce contaminants from upstream well pads into the river. However, the Colorado River has a high volume of water and it is most likely that any contamination would be diluted to non-harmful concentrations. The annual surface water quality results have not indicated any detectable levels of contamination from natural gas production operations at the intakes. In addition, natural gas operators must inform the Battlement Mesa Water Treatment Plant of upstream spills or incidents affecting the river per COGCC rules. In the event of such a spill or incident the intakes to the treatment plant can be shut down. The treatment plant routinely stores a week's supply of water allowing time for remediation of spills. Therefore, while the ingestion of surface water is a potentially complete pathway, its contribution to human health risk is considered to be minimal. This pathway was not considered further in the HHRA.

In the event that the Battlement Mesa Water Treatment Plant was shut down, drinking and domestic water for Battlement Mesa residents would be supplied from four groundwater wells along the south bank of the Colorado River (Figure 3-2). These wells are not supplied with water from the Colorado River and it is believed that the source of water in these wells is from an up-gradient aquifer. There could be a hydrologic connection between these wells and the aquifer on Battlement Mesa, allowing for a conduit of natural gas extraction activity contaminants to the secondary drinking water source. However, the hydrologic connection has not been studied and is currently theoretical. The annual water quality results from these wells have not indicated any detectable levels of contamination. For these reasons, the ingestion of, dermal contact with, and inhalation pathway for contaminants in groundwater is considered to be minimal under current conditions. These pathways were not considered further in the HHRA.

Air inside of an occupied building (indoor air) could become contaminated with VOCs through infiltration if shallow subsurface soil or shallow groundwater in close proximity to the building were contaminated with VOCs. EPA recommends considering this pathway if groundwater or soil within 100 feet (laterally or vertically) of an occupied building is contaminated with VOCs (EPA 2002). This pathway is considered to be minimal because the wells in Battlement Mesa will be set back at least 500 feet from any buildings (Antero Plan), and fracturing occurs at depths much greater than 100 feet bgs. This pathway was not considered further in the HHRA.

3.4.3 Incomplete Pathways

Incomplete pathways for residents include:

- Incidental ingestion of subsurface soil
- Dermal contact with subsurface soil
- Inhalation of subsurface soil particulates

These pathways are incomplete because direct contact with subsurface soil (i.e. greater than 2 feet bgs) involves significant digging or excavation activities unlikely under the residential scenario.

3.5 Exposure Assumptions and Intake Equations

This section presents assumptions for chronic exposures of all residents and residents living adjacent to well pads to contaminants from natural gas production operations within the Battlement Mesa PUD. Assumptions for child residents living adjacent to well pads also are presented.

3.5.1 All Resident Chronic Exposure Assumptions and Intake Equations

Only ambient air was quantitatively evaluated for the residential chronic exposure scenario because data on which to estimate for surface soil EPCs is not available and exposure to surface water run-off from pads is expected to be of short duration. The chronic exposure area for contaminants in ambient air is the entire Battlement Mesa PUD.

Chronic EPCs for ambient air were estimated from ambient air samples collected from 2005 through March 2010 at the Bell-Melton Ranch Monitoring Station (CDPHE 2007, Garfield County 2008, Garfield County 2009, Garfield County, 2010). Of the three ambient air monitoring stations within Garfield County where data has been regularly collected in this time period, Bell-Melton Ranch was considered to most closely represent the impacts of the nature gas production operations that may occur within the Battlement Mesa PUD. The other two monitoring locations, Rifle and Parachute, have greater traffic density, are in closer proximity to a major Interstate (I-70), and have more influence from other industries than Battlement Mesa. The Bell-Melton Ranch monitoring is located south of Silt Colorado within the midst of natural gas production operations and rural home sites and ranches, as shown in Figure 3-3.

The following assumptions are used in this HHRA based on the EPA methodology regarding chronic exposure and Antero's proposed plan:

- The duration of Antero's project, from preparation of the first well pads to abandonment of the last well will be 30 years.
- A resident lives, works, and otherwise stays within the Battlement Mesa PUD for 24 hours per day, 350 days per year, for a 30-year time period.
- The air a resident breathes, both while indoors and outdoors, contains the same concentration of contaminants measured in the Bell-Melton Ranch ambient air samples.
- Air quality, as reflected by the Bell-Melton Ranch ambient air results, will remain relatively constant over the entire 30-year duration of Antero's proposed project.
- The lifetime of a resident is 70 years.

Table 3-1 summarizes intake rates for ambient air. The intake equation for the chronic exposure scenario follows.

$AI = (EPC_c \text{ x } EF_c \text{ x } ED_c \text{ x } ET \text{ x } 1 \text{ day}/24 \text{ hours})/AT$

AI = Air Intake (µg/m^3)
EPC_c = Chronic exposure point concentration (µg/m^3)
EF_c = Chronic exposure frequency = 350 days/year
ED_c = Chronic exposure duration = 30 years
ET = Exposure time = 24 hours/day
Non-cancer AT = averaging time = 10950 days
Cancer AT = 25550

3.5.2 Residents Living Adjacent to Well Pads Exposure Assumptions and Intake Equations

Only the ambient air exposure pathway was quantitatively evaluated for the residents living adjacent to well pads because data on which to estimate surface soil EPCs is not available and exposure to surface water run-off from pads is of short duration. The exposure area for contaminants in ambient air is homes and yards adjacent to well pads.

Based on Garfield County's 2008 Air Toxic's Study, the highest concentrations of SNMOCs in ambient air were observed during well completion activities (Garfield County 2008). Therefore, intermediate EPCs for ambient air were estimated from ambient air samples collected at four separate well completion sites in Garfield County's 2008 air toxics study. Four ambient air samples (one from each cardinal direction) were collected at distances ranging from 130 to 430 feet from the well pad center at each site (Paul Reaser, personal communication 7/6/2010).

The EPC for chronic exposure was estimated by calculating a time weighted average (TWA) from the intermediate EPCs described in the preceding paragraph and chronic EPCs described in Section 3.5.1.

The following assumptions regarding the chronic scenario for residents living adjacent to a well pad are used in this HHRA based on the EPA methodology and Antero's proposed plan:

- The duration of Antero's project, from preparation of the first well pads to abandonment of the last well will be 30 years.
- A resident lives, works, and otherwise stays within the Battlement Mesa PUD for 24 hours per day, 350 days per year, for a 30-year time period.
- The resident's home is adjacent to well pad.
- Well completion activities, including plug pull outs, hydraulic fracturing, and flow back occur over two weeks for each well on the well pad. This assumes some overlap between activities and wells.
- For a 20 well pad, well completion activities (flow back and hydraulic fracturing) will occur over 10 months.
- The resident lives, works, or otherwise stays at the home during the duration of well completion activities.
- The air that the resident breathes, both while indoors and outdoors, contains the same concentrations of contaminants measured in the Air Toxics Study during the duration of the well completion activities.
- The air a resident breathes, both while indoors and outdoors, after the well completion activities contains the same concentration of contaminants measured in the Bell-Melton Ranch ambient air samples.
- Air contaminant concentrations will remain constant over the 10-month period of well completion.
- Air quality, as reflected by the Bell-Melton Ranch ambient air results, will remain relatively constant over the entire 30-year duration of Antero's proposed project.
- The lifetime of a resident is 70 years.

Table 3-1 summarizes intake rates for ambient air, which were calculated by the intake equations presented in Section 3.5.1. TWA EPCs for residents living adjacent to well pads were calculated as follows:

$$EPC_{I+c} = (EPC_c \text{ x } ED_c/ED) + (EPC_I \text{ x } ED_I/ED)$$

EPC_c = Chronic exposure point concentration (µg/m^3)
ED_c = Chronic exposure duration = 350 months
EPC_I = Intermediate exposure point concentration (µg/m^3)
ED_I = Intermediate exposure duration = 10 months
ED = Total exposure duration = 360 months

3.5.3 Child Resident Acute Exposure Assumptions and Intake Equations

Only ambient air and surface water pathways were quantitatively evaluated for the child acute exposure scenario because data on which to estimate for surface soil EPCs is not available. The acute exposure area for contaminants in ambient air is homes and yards located adjacent to a well pad. The acute exposure areas for contaminants in surface water are puddles in the yards of homes adjacent to well pads resulting from well pad run-off during precipitation events. A child resident was evaluated as the receptor for this exposure scenario because a child is more likely to play in a puddle and is a more sensitive receptor than an adult. The acute risk calculated for the ambient air pathway is applicable to both the child and adult resident living adjacent to a well pad.

The EPC for ambient air was estimated from concentrations of contaminants observed during odor events in CPDHE's 2005-2007 ambient air study. If a contaminant was not measured in the 2005-2007 and was identified as the COPC in the 2008 Air Toxics study, the maximum concentration observed in the 2008 Air Toxics study was used as the EPC. If a contaminant was not measured in either of these studies and was identified as a COPC from 2008-2010 ambient air study data, the maximum concentration observed in the 2008-2010 ambient air study was used as the EPC. The EPC for a puddle of surface water run-off was estimated from contaminants observed in snow-melt run-off collected from a well pad within the three-mile radius of the former Project Rulison near Rulison, Colorado (URS 2008).

The following assumptions for acute exposure of a child resident to contaminants in surface water puddles are used in this HHRA based on EPA methodology.

- A child lives, plays, and otherwise stays at the home for 24 hours per day for 7 days.
- The child is 3-6 years old.
- The air the child breathes, both while indoors and outdoors, contains the same concentration of contaminants measured during odor events in the 2005-2007 ambient air study.
- The concentration of contaminants in ambient air will stay constant over the 7-day period.
- The surface water puddle will exist for 7 days before it evaporates or is absorbed into the ground
- The child will have a 70 year lifetime (EPA 1989).
- A child will play for 2 hours per day in the puddle (EPA 2009 and professional judgment).
- The child has a body mass of 18.6 kg (EPA 2009)
- The child will have an exposed skin surface area (arms, hands, legs, and feet) of 5190 cm^2 (EPA 2009).
- The child does not ingest the water.

Table 3-2 summarizes intake rates for surface water. The following equations were used to calculate the intake rates for surface water.

SWI = [(EPC x ET x EF x ED x CF)/(BW x AT)] x [(PC x SA)]

SWI = Surface Water Intake (mg/kg-day)
EPC = Exposure Point Concentration (mg/L for surface water, µg/m^3 for air)
ET = Exposure Time = 2 hours/day
EF = Exposure Frequency = 7 days per year
ED = Exposure Duration = 1 year
BW = Body Weight = 18.6 kg
AT = Averaging time = 365 days
PC = chemical-specific dermal permeability constant (cm/hour)
SA = exposed skin surface area = 5190 cm^2
CF = conversion factor = 1 L/1000 cm^3

4 Toxicity Assessment

This section presents the toxicity assessment. The purpose of the toxicity assessment is to evaluate available evidence regarding the potential for a particular contaminant to cause adverse health effects in exposed individuals and how the appearance and severity of these adverse effects depends on the dose of the contaminant. In addition, the toxic effects of a chemical frequently depend on the route of exposure (oral, inhalation, dermal), the duration of exposure (acute, intermediate, chronic or lifetime), age, sex, diet, family traits, lifestyle, and state of health.

4.1 Selection of Toxicity Values

The following hierarchy was used to compile a list of inhalation toxicity values for the HHRA. For COPCs identified in ambient air, inhalation values established specifically by the State of Colorado were given priority over all other sources of toxicity values, followed by EPA's Air Toxics Website (http://www.epa.gov/ttn/atw/toxsource/summary.html). The State of Colorado has not established toxicity values for the COPCs identified in this HHRA. If values were not available the Air Toxics Website, toxicity values were filled (in order of preference) EPA's Integrated Risk Information System (IRIS), EPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs), and other applicable secondary sources (e.g., California EPA; ATSDR). Inhalation toxicity values were available for 19 out of 82 COPCs as presented in Table 4-1. Inhalation toxicity values were not available for the remaining 63 COPCs presented in Table 4-2. These COPCs were omitted altogether from the quantitative inhalation risk estimation.

A list of oral toxicity values was complied for the HHRA (in order of preference) from EPA's IRIS and the Agency for Toxic Substances and Disease Registry (ATSDR). Oral toxicity values were available for all the surface water COPC presented in Table 4-3. Dermal toxicity values can be extrapolated from oral toxicity values by adjusting the oral RfD by its oral absorption factor, per EPA guidance (EPA 1989). The oral absorption factor for all the COPCs identified in surface water was 100 percent. Therefore, the dermal RfD is equivalent to the oral RfD.

4.1.1 Cancer Toxicity Values

Potential carcinogens are grouped according to the likelihood that the chemical is human carcinogen, depending on the quality and quantity of carcinogenic potency data for a given chemical.

Group A – Human Carcinogen (sufficient evidence of carcinogenicity in humans)

Group B – Probable Human Carcinogen (B1 – limited evidence of carcinogenicity in humans; B2- sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans).

Group C – Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of evidence in humans)

Group D – Not Classifiable as to human carcinogenicity (inadequate or no evidence)

Group E – Evidence of non-carcinogenicity (no evidence of carcinogenicity in adequate studies).

Weight of evidence classifications for COPCs are provided in Section 4-2.

Cancer risks are expressed as a probability of suffering an adverse effect (cancer) during a lifetime. They estimate risks to individuals in a population and not to a particular individual.

For carcinogens, inhalation toxicity measurements are generally expressed as a risk per unit concentration (e.g., an inhalation unit risk (IUR) in units of risk per $\mu g/m^3$). The IUR is based on an upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of $1 \mu g/m^3$ in air.

4.1.2 Non-Cancer Toxicity Values

Non-cancer hazards are expressed, semi-quantitatively, in terms of the HQ, defined as the ratio between an individual's estimated exposure and the toxicity value. HQs are not an estimate of the likelihood that an effect will occur, but rather an indication of whether there is potential cause for concern for adverse health effects. Like cancer risks, HQs estimate risks to individuals in a population and not to a particular individual (i.e., personal risk).

For non-carcinogens, inhalation toxicity measurements are generally expressed as a concentration in air (e.g., an RfC in units of $\mu g/m^3$ air). The RfC is an exposure that is believed to be without significant risk of adverse non-cancer health effects in a chronically exposed population, including sensitive individuals.

For non-carcinogens, oral toxicity measurements are generally expressed as a reference dose (RfD). The RfD is an estimate of a daily chemical intake per unit body weight for the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious effects during a lifetime.

Chronic RfDs and RfCs are developed to evaluate long-term exposures of 7 years to a lifetime (70 years), intermediate RfDs and RfCs are developed to evaluate exposures of >14 to 364 days, and acute RfDs and RfCs are developed to evaluate exposures of 1 to 14 days. Chronic RfCs were used for the chronic all resident and resident adjacent to a well pad scenarios. Acute RfDs and RfCs were used for the acute child resident adjacent to a well pad scenario. If an acute value was not available, the intermediate toxicity value was used. If an intermediate value was not available, the chronic toxicity value was used, per EPA guidance (EPA 1989).

4.2 Summary of Health Effects of COPCs

This section summarizes the adverse of effects for the COPCs with toxicity values (Tables 4-1 and 4-3).

4.2.1 Acetylaldehyde

EPA has classified acetylaldehyde as probable human carcinogen (Class B2). There is inadequate evidence of carcinogenicity in humans, but adequate evidence of carcinogenicity in animals. An increased incidence of nasal and laryngeal tumors has been observed in animals after inhalation exposure (EPA IRIS 2010).

Short term inhalation exposure of rats to high concentrations of actylaldehyde was observed to result in degradation of the olfactory epithelium (EPA IRIS 2010, 1991 revision).

4.2.2 Benzene

Benzene is classified as a "known" human carcinogen (Category A) for all routes of exposure based upon convincing human evidence as well as supporting evidence from animal studies. Exposure to benzene can cause acute nonlymphocytic leukemia, acute myeloid leukemia, and also may cause chronic nonlymphocytic and chronic lymphocytic leukemia. (ATSDR, 2007, IRIS 2010).

Benzene's non-cancer toxicity is observed by all routes of administration. The following is ATSDR's summary of non-cancer health effects. "Brief exposure (5–10 minutes) to very high levels of benzene in air (10,000–20,000 ppm) can result in death. Lower levels (700–3,000 ppm) can cause drowsiness, dizziness, rapid heart rate, headaches, tremors, confusion, and unconsciousness. In most cases, people will stop feeling these effects when they are no longer exposed and begin to breathe fresh air. Eating foods or drinking liquids containing high levels of benzene can cause vomiting, irritation of the stomach, dizziness, sleepiness, convulsions, rapid heart rate, coma, and death. If you spill benzene on your skin, it may cause redness and sores. Benzene in your eyes may cause general irritation and damage to your cornea. Benzene causes problems in the blood. People who breathe benzene for long periods may experience harmful effects in the tissues that form blood cells, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components. A decrease in red blood cells can lead to anemia. Reduction in other components in the blood can cause excessive bleeding. Blood production may return to normal after exposure to benzene stops. Excessive exposure to benzene can be harmful to the immune system, increasing the chance for infection and perhaps lowering the body's defense against cancer (ATSDR 2007a)".

4.2.3 1,3-Butadiene

EPA has classified 1,3-butadiene as a known human carcinogen (Class A). Occupational studies suggest exposure to 1,3 butadiene in ambient air results in an increased risk for cancers of the stomach, blood, respiratory system, and lymphatic system (ATSDR 2009).

Very high exposures to 1,3-butadiene vapors in humans (>10,000 ppm) may result in narcosis and death from respiratory paralysis. Short term exposure to lower levels in ambient air may cause nausea, dry mouth and nose, headache, and decreased blood pressure and heart rate (ATSDR 2009).

4.2.4 Chloroform

EPA has determined that chloroform is a probable carcinogen (Class B2) based on sufficient animal evidence. Cancer of the liver and kidneys was observed in rats and mice that ingested chloroform (ATSDR 1997). "Chloroform is *likely to be carcinogenic to humans by all routes of exposure* under high-exposure conditions that lead to cytotoxicity and regenerative hyperplasia in susceptible tissues. Chloroform is *not likely to be carcinogenic to humans by any route of exposure* under exposure conditions that do not cause cytotoxicity and cell regeneration" (IRIS 2001).

Short term exposure to high concentrations of chloroform in ambient air causes fatigue, dizziness and headache. Long term exposure in ambient air, food, or water may cause liver and kidney damage (ATSDR 1997).

4.2.5 Crotonaldehyde

Crotonaldehyde is classified as a possible human carcinogen (Category C) based on limited animal evidence. An increased incidence of hepatic neoplastic nodules and hepatocellular carcinomas were observed in animal carcinogenicity study that was limited by only one sex of one species (IARC 1995).

Crotonaldehyde is a potent eye, respiratory and skin irritant and brief exposures to moderate concentrations in ambient air can irritate the nose and upper respiratory tract, with lachrymation (IARC 1995). However, no RfC is available for crotonaldehyde.

4.2.6 1,4-Dichlorobenzene

EPA has determined 1,4-dichlorobenzene is likely to be a human carcinogen based on limited animal studies (Class C). Increased risk in kidney and liver tumors have been observed in rats after ingestion of 1,4-dichlorobenzene. An increased incidence of lung adenomas in males and of liver adenomas in females was observed in an inhalation study on mice (IRAC 2000).

Short term exposure to high concentrations of 1,4-dichlorobenzene in ambient may cause eye, nose, and eye irritation and burning, coughing, breathing difficulties, and upset stomach. Long term exposures to high concentrations may case decreased lung function, dizziness, headache, liver problems, skin blotches, and anemia.

4.2.7 Ethylbenzene

EPA has determined ethylbenzene is not classifiable as human carcinogen (Class D). The International Agency for Research on Cancer (IARC) has classified ethylbenzene as possibly carcinogenic to humans, based on sufficient evidence in animal studies (IARC 2000). An increased incidence of lung adenomas in males and of liver adenomas in females was observed in an inhalation study on mice (IRAC 2000).

Short term exposure to high levels of ethylbenzene in ambient air can cause eye and throat irritation, vertigo, and dizziness. Evidence of long-term exposure effects in humans is lacking. Animal studies indicate long-term exposure to low levels of ethylbenzene in ambient air may result in irreversible damage to the inner ear and hearing, as well as kidney damage. Rats ingesting large amounts of ethylbenzene had severe damage to the inner ear. Dermal exposure has caused eye damage and skin irritation in rabbits (ATSDR 2007b).

4.2.8 Formaldehyde

EPA has determined formaldehyde is probable human carcinogen with limited evidence of carcinogenicity in humans and sufficient evidence in animals (Class B1). Exposure to formaldehyde in ambient air may result in an increased risk for nasal and throat cancers (ATSDR 1999a).

NIOSH states that exposure to formaldehyde in ambient air is immediately dangerous to life and health at 20,000 ppb. Lower short-term exposures to lower concentrations can irritate the eyes, nose, and throat (ATSDR 1999a).

4.2.9 n-Hexane

EPA has determined n-hexane is not classifiable as human carcinogen (Class D) (ATSDR 1999b).

Workers exposed to greater than 500,000 ppb of n-hexane in ambient air for over 6 months have experienced numbness in their feet and hands followed by muscle weakness in their feet and lower legs. With continuing exposure, peripheral neuropathy can result in paralysis of the arms and legs developed (ATSDR 1999b).

4.2.10 2-Hexanone

EPA has determined 2-hexanone is not classifiable as human carcinogen (Class D) (EPA IRIS 2010/2009).

Workers exposed to 2-hexanone for almost a year experienced harmful effects to the nervous system. Symptoms included weakness, numbness, and tingling in the skin of the hands and feet (ATSDR 1992).

4.2.11 Methylcyclohexane

EPA has not determined a cancer classification for methylcyclohexane.

Evidence on human exposure to methylcyclohexane is lacking. Decreased body weight has been observed in animal studies on hamsters and male rats, as well as progressive renal nephropathy in male rats, after inhalation of methylcyclohexane (Kinkead et al. 1985)

4.2.12 Methylene Chloride

EPA has classified methylene chloride as a probable human carcinogen (Class B2) based on sufficient evidence in animal studies. Increased incidence of hepatocellular neoplasms, alveolar/bronchiolar neoplasms, mammary tumors, salivary gland sarcomas, and leukemia have been observed in studies on rats (EPA IRIS 1995/2010).

Inhalation of very high concentrations of methylene chloride can cause death. Inhalation of lower concentrations can cause dizziness, nausea, tingling or numbness of fingers and toes, and drunkenness. Symptoms usually disappear shortly after the exposure ends. Methylene chloride vapors also may cause eye irritation. (ATSDR 2000).

4.2.13 n-Nonane

EPA has not determined a cancer classification for n-nonane.

Evidence on human exposure to n-nonane is lacking. Central nervous system or peripheral nervous system abnormalities (tremors, convulsions, coordination loss, and limb paralysis) and irritation, as well as liver and lung lesions have been observed in rats exposed to n-nonane vapor (Carpenter et al. 1978; Nilsen et al. 1988).

4.2.14 n-Pentane

EPA has not determined a cancer classification for n-pentane.

Breathing very high concentrations of n-pentane can cause drowsiness and anesthetic effects. At even higher concentrations, n-pentane can act as an asphyxiant (Galvin and Marashi 1999).

4.2.15 Toluene

Toluene can not be classified as a carcinogen because of inadequate evidence (Class D) (EPA Toxicological Review of Toluene, September 2005, EPA/635/R-05/004).

Human occupational studies have reported experienced altered color vision, dizziness, fatigue, headache, and decreased performance in neurobehavioral tests in humans exposed to toluene via inhalation. Children of mothers who inhaled very high levels of toluene during pregnancy exhibited a number of physical (small mid face, deep-set eyes, micrognathia, and blunting of the fingertips) and clinical (microcephaly, CNS dysfunction, attention deficits, and developmental delay/mental deficiency) changes which were attributed to toluene. Histopathologic lesions, damage to the tubular epithelia of the kidney, decreased antibody body response, and increases in brain neurotransmitter levels have been observed in animals following oral exposure to toluene. (EPA Toxicological Review of Toluene, September 2005, EPA/635/R-05/004).

4.2.16 Trimethylbenzenes

EPA has not classified the trimethylbenzenes for carcinogenicity.

Breathing high levels of 1,2,4-trimethylbenzene for short periods of time adversely affects the human nervous system. Effects range from headaches to fatigue and drowsiness. TMB vapor irritates the nose and the throat. Prolonged contact with liquid TMB irritates the skin (EPA 1994). Health effects and toxicity of 1,3,5-trimethylbenzene and 1,2,3-trimethylbenzene may be similar to those of 1,2,4-trimethylbenzene. Therefore, the RfC for 1,2,4-trimethylbenzene was used as a surrogate for 1,3,5-trimethylbenzene and 1,2,3-trimethylbenzene.

4.2.17 Xylenes

Xylenes have not been classified as carcinogens because of inadequate evidence (Class D) (ATSDR 2007c).

The three forms of xylene (m-xylene, p-xylene, and o-xylene) have very similar effects on human health. Exposure to very high levels of xylene can cause death. Short-term exposure of people to high levels of xylene can cause irritation of the skin, eyes, nose, and throat; difficulty in breathing; impaired function of the lungs; delayed response to a visual stimulus; impaired memory; stomach discomfort; and possible changes in the liver and kidneys. Both short- and long-term exposure to high concentrations of xylene can also cause a number of effects on the nervous system, such as headaches, lack of muscle coordination, dizziness, confusion, and changes in one's sense of balance (ATSDR 2007c).

5 Risk Characterization

Risk characterization integrates the information from the data, exposure and toxicity assessments to provide an estimate of the magnitude of potential risk. Both cancer and non-cancer health effects are evaluated in this HHRA. This section presents an estimation of the baseline risk within the Battlement Mesa PUD and an estimation of excess risk that may be introduced within the Battlement Mesa PUD as a result of Antero's drilling plan.

5.1 Risk Estimations

The methods for estimating cancer, non-cancer, and multiple contaminant risk follow.

5.1.1 Cancer Risk Estimation

The lifetime cancer risk for each COPC for which there is a toxicity value is derived by multiplying the intake values in presented in Table 3-1 for the chronic exposure scenarios and Table 3-2 for the acute exposure scenario by the respective IUR value, as shown in the following equation.

$$Risk_x = Intake_x * IUR_x$$

Where:
$Risk_x$ = the risk of the X^{th} COPC at a monitor;
$Intake_x$ = the intake concentration of the substance or the maximum detected value;

Estimates of cancer risk are expressed as a probability, represented in scientific notation as a negative exponent of 10. For example, an additional lifetime risk of contracting cancer of 1 chance in 1,000,000 (or one additional person in 1,000,000) is written as 1E-06.

The level of cancer risk that is of concern is a matter of individual, community, and regulatory judgment. However, the EPA typically considers risks below 1E-06 to be so small as to be negligible (USEPA 1991). Therefore, the EPA uses a cancer risk of one in a million (1E-06) as a regulatory goal, which means that regulatory programs are generally designed to try to reduce risk to this level. When it is not feasible to meet this regulatory goal, the EPA may consider cancer risks lower than 1 in 10,000 (1E-04) to be acceptable.

5.1.2 Non-Cancer Hazard Estimation

In contrast to cancer risks, non-cancer hazards are not expressed as a probability of an individual suffering an adverse effect. Instead, the non-cancer hazard to individuals is expressed in terms of the HQ. For a given contaminant, exposures below the reference concentration (HQ less than one) are not likely to be associated with an appreciable risk of adverse health effects. With exposures increasingly greater than the reference concentration, the potential for adverse effects increases. HQs are calculated as follows:

$$HQ_x = Intake_x / RfC_x$$
$$HQ_x = Intake_x / RfD_x$$

Where:

HQ_x = the hazard quotient of the X^{th} COPC at a monitor;
$Intake_x$ = the intake concentration of the substance (i.e., most stringent of the 95% UCL or maximum air concentration); and
RfC_x = the reference concentration of the substance.
RfD_x = the reference dose of the substance

When used in the assessment of non-cancer risks, the HQ is commonly reported to one significant figure (USEPA, 1989). For example, a HQ of 0.13 is rounded to 0.1, and a HQ of 1.6 is rounded to 2.

5.1.3 Cumulative Risks for Multiple Chemicals

As noted in the 2008 risk assessment, emissions from natural gas development activities represent a complex mixture of hundreds of contaminants that can include aliphatic, aromatic, and polycyclic aromatic hydrocarbons, and carbonyls. Exposures to these contaminants may occur acutely or chronically, and commonly occur concurrently with exposure to other contaminants and stressors. The toxicity of contaminants in complex mixtures may differ greatly from that of a single compound. Therefore, estimating cancer risks or non-cancer hazard potential by considering one contaminant at a time might significantly underestimate the risks associated with simultaneous exposures to several contaminants. The consequences of the multiple exposures can be quantified, within some limitations, based on EPA's default assumption of additivity.

For cancer risk, the individual contaminant risks are added to estimate the total risk for the site. This summation is based upon the principle that the addition of each risk produces a combined total cancer risk estimate.

For non-carcinogenic contaminants, the HQs for each exposure pathway can be summed to develop a HI for that exposure pathway. For screening purposes, it is acceptable to sum all HQ values in order to derive an HI value. If the resulting HI is less than one, no further evaluation is necessary and it can be concluded that no unacceptable risks are present. If the HI is greater than one as a consequence of summing several HQs of similar value, it would be appropriate to segregate the contaminants by effect and by mechanism of action and to derive separate HIs for each group.

5.2 Baseline Risk

Baseline risks were estimated for ambient air, groundwater, and surface water. There is no data available for the estimation of a baseline risk for surface or subsurface soil.

5.2.1 Ambient Air Baseline Risk

The baseline risks determined for the Silt-Daley and Silt-Cox monitoring sites in the risk assessment performed with the 2005-2007 ambient air study data were employed as an estimate of the baseline risk within the Battlement Mesa PUD (CDPHE 2007). The Silt-Daley and Silt-Cox monitoring sites are described as rural sites without natural gas production operations.

COPCs for cancer risk across the two rural background monitoring sites are limited to benzene at Silt-Daley and 1,4-dichlorobenzene at Silt-Cox. The cancer risk estimates ranged from 1.5E-05 for benzene (15 excess cancers per 1 million individuals) to 5.1E-05 for 1,4-dichlorobenzene (51 excess cancers per 1 million individuals). These risks were based on a 70-year exposure duration and a 365 day/year exposure frequency. Adjusting these risks for a 30-year exposure duration and a 350 day/year, results in baseline cancer risks ranging from 6.2 E-06 to 2.1E-05 (6.2 to 21 excess cancers per 1 million individuals).

None of the individual chemicals that were assessed at any monitoring location were found to have an HQ exceeding a value of one for chronic as well as short-term (average) exposure durations. None of the HIs exceeded a value of one for either exposure duration.

It is important to note that the following 11 out of 19 COPCs with toxicity values identified in this HHRA were not determined in the 2005-2007 study.

1,3-Butadiene
Acetylaldehyde
Crotonaldehye
Formaldehyde
Methylcyclohexane
n-Hexane
n-Nonane
n-Pentane
1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene

Seven background results for the trimethylbenzenes, 1,3-butadiene, methylcyclohexane, n-hexane, n-nonane, and n-pentane are available from the 2008 air toxics study. As shown in table 2-10, 1,3-butadiene was not detected in any of the background samples. The trimethylbenzenes, n-hexane, n-nonane, and n-pentane were detected in 100 percent of these background samples, but their maximum detected values did not exceed the EPA

RSL for residential ambient air. Methylcyclohexane also was detected in 100 percent these background samples. However, the maximum detected concentration for methylcyclohexane was much less than the RfC listed in Table 4-1. For these reasons, it is unlikely that the trimethylbenzenes, 1,3-butadiene, methylcyclohexane, n-hexane, n-nonane, and n-pentane contribute significantly to the baseline risk in the Battlement Mesa PUD.

There are no background results available for acetylaldehyde, formaldehyde, and crotonaldehyde. Therefore, it is not possible to estimate the contribution of these chemicals to the baseline risk.

5.3 Risk After Implementation of Natural Gas Production operations

The risk for each of the three populations discussed in Section 3 was quantitatively evaluated for COPCs with toxicity values. Risk for COPCs without toxicity values was addressed qualitatively.

5.3.1 All Battlement Mesa Residents Chronic Risk

Cancer Risk Estimates

The sum of the cancer risk to all Battlement Mesa residents (i.e., not living adjacent to a well pad is estimated at 7.1E-05 (71 cancers per 1,000,000 individuals), as shown in Table 5-1. This cancer risk is within EPA's acceptable range of 1E-06 to 1E-04. Crotonaldehyde, a possible human carcinogen, is the major contributor to the cancer risk (4.5E-05), followed by 1,4-dichlorobenzene, a possible human carcinogen, (1.0E-05), formaldehyde, a probable human carcinogen, (6.7E-06), benzene, a known human carcinogen, (5.4E-06), and 1,3-butadiene, a known human carcinogen (1.9E-06). Acetylaldehyde, a probable human carcinogen, methylene chloride, a probable human carcinogen, and ethylbenzene, a possible human carcinogen, also contribute to the cancer risk at levels less than 1E-06.

As noted in Section 5-2, data for crotonaldehyde, acetylaldehyde, and formaldehyde were not available for the baseline risk assessment. Therefore, it is not appropriate to directly compare the 7.1E-05 cancer risk to the baseline risk. It is possible to compare contribution of benzene, 1,4-dichlorobenzene, 1,3-butadiene, methylene chloride, and ethylbenzene to cancer risk to the baseline risk. These contaminants contribute 1.9E-05 of the cancer risk, which is within the baseline cancer risk range of 6.2E-06 to 2.1E-05.

The cancer risk of 7.1E-05 is less than the 1.2E-4 cancer risk reported in the 2008 risk assessment for the Bell-Melton Ranch monitoring station (CDPHE 2010). Adjusting the 1.2E-04 cancer risk reported in the 2008 risk assessment for Bell-Melton Ranch for a 30-year exposure duration and a 350 day/year exposure frequency results in a cancer risk of 4.9 E-05, which is less than the 7.1E-05 cancer risk for the resident not living adjacent to a well pad. The main reasons for this difference is because of the inclusion of 1,4-

dichlorobenzene results from the 2005-2007 air study that were not considered in the 2008 risk assessment and differences in EPCs. EPCs were different because this HHRA included results from 2009 and 2010.

Non-Cancer Risk Estimates

No COPC had an HQ greater than one, as shown in Table 5-1. The HI for non-cancer hazard is 0.6, which is less than EPA's level of one below which health effects are not expected to occur.

The HI of 0.6 is higher than the 0.4 HI (0.2 adjusted for a 30-year exposure duration) reported in the 2008 risk assessment for the Bell-Melton monitoring station (CDPHE 2010). Differences between the two estimates are mainly because this HHRA included chemicals not measured in the 2005-2007 study.

Qualitative Risk Evaluation

Of the COPCs identified from the 2005 to 2010 data set used to evaluate the risk for residents not living near a well pad, 61 did not have toxicity values. However, background information is available for 55 of these COPCs. As shown in Table 5-2, the EPC for 42 of these COPCs did not exceed the BTV, indicating they would not contribute more to risk than already contributed by the baseline. The remaining 13 COPCs are alkenes and alkanes that may contribute to the risk over baseline.

At low concentrations, the toxicity of alkanes and alkenes is generally considered to be minimal (Sandmeyer, 1981). For example, the RfCs for the three alkanes with toxicity values, n-hexane, n-pentane, and n-nonane, range from 200 to 1000 $\mu g/m^3$. None of the EPCs for the alkenes and alkanes listed in table 5-2 exceed $100 \mu g/m^3$.

Six of the COPCs for which there are no toxicity values or background/baseline data are aldehydes, which generally act as irritants of the eyes, skin, and respiratory tract. Some aldehydes have also been shown to be mutagenic and/or carcinogenic. The variation in toxicity among the individual aldehydes is large. Investigations are needed to further characterize the health effects of the common aldehydes.

Overall, based on the qualitative evaluation of health risks, it appears that exposure to 55 COPCs identified in Table 5-2 individually is not likely to result in significant cancer and non-cancer effects. Any of the six carbonyls without toxicity values could potentially have a significant contribution to the cancer and/or non-cancer effects. In addition, the cumulative health effects of these 61 COPCs cannot be estimated. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

5.3.2 Residents Living Adjacent to a Well Pad

Cancer Risk Estimates

The sum of the cancer risk to Battlement Mesa residents living adjacent to a well pad is estimated at 8.3 E-05 (83 cancers per 1,000,000 individuals), as shown in Table 5-3. This cancer risk is within EPA's acceptable range of 1E-06 to 1E-04. Crotonaldehyde, a possible human carcinogen, is the major contributor to the cancer risk (4.5E-05), followed by benzene, a known human carcinogen (1.13E-5), 1,4-dichlorobenzene, a possible human carcinogen, (1.0E-05), ethylbenzene, a possible human carcinogen (6.9E-06), formaldehyde, a probable human carcinogen, (6.7E-06), and 1,3-butadiene, a known human carcinogen (1.9 E-06). Acetylaldehyde, a probable human carcinogen, and methylene chloride, a probable human carcinogen, also contribute to the cancer risk at levels less than 1E-06.

As noted in Section 5-2, data for crotonaldehyde, acetylaldehyde, and formaldehyde were not available for the baseline risk assessment. Therefore, it is not appropriate to directly compare the 9.4E-05 cancer risk to the baseline risk. It is possible to compare contribution of benzene, 1,4-dichlorobenzene, 1,3-butadiene, methylene chloride, and ethylbenzene to cancer risk to the baseline risk. These contaminants contribute 3.1E-05 of the cancer risk, which is greater than the baseline cancer risk range of 6.2E-06 to 2.1E-05.

The cancer risk of 8.3E-05 for the resident living adjacent to a well pad is higher than the 7.1E-05 estimated cancer risk for the resident not living adjacent to a well pad. The increase is due the increase in cancer risk from benzene and ethylbenzene. It is important to note that intakes for crotonaldehyde, acetylaldehyde, formaldehyde, methylene chloride, and 1,4-dichlorobenzene were the same as the chronic intakes for the residents not living near a well pad because data for these chemical was not available from the 2008 air toxics study. If concentrations of these compounds in ambient air are higher during well completion activities, the actual cancer risks for residents living adjacent to a well pad may be higher.

Non-Cancer Risk Estimates

While no individual contaminant had an HQ greater than one, the HI for the non-cancer hazard is 2, as shown in Table 5-3. The HI is greater than EPA's level of one above which health effects may occur. It also is greater than the baseline non-cancer hazard. It is important to note that if concentrations of acetylaldehyde, formaldehyde, methylene chloride, and 1,4-dichlorobenzene in ambient air are higher during well completion activities, the actual non-cancer hazards for residents living adjacent to a well pad may be even greater.

Qualitative Risk Evaluation

Of the COPCs identified from the 2008 well completion data sets used to evaluate the risk for residents living near a well pad, 64 did not have toxicity values. However, background information is available for 57 of these COPCs. As shown in Table 5-2, the maximum detected concentration for six of these COPCs did not exceed the BTV, indicating they would not contribute more to risk than already contributed by the baseline. The remaining 51 COPCs are alkenes, alkanes, and aromatic hydrocarbons that may contribute to the risk over baseline.

At low concentrations, the toxicity of alkanes and alkenes is generally considered to be minimal (Sandmeyer, 1981). For example, the RfCs for the three alkanes with toxicity values, n-hexane, n-pentane, and n-nonane, range from 200 to 1000 µg/m^3. The maximum concentrations for 15 alkanes listed in Table 5-2 exceed 100µg/m^3. Ethane, propane, n-butane, and iso-butane concentrations exceed 1000µg/m^3. At high concentrations, health effects that are associated with alkanes include acting as anesthetics and subsequently asphyxiants, showing narcotic or other central nervous system depression effects, and dermal and pulmonary irritation. Some alkanes (propane, butane and isobutane) may be weak cardiac sensitizers in humans following inhalation exposures to high concentrations (greater than 5 percent for isobutane and greater than 10 percent for propane).

Five of the COPCs which exceed BTVs and for which there are no toxicity values are aromatic hydrocarbons. The toxicity of aromatic hydrocarbons has is varied and some, such as benzene and ethylbenzene have been shown to carcinogenic. Investigations are needed to further characterize the health effects of these aromatic hydrocarbons.

Six of the COPCs for which there are no toxicity values or background/baseline data are aldehydes, which generally act as irritants of the eyes, skin, and respiratory tract. Some aldehydes have also been shown to be mutagenic and/or carcinogenic. The variation in toxicity among the individual aldehydes is large. Investigations are needed to further characterize the health effects of the common aldehydes.

Overall, based on the qualitative evaluation of health risks, it appears that exposure to several of the alkanes, and aromatic hydrocarbons identified in Table 5-2 that exceed BTVs could potentially make a significant contribution to cancer and/or non-cancer effects for residents living adjacent to well pads. Any of the six carbonyls without toxicity values also could potentially have a significant contribution to the cancer and/or non-cancer effects. In addition, the cumulative health effects of these 63 COPCs cannot be estimated. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

5.3.3 Acute Risk - Child Living Adjacent to a Well Pad

Non-Cancer Risk Estimates Ambient Air

Ambient air HQs for 1,2,3-trimethylbenzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, and n-nonane all exceed EPA's level of one above which health effects may occur, as shown in Table 5-4. The HI for the ambient air pathway is 30.

It is important to note that acetylaldehyde, formaldehyde, the trimethylbenzenes, 1,3-butadiene, methycyclohexane, n-hexane, n-pentane, and n-nonane were not measured for odor complaints in the 2005 to 2007 air study. If concentrations of these chemicals are higher for odor complaints, the actual acute non-cancer hazards for the child resident living adjacent to a well pad may be even greater.

This acute non-cancer hazard in ambient air is greater than the acute non-cancer hazard estimated (HI 2-6) in CDPHE's 2007 HHRA. The difference is due the inclusion of the trimethylbenzenes in this estimate. The data for the trimethylbenzenes had not been collected at the time of the 2007 HHRA.

Non-Cancer Risk Estimates Surface Water

For the surface water pathway, no individual COPC has an HQ greater than one, as shown in Table 5-4. The HI for non-cancer risks is 0.6, which is less than EPA's level of one below which health effects are not expected to occur.

Non-Cancer Risk Estimates Combined Ambient Air and Surface Water

The overall HI of 40 for the acute exposure of a resident child living adjacent to a well pad is 40, which is much greater than EPA's acceptable level of one at which health effects may occur. The trimethylbenzenes, benzene, and n-nonane in ambient air are the primary contributors to the overall HI.

Qualitative Risk Evaluation

The qualitative risk evaluation performed for the resident living near a well pad also applies to the acute risk for a child resident living near a well pad. Overall, based on the qualitative evaluation of health risks, it appears that exposure to several of the alkanes, and aromatic hydrocarbons identified in Table 5-2 that exceed BTVs could make a significant contribution to acute non-cancer effects for child residents living adjacent to well pads. Any of the six carbonyls without toxicity values also could potentially have a significant contribution to the acute non-cancer effects. In addition, the cumulative health effects cannot be estimated. It should be noted that the current state of the science is unable to assess exposures to complex mixtures of air toxics, especially, synergistic and antagonistic interactions at low levels.

6 Uncertainty in Risk Assessment

Uncertainties and limitations are inherent in the risk assessment process. The level of uncertainty associated with the conclusions of a risk assessment is conditional upon data quality and models used to estimate exposure concentrations, assumptions in estimating exposure, and methods used to develop toxicity factors. Uncertainties in the risk assessment process could result in an underestimation or overestimation of risk. However, it is standard in risk assessment (per EPA guidance) to use health protective assumptions when uncertainty in quantifying risks exist, so as not to underestimate potential risk. While, the risk assessment process is generally skewed towards overestimating rather than underestimating risk, the risk estimated is this HHRA is most likely underestimated because of lack of data for the surface soil and water pathways, lack of toxicity data for most of the COPCs, lack of data for many potential COPCs, ozone and PM are not included in the quantitative risk assessment, and the chemicals reactions between the hundreds of chemicals in ambient air are not evaluated.

6.1 Uncertainties in Chemical Data

Section 2 discusses the evaluation and usability of the chemical data used in the HHRA in detail.

6.1.1 Bell-Melton Ranch Monitoring Station Data

Sample Frequency

Twenty-nine ambient air samples for VOCs were collected from the Bell-Melton monitoring station once per month for 29 months, followed by the collection of 128 samples for SNMOCs and 60 samples for carbonyls over the next 27 months. There is a low to moderate uncertainty that this dataset reflects the 30-year exposure assumed in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from year to year. However, the temporal trends illustrated in Figures 2-1 and 2-2 indicate no overall increase or decrease in ambient air concentrations over the past five years. To reduce this uncertainty would require monitoring over several years or modeling based on observed changes in meteorology and chemical emissions.

The 29 ambient air samples collected for VOCs were analyzed for 43 chemicals. Thirty-six of these chemicals were not included in the SNMOC or carbonyl analysis. Therefore, for 36 chemicals evaluated in this HHRA, there are only 29 results for a 29 month period. There is more uncertainty that this sub-dataset reflects the 30-year exposure assumed in the HHRA, than the overall dataset.

Method Reporting Limits

For the 15 VOCs listed in Section 2.2.1 with a detection frequency of less than five percent, the RSL was less than the MRL. It is uncertain if these chemicals are present at a concentration that may impact human health. The presence of any of these chemicals in ambient at concentrations that could impact human health would contribute to an underestimation of the risks calculated in this HHRA. The contribution to the uncertainty would be expected be low because these chemicals are mostly chlorinated solvents which have not been associated with natural gas production operations. To reduce this uncertainty would require collection of ambient air samples for VOCs for analysis by a method with MRLs below EPA RSLs for ambient air.

6.1.2 Well Completion Data

Sixteen ambient air samples for SNMOCs were collected from the perimeter of four different well pads undergoing well completion activities. At each well pad, one sample was collected from each of the four cardinal directions (four total samples). There is high level of uncertainty that this dataset reflects the 10-month exposure assumed for well completion in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from month to month. In addition, it is uncertain whether this dataset reflects all stages of well completion as different stages of well completion can lead to lower or higher concentrations in ambient air. To reduce this uncertainty would require daily monitoring over all stages of well completion or modeling based on observed changes in meteorology and chemical emissions.

6.1.3 Data Collected with Observed Odors at Residences

Sample Collection

Grab samples rather than 24-hour integrated samples were collected during odor events. There is a high level of uncertainty that a grab sample reflects the 24 hour per day exposure time assumed in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from minute to minute.

Sample Frequency

Twenty-eight samples for VOCs were collected during the 2005-2007 Garfield County Air Quality Study by residents when they observed odors. There is a high level of uncertainty that this dataset reflects the 7 day acute exposure scenario in this HHRA as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from day to day. In addition, it is uncertain whether this dataset reflects all stages of well completion as different stages of well completion can lead to lower or higher concentrations of chemicals in ambient air. To reduce this uncertainty would require sample collection over many odor events associated with different stages of well completion or modeling based on observed changes in meteorology and chemical emissions.

Method Reporting Limits

For the 15 VOCs listed in Section 2.2.1 with a detection frequency of less than five percent, the RSL was less than the MRL. It is uncertain if these chemicals are present at a concentration that may impact human health. The presence of any of these chemicals in ambient at concentrations that could impact human health would contribute to an underestimation of the risks calculated in this HHRA. The contribution to the uncertainty would be expected be low because these chemicals are mostly chlorinated solvents which have not been associated with natural gas production operations. To reduce this uncertainty would require collection of ambient air samples for VOCs for analysis by a method with MRLs below EPA RSLs for ambient air.

6.1.4 Surface Water Run-off Data

One sample of snow melt from one well pad was collected and analyzed for BTEX. There is a high level of uncertainty that this sample represents concentrations in surface water run-off from other well pads and during various stages of well drilling and completion. Potential surface water run off from the well pads proposed for Battlement Mesa could have lower or higher concentrations of chemicals. To reduce this uncertainty would require sample collection of surface water run off from many well pads over the stages of well completion.

6.1.5 Background Data for Ambient Air

BTVs determined for 72 out of the 115 chemicals listed in Table 2-7 were determined from seven background samples collected during the 2008 Air Toxics study. For the remaining 43 chemicals, only 5 had 8 or more detected observations. EPA recommends that BTVs be determined from data sets containing at least 8 to 10 samples with detectable observations (EPA 2010). It is moderately uncertain that the datasets with only 7 samples or less than 8 detected observations truly reflect background conditions. Actual background concentrations may be higher or lower. To reduce this uncertainty would require collection of additional background samples.

6.1.6 Groundwater Data

Out of 98 contaminants measured in groundwater, 29 had MRLs greater than the EPA RSL for tapwater. Because the groundwater exposure pathway is currently incomplete, this has minimal impact on this HHRA.

6.2 Uncertainty in Exposure Assessment

There are uncertainties in the exposure assessment related to potentially complete pathways that were not evaluated, use of ambient air stations to represent residential exposure, use of Bell-Melton Ranch monitoring station to represent Battlement Mesa, using well completion data from the 2008 perimeter study to estimate exposure during well completion, using default exposure factor values, and estimating exposure point concentrations.

6.2.1 Potentially Complete Exposure Pathways Not Evaluated

As discussed in Section 3, complete pathways involving surface soil were not evaluated in this HHRA because data was not available. Excluding the surface soil pathway could moderately affect the results of the HHRA and lead to an underestimation of the risk.

Several potentially complete pathways were not evaluated in this HHRA because data was not available or potential for exposure is low. Excluding these pathways would not be expected to significantly affect the results of this HHRA and may lead to a low underestimation of the risk. It is important to note that if the groundwater became contaminated as a result of natural gas production operations and was used as a source of drinking water, the risk calculated in this HHRA could be significantly underestimated.

6.2.2 Use of Bell-Melton Ranch Monitoring Station

There is a moderate level of uncertainty that the Bell-Melton Ranch monitoring station is representative of air concentrations to which a resident is exposed in the breathing zone 24 hours a day over 30 years. Actual concentrations may be higher or lower. Additionally, actual risk to residents living near sources of high concentrations of contaminant emissions may be underestimated.

There also is moderate level of uncertainty that the concentrations of contaminants measured at the Bell-Melton Ranch monitoring station are representative of what may be expected within the Battlement Mesa PUD. The Bell-Melton Ranch Monitoring Station is located in the Mamm Creek natural gas field. The natural gas produced from this field contains 83.1 to 84.3 molar percent methane and 13.5 to 16.2 molar percent heavier hydrocarbons (S.S. Papadopulos, 2008). Measurements of natural gas produced from Antero's Watson Ranch well pad (which is on the border of the PUD and within the same natural gas field as the PUD) indicate the produced gas is 91.1 molar percent methane and 6.4 molar percent heavier hydrocarbons (Antero personnel communication). However, the natural gas from the Watson Ranch pad contains 0.45 molar percent of hydrocarbons with 6 or more carbon atoms, which is a larger fraction than the 0.155 to 0.369 molar percent of hydrocarbons with 6 or more carbon atoms measured at Mamm Creek. Of the hydrocarbons identified as COPCs in this HHRA, all but one (n-pentane) have 6 or more carbon atoms. Therefore the uncertainty associated with the difference in the natural gas resources my result in an underestimation of the estimated risk for the Battlement Mesa PUD.

Other differences between the Bell-Melton Ranch monitoring station and Battlement Mesa include:

- Population density - Battlement Mesa is more densely populated which could result in greater emissions of contaminants in ambient air, leading to an underestimation of the risk calculated in the HHRA.
- Well Emission Controls – Not all of the wells in the vicinity of Bell-Melton Ranch flare vented gas, whereas Antero has indicated flares will be installed on all wells within the Battlement Mesa PUD. This could result in an overestimation of the risk calculated in the HHRA

Overall, using data from the Bell Melton Ranch monitoring station to estimate risk to Battlement Mesa residents introduces a low to moderate level of uncertainty to the risk estimates. Actual risks may be lower or higher.

6.2.3 Use of Well Completion Samples

As with the samples collected at the Bell-Melton Ranch monitoring station, there is a moderate level of uncertainty that the samples collected at the perimeter of the well pads represent air concentrations to which a resident is exposed in the breathing zone for 24 hours a day over 10 months. Actual concentrations may be higher or lower. Additionally, samples were collected at distances nearer the well head than the 500 foot set back proposed by Antero. This may result in a low overestimation in the calculated risk.

A large uncertainty stems from inability to monitor intermittent peak exposure. The nature of oil and gas operations is such that emissions vary strongly with time. To reduce this uncertainty, short-term air monitoring is needed.

6.2.4 Use of EPA Default Exposure Factor Values

EPA recommends the use of site-specific exposure factor values for HHRAs when available. When site-specific information is not available, such as was the case for exposure frequencies and the surface water exposure factor values, EPA standard default values are recommended. In general, there is a higher uncertainty and protectiveness of health involved in using default values instead of site-specific values. Therefore default values used for exposure frequency and the surface water exposure factor values may have contributed to a low to moderate overestimation of risk.

6.2.5 Exposure Point Concentrations

The EPCs for 1,4-dichlorobenzene, 2-hexanone, and methylene chloride are based on one detected result out of 29 samples. Actual concentrations of 1,4-dichlorbenzene, 2-

hexanone, and methylene chloride may be lower and risks from these contaminants may be overestimated.

The maximum detected concentration was used from the well completion data was used to calculate the TWA for the EPC used to estimate the exposure of a resident living adjacent to a well pad. The maximum concentration was observed in the sample collected at 200 feet from the well head at an Antero well pad. The proposed set back for the wells in the Battlement Mesa PUD is 500 feet. Using the maximum concentration collected from a sample collected at a distance closer to a well head than the proposed set back may contribute moderately to an overestimation of the risk calculated in this HHRA. To reduce this uncertainty would require collection of samples at the proposed set back distance.

The maximum detected concentration for the data collected during odor events was used as the EPC to estimate an acute exposure of a child resident living adjacent to a well pad. Using the maximum concentration may contribute moderately to an overestimation of the risk calculated in this HHRA. However, the intention of the acute exposure scenario was to evaluate the MEI.

6.2.6 Exposures for children

The uncertainty noted for children in the 2007 risk assessment also applies to this HHRA (CDPHE 2007). Children generally are expected to have some exposures that differ (higher or lower) from those of adults because of differences in size, physiology, and behavior. For example, children exposed to the same concentration of a chemical in air as adults may receive a higher dose because of greater lung surface area-to-body weight ratios and higher ventilation rate per kilogram of body weight. EPA has recently concluded that cancer risks of mutagenic carcinogens generally are higher from early-life exposures than from similar exposure durations later in life. It is, however, important to note that when exposures are fairly uniform over a lifetime exposure of 70 years, the effect of child adjustments on the estimated lifetime cancer risk is relatively small. These adjustments are more important when estimating the cancer risks from less than 70 years of exposure duration, such as the 30-year exposure duration used in this HHRA. In addition, children are more at risk because of the availability of a longer latency period for the development of cancer.

6.3 Uncertainty in the Toxicity Assessment

There are uncertainties in the toxicity assessment related to the toxicity values, COPCs without toxicity data, the lack of data on potential COPCs for which there is no data, interactions resulting from exposures to multiple chemicals, and the effect of other pollutants such as ozone and particulate matter on toxicity.

6.3.1 Toxicity Values

The RfC and RfD values used to evaluate non-cancer risk and the IUR values used to quantify cancer are often derived from limited toxicity databases. This can result in substantial qualitative and quantitative uncertainty. To account for this uncertainty, EPA derives RfCs, RfDs, and IURs in a way that is intentionally conservative (protective of human health). Risk estimates based on the RfCs, RfDs, and IURs are likely to overestimate risk.

The 2008 risk assessment notes that the EPA has calculated a range of IURs for benzene between 2.2×10^{-6} and 7.8×10^{-6} per µg/m³. The upper-bound value was used in this HHRA, as was done in the 2008 risk assessment, in accordance with the EPA Air Toxic guidance, which may slightly overestimate risk (up to 3-fold). The set of risk estimates falling within this interval reflects both the inherent uncertainties in the risk assessment of benzene and the limitations of the epidemiologic studies in determining dose-response and exposure data (CDPHE 2010).

Also noted in the 2008 risk assessment, the IUR for crotonaldehyde is particularly uncertain (CDPHE 2010). An IUR is not reported in EPA's IRIS for crotonaldehyde. The toxicity of crotonaldehyde was evaluated using a cancer toxicity value derived in the EPA Health Effects Assessment Summary Tables (HEAST) from oral exposure studies. Although conversion of oral dose-response information to inhalation exposure is not optimal risk assessment practice, the alternative would be to omit this substance altogether from any quantitative evaluation. Crotonaldehyde is classified as a possible human carcinogen (Category C). The classification was assigned based on one animal study in which an increase in the incidence of hepatic neoplastic nodules and hepatocellular carcinomas was observed in only one sex of one species. There is insufficient evidence that inhalation is a route that results in crotonaldehyde- induced liver lesions or neoplastia.

The IUR for 1,4-dichlorobenzene also is particularly uncertain. An IUR is not reported in EPA's IRIS for 1,4-dichlorobenzene. The toxicity of 1,4-dichlorobenzene was evaluated using a cancer toxicity derived by CALEPA from oral exposure studies. 1,4-dichlorobenzene is classified as a possible human carcinogen (Category C). The classification was assigned based on two animal studies in which an increase in the incidence of hepatocellular adenomas and carcinomas was observed in male rats and both sexes of mice.

The RfC for 1,2,4-trichlorobenzene was used as a surrogate toxicity value for 1,2,3-trichlorobenzene and 1,3,5-trichlorobenzene. This may have resulted in an underestimation or overestimation of the contribution of these two contaminants to the risk.

The RfD for chronic benzene exposure was used for the acute benzene exposure in surface water. This may have contributed to an overestimation of the risk from surface water. However, the HI from the acute surface water exposure was less than one and the overall effect on the risk estimate is minimal.

The RfC for intermediate ethylbenzene exposure was used for the acute ethylbenzene exposure in surface water. This may have contributed to an overestimation of the risk from surface water. However, the HI from the acute surface water exposure was less than one and the overall effect on the risk estimate is minimal.

RfDs for dermal exposure were extrapolated from oral RfDs for the evaluation of acute exposure from surface water. This may have contributed to an overestimation of the risk from surface water. However, the HI from the acute surface water exposure was less than one and the overall effect on the risk estimate is minimal.

6.3.2 COPCs without toxicity values

One of the largest sources of uncertainty in the toxicity assessment is unavailability of toxicity values for 63 out of 82 COPCs in ambient air. Therefore, cancer risks and non-cancer hazards are likely to be underestimated for ambient air.

6.3.3 Potential COPCs Not Measured

Another one of the largest sources of uncertainty in the HHRA is lack of data for many chemicals in ambient air and surface water run-off that could be associated with natural gas production operations. These include chemicals in hydraulic fracturing fluid and drilling mud, polycyclic aromatic hydrocarbons (PAHs), and metals. Of the contaminants detected in samples collected at observed odor events between 2005 and 2007, only m&p-xylene exceeded Texas Commission on Environmental Quality’s acute odor based effects screening level (ESL) (Table 2-6). The ESL is the level at which 50 percent of people can smell a contaminant and is not necessarily associated with health effects (TCEQ 2006). Health effects are possible for some contaminants, such as benzene, at levels below the odor threshold. The fact that only m&p-xylene exceeded the odor threshold indicates that there may be other ambient air contaminants associated in with natural gas production operations that have not been measured.

Table 6-1 lists 234 chemicals complied from Antero’s material safety data sheets (MSDS) for natural gas production operations that have not been measured in ambient air or surface water samples. These include chemicals in hydraulic fracturing fluids and drilling mud. The list includes carcinogenic PAHs, metals, irritants, and odorous compounds, such as glutaraldehyde. Cancer risks and non-cancer hazards may be significantly underestimated without data for these chemicals.

Several of the PAHs are probable human carcinogens, including benzo (a) pyrene, dibenz(a,h)anthracene, benz(a)anthracene, benzo(b)fluoranthene, and indeno(c,d)pyrene (EPA IRIS). Others, such as naphthalene, are possible human carcinogens (EPA IRIS).

PAHs are associated with emissions from diesel engines. Once emitted to the air, the PAHs can contaminate surface soil and water via dry deposition. The trucks and generators used during natural gas production operations are powered by diesel engines. The truck traffic within the Battlement Mesa PUD is expected to be extensive with as many as 280 truck trips per day during peak well pad construction activities (Antero, 2010). Generator use is expected to be extensive during hydraulic fracturing operations. Naphthalene also is one of the chemicals listed on the MSDS sheets for hydraulic fracturing fluids, as well as being one of the components of the natural gas resource. Cancer risks may be significantly underestimated without PAH data for both ambient air and surface soil.

6.4 Uncertainty in Risk Estimation Due to Ozone and Particulate Matter

Ozone, PM_{10} and $PM_{2.5}$ were not evaluated in the HHRA because they are regulated by federal Air Quality Standards (AQS). The purpose of the AQSs is to protect human health. However, there has been much debate over whether the 75 ppb (147 $\mu g/m^3$) (averaged over 8 hours) AQS for ozone is protective and EPA is proposing a lower AQS of 60 ppb (118 $\mu g/m^3$). In addition, applying these standards on an individual basis does not account for potential additive affects in multiple chemical mixtures, as occurs in ambient air. A qualitative evaluation of the effects of these air pollutants on the risk estimates follows.

<u>Ozone</u>

There is not any conclusive evidence that ozone is a human carcinogen (EPA 2006, EPA 2009a).

Short-term exposure to ground level ozone through inhalation can cause reversible decrements to lung function, airway inflammation, coughing, chest pain, wheezing, and airway hyperactivity. These symptoms may be more long-lasting and pronounced in sensitive populations, such as people with asthma, children, and adults over 65 years of age. Acute ozone exposure also is associated with increased cardiovascular morbidity and non-accidental and cardiovascular mortality. There is some evidence long term exposure to ozone may cause decreased pulmonary function, but it is inconclusive (EPA 2006, EPA 2009a).

High concentrations of ozone precursors (VOCs and nitrogen oxides) have been observed in areas with high natural gas production operations in Garfield County (CDPHE 2009b). CDPHE ranked Garfield County as 5^{th} out of 64 Colorado counties in levels of these ozone precursors in 2009, while Garfield ranked only 14^{th} in population (CDPHE 2009c). In 2009, the 8-hr average ozone concentrations measured at the Rifle monitoring station did not exceed the 75 ppb AQS. However, 8-hour average ozone concentrations did exceed the proposed 60 ppb AQS on five days in March and April 2009, with a maximum concentration of 64 ppb (Garfield County 2010). For days on which the proposed 8-hour ozone AQS is exceeded, the acute non-cancer hazard calculated in this HHRA may be underestimated.

Particulate Matter

There is suggestive evidence indicating $PM_{2.5}$ may be associated with increased mortality from lung cancer (EPA 2009b).

Short-term exposure to $PM_{2.5}$ through inhalation is associated with increased emergency room visits and hospitalizations for ischemic heart disease, congestive heart failure chronic obstructive pulmonary disease (COPD), respiratory infections. Increases in all-cause, cardiovascular, and respiratory mortality are associated with short exposure to $PM_{2.5}$. Long-term exposure to $PM_{2.5}$ has been associated with cardiovascular mortality, decrements in lung function, and development of asthma (EPA 2009b). There is suggestive evidence that short-term and long term exposure to PM_{10} may cause health effects similar to those of $PM_{2.5.}$ Sensitive populations, such as children, older adults, and people with cardiopulmonary disease are more susceptible to these health effects.

Increased truck traffic can result in increased levels of $PM_{2.5}$ and PM_{10} through diesel emissions and stirring up road dust, respectively. The AQSs for $PM_{2.5}$ are 35 $\mu g/m^3$ (24-hour, 98th percentile averaged over 3 years) and 15 $\mu g/m^3$ (annual, mean averaged over 3 years). The AQS for PM_{10} is 150 $\mu g/m^3$ (24-hour, not to be exceeded more than once per year on a 3-year average). Neither $PM_{2.5}$ or PM_{10} concentrations measured at the Rifle monitoring station nor PM_{10} concentrations measured at the Parachute monitoring station exceeded any of these AQSs. However, several 24-hour $PM_{2.5}$ concentrations exceeded 35 $\mu g/m^3$ in 2009. The highest observed concentration was 41$\mu g/m^3$ (Garfield County 2010). $PM_{2.5}$ concentrations measured during the 2008 Air Toxics Study were all less than the 24-hour AQS ranging from 4.9 to 20.5 $\mu g/m^3$ (Garfield County 2009). For days on which the 24-hour $PM_{2.5}$ AQS is exceeded, the acute non-cancer hazard calculated in this HHRA may be underestimated.

6.5 Uncertainty in Risk Estimation Due to Chemical Mixtures

Interactions among components within ambient air, such as hydrocarbons, carbonyls, ozone, and ozone, are not well understood. Natural gas production operations and the diesel engines used to support them have the potential to release hundreds of hydrocarbons, including alkanes, alkenes, aromatics, and PAHs, and chemicals used in operations, such as hydraulic fracturing into the air, soil, and water. The diesel engines also release $PM_{2.5}$ and nitrogen oxides. Hydrocarbons, carbonyls, and nitrogen oxides serve as precursors for ground level ozone formation. The number of possible interactions this complex mixture of hydrocarbons, carbonyls, ozone, particulate matter, and other chemicals is very large. The effects of these complex interactions on human health are not well understood, but there is some indication that these complex mixtures can act additively or synergistically to increase effects on human health.

As previously stated, diesel engine exhaust is a complex mixture of hydrocarbons, $PM_{2.5}$ and nitrogen oxides. EPA has classified diesel engine exhaust as *likely to be carcinogenic to humans* based on: (1) strong, but less than sufficient evidence for a causal association between diesel engine exhaust exposure and increased lung cancer risk among workers in occupational studies; (2) extensive supporting data including the demonstrated mutagenic and/or chromosomal effects of diesel engine exhaust and its organic constituents, and knowledge of the known mutagenic and/or carcinogenic activity of a number of individual organic compounds that adhere to the particles and are present in the diesel engine gases; (3) evidence of carcinogenicity of diesel particulate matter and the associated organic compounds in rats and mice by other routes of exposure (dermal, intratracheal, and subcutaneous and intraperitoneal injection); and (4) suggestive evidence for the bioavailability of organic compounds from diesel engine exhaust in humans and animals. Non-cancer health effects of exposure to diesel engine exhaust include pulmonary inflammation and histopathology (IRIS 2003/2010).

Studies on air pollution indicate that continuous exposure of healthy human adults to sulfur dioxide or nitrogen dioxide increases ozone absorption, suggesting that co-exposure to other gaseous pollutants in the ambient air may enhance ozone absorption. Studies that evaluated response to allergens in asthmatics (allergic and dust-mite sensitive) suggest that ozone enhances response to allergen challenge. Other studies have reported increased response (lung tissue injury, inflammatory and phagocytosis) to the mixture of PM and ozone compared to either PM or ozone alone (EPA 2006).

There also is the potential that some interactions may have an antagonistic effect on human health, resulting in the over- estimation of risk. However, it is more likely that the risk calculated in this HHRA is underestimated by not accounting for interactions of the complex mixture of chemicals in ambient air.

7 Summary and Conclusions

7.1 Summary

COPCs for ambient air were selected from data collected in three major Garfield County air studies between 2005 and 2010 by comparing the maximum detected concentration for each contaminant determined in the study to 1/10 EPA's RSL for that contaminant in residential ambient air. If an EPA RSL was not available for a contaminant it was retained as a COPC if it had a detection frequency greater than 5 percent. The following 20 COPCs for which toxicity values are available were evaluated quantitatively.

- Acetaldehyde
- Crotonaldehyde
- Formaldehyde
- 1,2,3-Trimethylbenzene
- 1,2,4-Trimethylbenzene
- 1,3,5-Trimethylbenzene
- 1,4-Dichlorobenzene
- 2-Hexanone
- Benzene
- Ethylbenzene
- 1,3-Butadiene
- m&p-Xylene
- methylcyclohexane
- n-Hexane
- n-Octane
- n-Nonane
- n-Pentane
- Chloroform
- o-Xylene
- Toluene

There are no toxicity values for the 62 COPCs listed in Table 4-2. These COPCs are primarily alkanes, alkenes, aromatic hydrocarbons, and carbonyls. They were addressed qualitatively in the HHRA.

The following COPCs were selected for surface water run-off.

- Benzene
- Ethylbenzene
- m&p-Xylene
- o-Xylene
- Toluene

Three exposure scenarios were evaluated:

(1) A long-term (30-year) chronic exposure scenario for all Battlement Mesa residents
(2) A long-term (30-year) chronic exposure scenario for Battlement Mesa residents living adjacent to a well pad.
(3) An acute (7-day) exposure scenario for Battlement Mesa child residents living adjacent to a well pad

Table 7-1 summarizes the cancer risk and non-cancer HI for each of these exposure scenarios.

7.2 Conclusions

The data evaluated in this HHRA suggest that there is a potential for natural gas production operations within the Battlement Mesa PUD to negatively impact public health, particularly through acute ambient air exposures during well completion activities, for the following reasons:

- The estimated HI of 40 for acute non-cancer hazard to a child resident living adjacent to a well pad is much greater than one. Benzene, the trimethylbenzenes, and n-nonane in ambient air are the primary contributors to this HI. The surface water exposure pathway contribution to this HI is less than one. Potential COPCs, such as PAHs and chemicals in hydraulic fracturing, that were not measured, ozone, $PM_{2.5,}$ PM_{10}, and COPCs without toxicity values could have significant contributions to the acute non-cancer hazard. These potential unmeasured contributions could increase the acute non-cancer hazard via inhalation for Battlement Mesa child residents living adjacent to well pads. This acute non-cancer hazard also applies to adult residents living adjacent to well pads.
- The estimated cancer risk of 83 cancers per one million people (8.3E-05) for Battlement Mesa residents living adjacent to a well pad, while within EPA's acceptable range of 1 to 100 cancers per million people, exceeds EPA's goal of less than 1 in a million and is near the high end of the acceptable range. It also exceeds the baseline cancer risk of 1 per million. This cancer risk translates to a population attributable risk (PAR) of less than 1 cancer in a population of 5,041 residents. The estimated HI of 2 for non-cancer hazards exceeds one, above which health effects may occur. The qualitative evaluation of the COPCs without toxicity values concluded the cancer risk and non-cancer hazard may be significant underestimates. In addition potential COPCs, such as PAHs and chemicals in hydraulic fracturing, that were not measured, could have contributions to the cancer risk and non-cancer hazard. These potential unmeasured contributions could increase the cancer risk or non-cancer hazard for Battlement Mesa residents living adjacent to well pads.
- The estimated cancer risk of 71 cancers per one million people (7.1 E-05) for all Battlement Mesa residents, while within EPA's acceptable range of 1 to 100

cancers per million people exceeds EPA's goal of less than 1 in a million and is near the high end of the acceptable range. This cancer risk translates to a PAR of less than 1 cancer in a population of 5,041 residents. The estimated HI of 0.6 for non-cancer hazards is less than one, below which health effects are not expected to occur. The qualitative evaluation of the COPCs without toxicity values concluded the cancer risk and non-cancer hazard are underestimates. In addition potential COPCs, such as PAHs and chemicals in hydraulic fracturing, that were not measured contribute to the cancer risk and non-cancer hazard. These potential unmeasured contributions could increase the cancer risk or non-cancer hazard for Battlement Mesa residents.

8 Key Data Gaps

To address the uncertainties in this HHRA, the following data is needed.

- Baseline air data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and chemicals associated with well installation collected within the Battlement Mesa PUD.
- 24-hour air monitoring data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and chemicals associated with well installation collected at 500 foot set backs from well heads at all stages of well installation and completion
- Short-term acute air monitoring data for SNMOCs, carbonyls, PAHs, $PM_{2.5}$, and chemicals associated with well installation collected at 500 foot set backs from well heads at all stages of well completion and when odors are observed.
- 24-hour air monitoring data for SNMOCs, carbonyls, PAHs, ozone, $PM_{2.5}$, and chemicals associated with well installation collected at a centralized monitoring station within Battlement Mesa.
- Direct measurements of air concentrations for toxics in the breathing zone.
- Toxicity values for 62 air toxics.
- Baseline surface soil data for PAHs.

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Table 2-1
Comparison of MRLs for 2005 - 2007 Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	EPA RSL[1] (µg/m3)	EPA RSL greater than Maximum MRL?	EPA RSL greater than minimum MRL?
1,1,2,2-Tetrachloroethane	**0**	**1.50E+00**	**2.20E+00**	**4.20E-02**	**no**	**no**
1,1,2-Trichloroethane	**0**	**1.50E+00**	**2.20E+00**	**1.50E-01**	**no**	**no**
1,1-Dichloroethane	**0**	**1.50E+00**	**2.20E+00**	**1.50E+00**	**no**	**no**
1,2-Dibromoethane	0	1.50E+00	2.20E+00	4.10E-03	no	yes
1,2-Dichloroethane	**0**	**1.50E+00**	**2.20E+00**	**9.40E-02**	**no**	**no**
1,2-Dichloropropane	**0**	**1.50E+00**	**2.20E+00**	**2.40E-01**	**no**	**no**
1,4-Dichlorobenzene	**3**	**1.50E+00**	**2.20E+00**	**2.20E-01**	**no**	**no**
Bromodichloromethane	**0**	**1.50E+00**	**2.20E+00**	**6.60E-02**	**no**	**no**
Bromoform	0	1.50E+00	2.20E+00	2.20E+00	yes	yes
Carbon Tetrachloride	**0**	**1.50E+00**	**2.20E+00**	**4.10E-01**	**no**	**no**
Chloroform	**0**	**1.50E+00**	**2.20E+00**	**1.10E-01**	**no**	**no**
cis-1,3-Dichloropropene	**0**	**1.50E+00**	**2.20E+00**	**6.10E-01**	**no**	**no**
Dibromochloromethane	**0**	**1.50E+00**	**2.20E+00**	**9.00E-02**	**no**	**no**
Tetrachloroethene	**0**	**1.50E+00**	**2.20E+00**	**4.10E-01**	**no**	**no**
trans-1,3-Dichloropropene	**0**	**1.50E+00**	**2.20E+00**	**6.10E-01**	**no**	**no**
Trichloroethene	**0**	**1.50E+00**	**2.20E+00**	**1.20E+00**	**no**	**no**
Vinyl Chloride	**0**	**1.50E+00**	**2.20E+00**	**1.60E-01**	**no**	**no**
1,1,1-Trichloroethane	0	1.50E+00	2.20E+00	5.20E+03	yes	yes
1,1-Dichloroethene	0	1.50E+00	2.20E+00	2.10E+02	yes	yes
1,2-Dichlorobenzene	0	1.50E+00	2.20E+00	2.10E+02	yes	yes
1,3-Dichlorobenzene	0	1.50E+00	2.20E+00	NA	yes	yes
2-Hexanone	3	1.50E+00	2.20E+00	3.10E+01	yes	yes
4-Methyl-2-pentanone	0	1.50E+00	2.20E+00	3.10E+03	yes	yes
Bromomethane	0	1.50E+00	2.20E+00	5.20E+00	yes	yes
Carbon Disulfide	0	1.50E+00	2.20E+00	7.30E+02	yes	yes
Chlorobenzene	0	1.50E+00	2.20E+00	5.20E+01	yes	yes
Chloroethane	0	1.50E+00	2.20E+00	1.00E+04	yes	yes
Chloromethane	0	1.50E+00	2.20E+00	9.40E+01	yes	yes
cis-1,2-Dichloroethene	0	1.50E+00	2.20E+00	NA	-	-
Methyl tert-Butyl Ether	0	1.50E+00	2.20E+00	9.40E+00	yes	yes
Methylene chloride	3	1.50E+00	2.20E+00	5.20E+00	yes	yes
Styrene	0	1.50E+00	2.20E+00	1.00E+03	yes	yes
trans-1,2-Dichloroethene	0	1.50E+00	2.20E+00	6.30E+01	yes	yes
Trichlorofluoromethane	0	1.50E+00	2.20E+00	7.30E+02	yes	yes
Trichlorotrifluoroethane	0	1.50E+00	2.20E+00	3.10E+04	yes	yes

Notes:

Bold text indicates the EPA RSL is lower than the MRL. The MRL is not adequate for a HHRA.

[1]EPA Regional Screening values for residential ambient air May 2010. Based on exposure of 24 hours per day for 350 days per year for 30 years: http://www.epa.gov/region9/superfund/prg/index.html

RSL = regional screening values: Health effects are not expected to occur at or below this level.

MRL = method reporting limit: Results less than this level were reported as not detected.

NA = not available

µg/m^3 = micrograms per cubic meter

% = percent

Table 2-2
Comparison of MRLs from 2008 to 2010 Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	Minimum MRL (μg/m^3)	Maximum MRL (μg/m3)	EPA RSL[1] (μg/m3)	EPA RSL greater than Maximum MRL?	EPA RSL greater than minimum MRL?
1-Decene	0	1.15E-01	1.43E-01	NA	-	-
2,5-Dimethylbenzaldehyde	0	2.20E-03	1.10E-02	NA	-	-
2-Ethyl-1-butene	1	1.49E-01	2.47E-01	NA	-	-
Propyne	1	9.83E-02	1.09E-01	NA	-	-
trans-2-Hexene	1	1.49E-01	2.47E-01	NA	-	-
2-Methyl-1-pentene	2	1.49E-01	2.47E-01	NA	-	-

[1]EPA Regional Screening values for residential ambient air May 2010. Based on exposure of
24 hours per day for 350 days per year for 30 years: http://www.epa.gov/region9/superfund/prg/index.html
RSL = regional screening values: Health effects are not expected to occur at or below this level.
MRL = method reporting limit: Results less than this level were reported as not detected.
NA = not available
μg/m^3 = micrograms per cubic meter
% = percent

Table 2-3
Comparison of MRLs for 2010 Groundwater Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	MRL (µg/L)	EPA RSL[1] (µg/L)	EPA RSL greater than MRL?
1,1,1,2-Tetrachloroethane	0	5.00E-01	5.10E-01	yes
1,1,1-Trichloroethane	0	5.00E-01	9.10E+03	yes
1,1,2,2-Tetrachloroethane	**0**	**5.00E-01**	**6.70E-02**	**no**
1,1,2-Trichloroethane	**0**	**5.00E-01**	**2.40E-01**	**no**
1,1-Dichloroethane	0	5.00E-01	2.40E+00	yes
1,1-Dichloroethylene	0	5.00E-01	3.40E+02	yes
1,1-Dichloropropylene	0	5.00E-01	NA	-
1,2,3-Trichlorobenzene	0	5.00E-01	2.90E+01	yes
1,2,3-Trichloropropane	**0**	**5.00E-01**	**7.20E-04**	**no**
1,2,4-Trichlorobenzene	0	5.00E-01	2.30E+00	yes
1,2,4-Trimethylbenzene	0	5.00E-01	1.50E+01	yes
1,2-Dibromo-3-chloropropane	**0**	**2.00E-02**	**3.40E-04**	**no**
1,2-Dibromoethane	**0**	**1.00E-02**	**6.50E-03**	**no**
1,2-Dichlorobenzene	0	5.00E-01	3.70E+02	yes
1,2-Dichloroethane	**0**	**5.00E-01**	**1.50E-01**	**no**
1,2-Dichloropropane	**0**	**5.00E-01**	**3.90E-01**	**no**
1,3,5-Trimethylbenzene	0	5.00E-01	3.70E+02	yes
1,3-Dichlorobenzene	0	5.00E-01	NA	-
1,3-Dichloropropane	0	5.00E-01	7.30E+02	yes
1,3-Dichloropropene	**0**	**5.00E-01**	**4.30E-01**	**no**
1,4-Dichlorobenzene	**0**	**5.00E-01**	**4.30E-01**	**no**
2,2-Dichloropropane	0	5.00E-01	NA	-
2,4,5-TP	0	2.00E-01	2.00E+01	yes
2,4-D	0	1.00E-01	3.70E+02	yes
3-Hydroxycarbofuran	0	5.00E-01	NA	-
Aldrin	**0**	**1.00E-02**	**4.00E-03**	**no**
Alicarb	0	5.00E-01	3.70E+01	yes
Alicarb Sulfone	0	5.00E-01	3.70E+01	yes
Alicarb Sulfoxide	0	5.00E-01	NA	-
alpha-Chlordane	0	1.00E-02	1.90E-01	yes
Arochlor 1016	0	8.00E-02	9.60E-01	yes
Arochlor 1221	**0**	**1.00E-01**	**6.80E-03**	**no**
Arochlor 1232	**0**	**1.00E-01**	**6.80E-03**	**no**
Arochlor 1242	**0**	**1.00E-01**	**3.40E-02**	**no**
Arochlor 1248	**0**	**1.00E-01**	**3.40E-02**	**no**
Arochlor 1254	**0**	**1.00E-01**	**3.40E-02**	**no**
Arochlor 1260	**0**	**1.00E-01**	**3.40E-02**	**no**
Benzene	**0**	**5.00E-01**	**4.10E-01**	**no**
Bromobenzene	0	5.00E-01	8.80E+01	yes
Bromochloromethane	0	5.00E-01	NA	-
Bromodichloromethane	**0**	**5.00E-01**	**1.20E-01**	**no**
Bromoform	0	5.00E-01	8.50E+00	yes
Bromomethane	0	5.00E-01	8.70E+00	yes
Carbaryl	0	5.00E-01	3.70E+03	yes
Carbofuran	0	5.00E-01	1.80E+02	yes

Table 2-3
Comparison of MRLs for 2010 Groundwater Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	MRL (µg/L)	EPA RSL[1] (µg/L)	EPA RSL greater than MRL?
Carbon Tetrachloride	0	5.00E-01	4.40E+01	yes
Chlordane	**0**	**2.00E-01**	**1.90E-01**	**no**
Chlorobenzene	0	5.00E-01	9.10E+01	yes
Chloroethane	0	5.00E-01	2.10E+04	yes
Chloroform	**0**	**5.00E-01**	**1.90E-01**	**no**
Chloromethane	0	5.00E-01	1.90E+02	yes
cis-1,2-dichloroethene	0	5.00E-01	3.70E+02	yes
cis-1,3-dichloropropene	**0**	**5.00E-01**	**4.30E-01**	**no**
Dalapon	0	1.00E+00	1.10E+03	yes
Dibromochloromethane	**0**	**5.00E-01**	**1.50E-01**	**no**
Dibromomethane	0	5.00E-01	8.20E+00	yes
Dicamba	0	3.00E-01	1.10E+03	yes
Dichlorodifluoromethane	0	5.00E-01	3.90E+02	yes
Dieldrin	**0**	**1.00E-02**	**4.20E-03**	**no**
Dinoseb	0	2.00E-01	3.70E+01	yes
Endothall	0	1.80E+00	7.30E+02	yes
Endrin	0	1.00E-02	1.10E+01	yes
Ethylbenzene	0	5.00E-01	1.50E+00	yes
gamma-BHC (Lindane)	0	1.00E-02	6.10E-02	yes
gamma-Chlordane	0	1.00E-02	1.90E-01	yes
Heptachlor	0	1.00E-02	1.50E-02	yes
Heptachlor Epoxide	**0**	**1.00E-02**	**7.43E-03**	**no**
Hexachlorobenzene	0	2.00E-02	4.20E-02	yes
Hexachlorobutadiene	0	5.00E-01	8.60E-01	yes
Hexachlorocyclopentadiene	0	5.00E-02	2.20E+02	yes
Isopropylbenzene	0	5.00E-01	6.80E+02	yes
m,p-Xylene	0	5.00E-01	1.20E+03	yes
Methiocarb	0	5.00E-01	NA	-
Methiomyl	0	5.00E-01	9.10E+02	yes
Methoxychlor	0	5.00E-02	1.80E+02	yes
Methylene chloride	0	5.00E-01	4.80E+00	yes
Naphthalene	**0**	**5.00E-01**	**1.40E-01**	**no**
n-Butylbenzene	0	5.00E-01	NA	-
n-propylbenzene	0	5.00E-01	1.30E+03	yes
o-Chlorotoluene	0	5.00E-01	7.30E+02	yes
Oxamyl	0	5.00E-01	9.10E+01	yes
o-Xylene	0	5.00E-01	1.20E+03	yes
p-Chlorotoluene	0	5.00E-01	2.60E+03	yes
Pentachlorophenol	0	4.00E-02	5.60E-01	yes
Picloram	0	1.00E-01	2.60E+03	yes
p-Isopropyltoluene	0	5.00E-01	NA	-
Propoxur	0	5.00E-01	1.50E+02	yes
sec-Butylbenzene	0	5.00E-01	NA	-
Styrene	0	5.00E-01	1.60E+03	yes
tert-Butylbenzene	0	5.00E-01	NA	-

Table 2-3
Comparison of MRLs for 2010 Groundwater Data to EPA RSLs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Detection frequency (%)	MRL (µg/L)	EPA RSL[1] (µg/L)	EPA RSL greater than MRL?
Tetrachloroethene	**0**	**5.00E-01**	**1.10E-01**	**no**
Toluene	0	5.00E-01	2.30E+03	yes
Toxaphene	**0**	**5.00E-01**	**6.10E-02**	**no**
trans-1,2-dichloroethene	0	5.00E-01	1.10E+02	yes
trans-1,3-dichloropropene	**0**	**5.00E-01**	**4.30E-01**	**no**
Trichloroethene	0	5.00E-01	2.00E+00	yes
Trichlorofluoromethane	0	5.00E-01	1.30E+03	yes
Vinyl chloride	**0**	**5.00E-01**	**1.60E-02**	**no**

Notes:

Bold text indicates the EPA RSL is lower than the MRL. The MRL is not adequate for a HHRA.

[1]EPA Regional Screening values for residential tapwater May 2010.

RSL = regional screening values: Health effects are not expected to occur at or below this level.

MRL = method reporting limit: Results less than this level were reported as not detected.

NA = not available

µg/L = micrograms per liter

% = percent

Table 2-4

Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]

2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
1,1,1-Trichloroethane	71-55-6	29	0	0	no	-	-	-	-	-	no
1,1,2,2-Tetrachloroethane	79-34-5	29	0	0	no	-	-	-	-	-	no
1,1,2-Trichloroethane	79-00-5	29	0	0	no	-	-	-	-	-	no
1,1-Dichloroethane	75-34-3	29	0	0	no	-	-	-	-	-	no
1,1-Dichloroethene	75-35-4	29	0	0	no	-	-	-	-	-	no
1,2,3-Trimethylbenzene	**526-73-8**	**128**	**44**	**34**	**yes**	**8.47E-01**	**NA**	**NA**	**-**	**8.10E-02**	**yes**
1,2,4-Trimethylbenzene	**95-63-6**	**128**	**121**	**95**	**yes**	**3.09E+00**	**7.30E+00**	**7.30E-01**	**yes**	**2.75E-01**	**yes**
1,2-Dibromoethane	106-93-4	29	0	0	no	-	-	-	-	-	no
1,2-Dichlorobenzene	95-50-1	29	0	0	no	-	-	-	-	-	no
1,2-Dichloroethane	107-06-2	29	0	0	no	-	-	-	-	-	no
1,2-Dichloropropane	78-87-5	29	0	0	no	-	-	-	-	-	no
1,3,5-Trimethylbenzene	**108-67-8**	**128**	**101**	**79**	**yes**	**1.20E+00**	**NA**	**NA**	**-**	**1.51E-01**	**yes**
1,3-Butadiene	**106-99-0**	**128**	**9**	**7**	**yes**	**1.53E-01**	**8.10E-02**	**8.10E-03**	**yes**	**5.58E-02**	**yes**
1,3-Dichlorobenzene	541-73-1	29	0	0	no	-	-	-	-	-	no
1,4-Dichlorobenzene	**106-46-7**	**29**	**1**	**3**	**no**	**2.30E+00**	**2.20E-01**	**2.20E-02**	**yes**	**9.36E-01**	**yes**
1-Decene	872-05-9	128	0	0	no	-	-	-	-	-	no
1-Dodecene	**112-41-4**	**128**	**32**	**25**	**yes**	**1.02E+00**	**NA**	**NA**	**-**	**1.44E-01**	**yes**
1-Heptene	**592-76-7**	**128**	**123**	**96**	**yes**	**2.98E+00**	**NA**	**NA**	**-**	**6.30E-01**	**yes**
1-Hexene	**592-41-6**	**128**	**69**	**54**	**yes**	**2.77E-01**	**NA**	**NA**	**-**	**9.55E-02**	**yes**
1-Nonene	**124-11-8**	**128**	**59**	**46**	**yes**	**4.28E-01**	**NA**	**NA**	**-**	**1.07E-01**	**yes**
1-Octene	**111-66-0**	**128**	**24**	**19**	**yes**	**1.37E+00**	**NA**	**NA**	**-**	**1.06E-01**	**yes**
1-Pentene	**109-67-1**	**128**	**124**	**97**	**yes**	**3.80E-01**	**NA**	**NA**	**-**	**1.04E-01**	**yes**
1-Tridecene	**2437-56-1**	**128**	**12**	**9**	**yes**	**2.04E-01**	**NA**	**NA**	**-**	**1.06E-01**	**yes**
1-Undecene	**821-95-4**	**128**	**35**	**27**	**yes**	**1.07E+00**	**NA**	**NA**	**-**	**1.21E-01**	**yes**
2,2,3-Trimethylpentane	**564-02-3**	**128**	**58**	**45**	**yes**	**1.64E+00**	**NA**	**NA**	**-**	**1.49E-01**	**yes**
2,2,4-Trimethylpentane	**540-84-1**	**128**	**58**	**45**	**yes**	**2.48E+00**	**NA**	**NA**	**-**	**1.52E-01**	**yes**
2,2-Dimethylbutane	**75-83-2**	**128**	**128**	**100**	**yes**	**2.34E+00**	**NA**	**NA**	**-**	**6.15E-01**	**yes**
2,3,4-Trimethylpentane	**565-75-3**	**128**	**74**	**58**	**yes**	**1.79E+00**	**NA**	**NA**	**-**	**9.21E-02**	**yes**
2,3-Dimethylbutane	**79-29-8**	**128**	**128**	**100**	**yes**	**5.05E+00**	**NA**	**NA**	**-**	**1.22E+00**	**yes**
2,3-Dimethylpentane	**565-59-3**	**128**	**128**	**100**	**yes**	**2.08E+00**	**NA**	**NA**	**-**	**5.26E-01**	**yes**

Table 2-4
Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]
2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (μg/m³)	EPA RSL[1] (μg/m³)	1/10 EPA RSL (μg/m³)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (μg/m³)	COPC?
2,4-Dimethylpentane	**108-08-7**	**128**	**127**	**99**	**yes**	**1.48E+00**	**NA**	**NA**	**-**	**3.69E-01**	**yes**
2,5-Dimethylbenzaldehyde	5779-94-2	128	0	0	no	-	-	-	-	-	no
2-Butanone (MEK)	78-93-3	29	16	55	yes	9.80E+00	5.20E+03	5.20E+02	no	2.62E+00	no
2-Ethyl-1-butene	760-21-4	128	1	1	no	2.75E+00	NA	NA	-	1.19E-01	no
2-Hexanone	**591-78-6**	**29**	**1**	**3**	**no**	**4.40E+00**	**3.10E+01**	**3.10E+00**	**yes**	**1.00E+00**	**yes**
2-Methyl-1-butene	**563-46-2**	**128**	**44**	**34**	**yes**	**3.94E+01**	**NA**	**NA**	**-**	**5.98E-01**	**yes**
2-Methyl-1-pentene	763-29-1	128	2	2	no	1.52E-01	NA	NA	-	9.82E-02	no
2-Methyl-2-butene	**513-35-9**	**128**	**51**	**40**	**yes**	**4.17E-01**	**NA**	**NA**	**-**	**8.95E-02**	**yes**
2-Methylheptane	**592-27-8**	**128**	**128**	**100**	**yes**	**2.93E+00**	**NA**	**NA**	**-**	**6.28E-01**	**yes**
2-Methylhexane	**591-76-4**	**128**	**126**	**98**	**yes**	**5.71E+00**	**NA**	**NA**	**-**	**1.39E+00**	**yes**
2-Methylpentane	**107-83-5**	**128**	**128**	**100**	**yes**	**2.20E+01**	**NA**	**NA**	**-**	**5.39E+00**	**yes**
3-Methyl-1-butene	**563-45-1**	**128**	**9**	**7**	**yes**	**2.00E-01**	**NA**	**NA**	**-**	**6.16E-02**	**yes**
3-Methylheptane	**589-81-1**	**128**	**128**	**100**	**yes**	**3.53E+00**	**NA**	**NA**	**-**	**4.17E-01**	**yes**
3-Methylhexane	**589-34-4**	**128**	**116**	**91**	**yes**	**4.84E+00**	**NA**	**NA**	**-**	**1.11E+00**	**yes**
3-Methylpentane	**96-14-0**	**128**	**128**	**100**	**yes**	**1.16E+01**	**NA**	**NA**	**-**	**2.80E+00**	**yes**
4-Methyl-1-pentene	**691-37-2**	**128**	**13**	**10**	**yes**	**4.68E+00**	**NA**	**NA**	**-**	**1.41E-01**	**yes**
4-Methyl-2-pentanone	108-10-1	29	0	0	no	-	-	-	-	-	no
Acetaldehyde	**75-07-0**	**128**	**128**	**100**	**yes**	**1.96E+00**	**1.10E+00**	**1.10E-01**	**yes**	**7.98E-01**	**yes**
Acetone	67-64-1	128	124	97	yes	5.70E+01	3.20E+04	3.20E+03	no	6.88E+00	no
Acetylene	**74-86-2**	**128**	**128**	**100**	**yes**	**2.92E+00**	**NA**	**NA**	**-**	**6.30E-01**	**yes**
a-Pinene	**80-56-8**	**128**	**75**	**59**	**yes**	**3.37E+00**	**NA**	**NA**	**-**	**1.74E-01**	**yes**
Benzaldehyde	**100-52-7**	**128**	**125**	**98**	**yes**	**2.04E-01**	**NA**	**NA**	**-**	**7.10E-02**	**yes**
Benzene	**71-43-2**	**128**	**112**	**88**	**yes**	**1.36E+01**	**3.10E-01**	**3.10E-02**	**yes**	**1.47E+00**	**yes**
b-Pinene	**127-91-3**	**128**	**10**	**8**	**yes**	**1.43E+00**	**NA**	**NA**	**-**	**8.08E-02**	**yes**
Bromodichloromethane	75-27-4	29	0	0	no	-	-	-	-	-	no
Bromoform	75-25-2	29	0	0	no	-	-	-	-	-	no
Bromomethane	74-83-9	29	0	0	no	-	-	-	-	-	no
Butyraldehyde	**123-72-8**	**128**	**126**	**98**	**yes**	**2.71E-01**	**NA**	**NA**	**-**	**6.98E-02**	**yes**
Carbon Disulfide	75-15-0	29	0	0	no	-	-	-	-	-	no
Carbon Tetrachloride	56-23-5	29	0	0	no	-	-	-	-	-	no

Table 2-4
Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]
2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
Chlorobenzene	108-90-7	29	0	0	no	-	-	-	-	-	no
Chloroethane	75-00-3	29	0	0	no	-	-	-	-	-	no
Chloroform	67-66-3	29	0	0	no	-	-	-	-	-	no
Chloromethane	74-87-3	29	0	0	no	-	-	-	-	-	no
cis-1,2-Dichloroethene	156-59-2	29	0	0	no	-	-	-	-	-	no
cis-1,3-Dichloropropene	10061-01-5	29	0	0	no	-	-	-	-	-	no
cis-2-Butene	**590-18-1**	**128**	**63**	**49**	**yes**	**3.73E-01**	**NA**	**NA**	**-**	**6.79E-02**	**yes**
cis-2-Hexene	**7688-21-3**	**128**	**21**	**16**	**yes**	**7.00E-01**	**NA**	**NA**	**-**	**9.97E-02**	**yes**
cis-2-Pentene	**627-20-3**	**128**	**34**	**27**	**yes**	**1.45E-01**	**NA**	**NA**	**-**	**5.37E-02**	**yes**
Crotonaldehyde	**123-73-9**	**128**	**128**	**100**	**yes**	**5.53E-01**	**NA**	**NA**	**-**	**1.26E-01**	**yes**
Cyclohexane	110-82-7	128	128	100	yes	1.05E+02	6.30E+03	6.30E+02	no	3.85E+00	no
Cyclopentane	**287-92-3**	**128**	**128**	**100**	**yes**	**2.94E+00**	**NA**	**NA**	**-**	**7.28E-01**	**yes**
Cyclopentene	**142-29-0**	**128**	**67**	**52**	**yes**	**9.58E-01**	**NA**	**NA**	**-**	**1.34E-01**	**yes**
Dibromochloromethane	124-48-1	29	0	0	no	-	-	-	-	-	no
Ethane	**74-84-0**	**128**	**128**	**100**	**yes**	**4.11E+02**	**NA**	**NA**	**-**	**8.00E+01**	**yes**
Ethylbenzene	**100-41-4**	**128**	**92**	**72**	**yes**	**4.34E+00**	**9.70E-01**	**9.70E-02**	**yes**	**3.78E-01**	**yes**
Ethylene	**74-85-1**	**128**	**128**	**100**	**yes**	**2.94E+00**	**NA**	**NA**	**-**	**1.00E+00**	**yes**
Formaldehyde	**50-00-0**	**128**	**128**	**100**	**yes**	**1.02E+01**	**1.90E-01**	**1.90E-02**	**yes**	**1.17E+00**	**yes**
Hexaldehyde	**66-25-1**	**128**	**113**	**88**	**yes**	**1.31E-01**	**NA**	**NA**	**-**	**4.21E-02**	**yes**
Isobutane	**75-28-5**	**128**	**128**	**100**	**yes**	**1.18E+02**	**NA**	**NA**	**-**	**2.34E+01**	**yes**
Isobutene/1-Butene	**-11-7 / 106-9**	**128**	**84**	**66**	**yes**	**1.36E+01**	**NA**	**NA**	**-**	**1.29E+00**	**yes**
Isopentane	**78-78-4**	**128**	**123**	**96**	**yes**	**1.23E+02**	**NA**	**NA**	**-**	**1.97E+01**	**yes**
Isoprene	**78-79-5**	**128**	**82**	**64**	**yes**	**3.33E+00**	**NA**	**NA**	**-**	**3.13E-01**	**yes**
Isopropylbenzene (cumene)	98-82-8	128	34	27	yes	3.27E-01	4.20E+02	4.20E+01	no	7.80E-02	no
Isovaleraldehyde	**590-86-3**	**128**	**71**	**55**	**yes**	**1.13E-01**	**NA**	**NA**	**-**	**5.69E-03**	**yes**
m-Diethylbenzene	**141-93-5**	**128**	**44**	**34**	**yes**	**8.84E-01**	**NA**	**NA**	**-**	**9.25E-02**	**yes**
Methyl tert-Butyl Ether	1634-04-4	29	0	0	no	-	-	-	-	-	no
Methylcyclohexane	**108-87-2**	**128**	**128**	**100**	**yes**	**2.39E+01**	**NA**	**NA**	**-**	**5.38E+00**	**yes**
Methylcyclopentane	**96-37-7**	**128**	**128**	**100**	**yes**	**1.04E+01**	**NA**	**NA**	**-**	**2.60E+00**	**yes**
Methylene chloride	**75-09-2**	**29**	**1**	**3**	**no**	**2.90E+00**	**5.20E+00**	**5.20E-01**	**yes**	**9.59E-01**	**yes**

Table 2-4

Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]

2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration ($\mu g/m^3$)	EPA RSL[1] ($\mu g/m^3$)	1/10 EPA RSL ($\mu g/m^3$)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration ($\mu g/m^3$)	COPC?
m-Ethyltoluene	**620-14-4**	**128**	**122**	**95**	**yes**	**1.63E+00**	**NA**	**NA**	**-**	**1.87E-01**	**yes**
m-Xylene/p-Xylene	-38-3 / 106-4	128	119	93	yes	1.40E+01	7.30E+02	7.30E+01	no	1.69E+00	no
n-Butane	**106-97-8**	**128**	**128**	**100**	**yes**	**1.57E+02**	**NA**	**NA**	**-**	**2.79E+01**	**yes**
n-Decane	**124-18-5**	**128**	**126**	**98**	**yes**	**6.98E+01**	**NA**	**NA**	**-**	**1.11E+00**	**yes**
n-Dodecane	**112-40-3**	**128**	**107**	**84**	**yes**	**7.14E+01**	**NA**	**NA**	**-**	**1.24E+00**	**yes**
n-Heptane	**142-82-5**	**128**	**128**	**100**	**yes**	**1.14E+01**	**NA**	**NA**	**-**	**2.55E+00**	**yes**
n-Hexane	110-54-3	128	128	100	yes	2.50E+01	7.30E+02	7.30E+01	no	5.89E+00	no
n-Nonane	111-84-2	128	127	99	yes	3.08E+00	2.10E+02	2.10E+01	no	6.36E-01	no
n-Octane	**111-65-9**	**128**	**128**	**100**	**yes**	**6.72E+00**	**NA**	**NA**	**-**	**1.45E+00**	**yes**
n-Pentane	109-66-0	128	128	100	yes	6.20E+01	1.00E+03	1.00E+02	no	1.36E+01	no
n-Propylbenzene	103-65-1	128	76	59	yes	7.10E-01	1.00E+03	1.00E+02	no	8.26E-02	no
n-Tridecane	**629-50-5**	**128**	**45**	**35**	**yes**	**5.68E+00**	**NA**	**NA**	**-**	**2.05E-01**	**yes**
n-Undecane	**1120-21-4**	**128**	**125**	**98**	**yes**	**2.55E+02**	**NA**	**NA**	**-**	**2.81E+00**	**yes**
o-Ethyltoluene	**611-14-3**	**128**	**86**	**67**	**yes**	**1.44E+00**	**NA**	**NA**	**-**	**1.31E-01**	**yes**
o-Xylene	95-47-6	128	97	76	yes	3.61E+00	7.30E+02	7.30E+01	no	4.35E-01	no
p-Diethylbenzene	**105-05-5**	**128**	**31**	**24**	**yes**	**4.20E-01**	**NA**	**NA**	**-**	**5.50E-02**	**yes**
p-Ethyltoluene	**622-96-8**	**128**	**93**	**73**	**yes**	**1.26E+00**	**NA**	**NA**	**-**	**1.33E-01**	**yes**
Propane	**74-98-6**	**128**	**128**	**100**	**yes**	**3.16E+02**	**NA**	**NA**	**-**	**6.15E+01**	**yes**
Propionaldehyde	123-38-6	60	57	95	yes	2.04E-01	8.30E+00	8.30E-01	no	8.14E-02	no
Propylene	115-07-1	128	128	100	yes	2.46E+00	3.10E+03	3.10E+02	no	3.62E-01	no
Propyne	74-99-7	128	1	1	no	3.50E-01	NA	NA	-	5.45E-02	no
Styrene	100-42-5	157	11	7	yes	3.45E+00	1.00E+03	1.00E+02	no	2.49E-01	no
Tetrachloroethene	127-18-4	29	0	0	no	-	-	-	-	-	no
Tolualdehydes	**NA**	**60**	**56**	**93**	**yes**	**2.51E-01**	**NA**	**NA**	**no**	**8.16E-02**	**yes**
Toluene	108-88-3	157	156	99	yes	7.91E+01	5.20E+03	5.20E+02	no	4.02E+00	no
trans-1,2-Dichloroethene	156-60-5	29	0	0	no	-	-	-	-	-	no
trans-1,3-Dichloropropene	10061-02-6	29	0	0	no	-	-	-	-	-	no
trans-2-Butene	**624-64-6**	**128**	**102**	**80**	**yes**	**3.34E+00**	**NA**	**NA**	**-**	**1.13E-01**	**yes**
trans-2-Hexene	4050-45-7	128	1	1	no	3.04E-02	NA	NA	-	9.83E-02	no
trans-2-Pentene	**4050-45-7**	**128**	**58**	**45**	**yes**	**3.18E-01**	**NA**	**NA**	**-**	**6.72E-02**	**yes**

Table 2-4

Summary Statistics and Selection of COPCs by Comparison to EPA RSL[1]

2005-2010 Ambient Air Data Bell-Melton Ranch Monitoring Station

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m^3)	EPA RSL[1] (µg/m^3)	1/10 EPA RSL (µg/m^3)	Maximum Detected Concentration ≥ 1/10 EPA RSL?	Mean Concentration (µg/m^3)	COPC?
Trichloroethene	79-01-6	29	0	0	no	-	-	-	-	-	no
Trichlorofluoromethane	75-69-4	29	0	0	no	-	-	-	-	-	no
Trichlorotrifluoroethane	76-13-1	29	0	0	no	-	-	-	-	-	no
Valeraldehyde	**110-62-3**	**60**	**32**	**53**	**yes**	**8.10E-02**	**NA**	**NA**	**-**	**2.25E-02**	**yes**
Vinyl Acetate	108-05-4	29	5	17	yes	1.30E+01	2.10E+02	2.10E+01	no	1.85E+00	no
Vinyl Chloride	75-01-4	29	0	0	no	-	-	-	-	-	no

Notes:

Bold text indicates contaminant selected as a COPC.

µg/m^3: micrograms per cubic meter

CAS: Chemical Abstract Service

COPC: Contaminant of potential concern

EPA: United States Environmental Protection Agency

NA: Not Available

[1]RSL = EPA regional screening levels for ambient air based on exposure of 24 hours per day for 350 days per year for 30 years :
Health effects are not expected to occur at or below the RSL. To select COPCs, maximum detected concentration was compared to 1/10 the RSL to account for additive health effects from multiple chemicals. : http://www.epa.gov/region9/superfund/prg/index.html, May 2010

Table 2-5
Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Summer 2008 Ambient Air Data Well Completion Operations
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (µg/m³)	Mean Concentration (µg/m³)	EPA RSL (µg/m³)	1/10 EPA RSL (µg/m³)	Maximum Concentration > 1/10 EPA RSL?	COPC?
1,2,3-Trimethylbenzene	**526-73-8**	**16**	**16**	**100**	**yes**	**1.17E+01**	**1.32E+00**	**NA**	**-**	**-**	**yes**
1,2,4-Trimethylbenzene	**95-63-6**	**16**	**16**	**100**	**yes**	**8.30E+01**	**7.66E+00**	**7.30E+00**	**7.30E-01**	**yes**	**yes**
1,3,5-Trimethylbenzene	**108-67-8**	**16**	**16**	**100**	**yes**	**7.75E+01**	**6.77E+00**	**NA**	**-**	**-**	**yes**
1,3-Butadiene	**106-99-0**	**16**	**7**	**44**	**yes**	**1.66E-01**	**1.02E-01**	**8.10E-02**	**8.10E-03**	**yes**	**yes**
1-Decene	872-05-9	16	0	0	no	-	-	-	-	-	no
1-Dodecene	**112-41-4**	**16**	**12**	**75**	**yes**	**6.08E+00**	**9.54E-01**	**NA**	**-**	**-**	**yes**
1-Heptene	**592-76-7**	**16**	**16**	**100**	**yes**	**6.08E+01**	**7.23E+00**	**NA**	**-**	**-**	**yes**
1-Hexene	**592-41-6**	**16**	**16**	**100**	**yes**	**1.63E-01**	**8.23E-02**	**NA**	**-**	**-**	**yes**
1-Nonene	**124-11-8**	**16**	**15**	**94**	**yes**	**1.68E+01**	**1.56E+00**	**NA**	**-**	**-**	**yes**
1-Octene	**111-66-0**	**16**	**11**	**69**	**yes**	**3.16E+00**	**3.94E-01**	**NA**	**-**	**-**	**yes**
1-Pentene	**109-67-1**	**16**	**16**	**100**	**yes**	**3.89E-01**	**1.31E-01**	**NA**	**-**	**-**	**yes**
1-Tridecene	**2437-56-1**	**16**	**6**	**38**	**yes**	**3.63E-01**	**2.05E-01**	**NA**	**-**	**-**	**yes**
1-Undecene	**821-95-4**	**16**	**11**	**69**	**yes**	**4.72E+00**	**5.25E-01**	**NA**	**-**	**-**	**yes**
2,2,3-Trimethylpentane	**564-02-3**	**16**	**16**	**100**	**yes**	**2.47E+01**	**2.62E+00**	**NA**	**-**	**-**	**yes**
2,2,4-Trimethylpentane	**540-84-1**	**16**	**1**	**6**	**yes**	**1.98E-01**	**1.33E-01**	**NA**	**-**	**-**	**yes**
2,2-Dimethylbutane	**75-83-2**	**16**	**16**	**100**	**yes**	**4.12E+01**	**4.73E+00**	**NA**	**-**	**-**	**yes**
2,3,4-Trimethylpentane	**565-75-3**	**16**	**16**	**100**	**yes**	**1.21E+00**	**2.17E-01**	**NA**	**-**	**-**	**yes**
2,3-Dimethylbutane	**79-29-8**	**16**	**16**	**100**	**yes**	**6.58E+01**	**8.49E+00**	**NA**	**-**	**-**	**yes**
2,3-Dimethylpentane	**565-59-3**	**16**	**16**	**100**	**yes**	**3.56E+01**	**4.46E+00**	**NA**	**-**	**-**	**yes**
2,4-Dimethylpentane	**108-08-7**	**16**	**16**	**100**	**yes**	**2.36E+01**	**2.92E+00**	**NA**	**-**	**-**	**yes**
2-Ethyl-1-butene	760-21-4	16	0	0	no	-	-	-	-	-	no
2-Methyl-1-butene	**563-46-2**	**16**	**9**	**56**	**yes**	**1.26E+00**	**3.28E-01**	**NA**	**-**	**-**	**yes**
2-Methyl-1-pentene	**763-29-1**	**16**	**1**	**6**	**yes**	**8.43E-02**	**2.37E-01**	**NA**	**-**	**-**	**yes**
2-Methyl-2-butene	**513-35-9**	**16**	**9**	**56**	**yes**	**3.87E-01**	**1.28E-01**	**NA**	**-**	**-**	**yes**
2-Methylheptane	**592-27-8**	**16**	**16**	**100**	**yes**	**1.46E+02**	**1.50E+01**	**NA**	**-**	**-**	**yes**
2-Methylhexane	**591-76-4**	**16**	**16**	**100**	**yes**	**1.21E+02**	**1.45E+01**	**NA**	**-**	**-**	**yes**
2-Methylpentane	**107-83-5**	**16**	**16**	**100**	**yes**	**2.21E+02**	**3.18E+01**	**NA**	**-**	**-**	**yes**
3-Methyl-1-butene	**563-45-1**	**16**	**1**	**6**	**yes**	**2.49E-01**	**1.23E-01**	**NA**	**-**	**-**	**yes**
3-Methylheptane	**589-81-1**	**16**	**16**	**100**	**yes**	**9.74E+01**	**9.73E+00**	**NA**	**-**	**-**	**yes**
3-Methylhexane	**589-34-4**	**16**	**16**	**100**	**yes**	**1.14E+02**	**1.38E+01**	**NA**	**-**	**-**	**yes**
3-Methylpentane	**96-14-0**	**16**	**16**	**100**	**yes**	**1.29E+02**	**1.80E+01**	**NA**	**-**	**-**	**yes**

Table 2-5
Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Summer 2008 Ambient Air Data Well Completion Operations
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (μg/m³)	Mean Concentration (μg/m³)	EPA RSL (μg/m³)	1/10 EPA RSL (μg/m³)	Maximum Concentration > 1/10 EPA RSL?	COPC?
4-Methyl-1-pentene	**691-37-2**	**16**	**8**	**50**	**yes**	**9.35E-01**	**3.05E-01**	**NA**	**-**	**-**	**yes**
Acetylene	**74-86-2**	**16**	**16**	**100**	**yes**	**8.40E-01**	**3.97E-01**	**NA**	**-**	**-**	**yes**
a-Pinene	**80-56-8**	**16**	**16**	**100**	**yes**	**3.09E+01**	**3.04E+00**	**NA**	**-**	**-**	**yes**
Benzene	**71-43-2**	**16**	**16**	**100**	**yes**	**6.85E+01**	**8.85E+00**	**3.10E-01**	**3.10E-02**	**yes**	**yes**
b-Pinene	**127-91-3**	**16**	**7**	**44**	**yes**	**8.96E+00**	**7.96E-01**	**NA**	**-**	**-**	**yes**
cis-2-Butene	**590-18-1**	**16**	**15**	**94**	**yes**	**1.97E-01**	**7.65E-02**	**NA**	**-**	**-**	**yes**
cis-2-Hexene	**7688-21-3**	**16**	**13**	**81**	**yes**	**2.93E-01**	**2.01E-01**	**NA**	**-**	**-**	**yes**
cis-2-Pentene	**627-20-3**	**16**	**9**	**56**	**yes**	**1.48E-01**	**8.14E-02**	**NA**	**-**	**-**	**yes**
Cyclohexane	110-82-7	16	16	100	yes	2.04E+02	2.64E+01	6.30E+03	6.30E+02	no	no
Cyclopentane	**287-92-3**	**16**	**16**	**100**	**yes**	**2.23E+01**	**3.84E+00**	**NA**	**-**	**-**	**yes**
Cyclopentene	**142-29-0**	**16**	**16**	**100**	**yes**	**6.51E-01**	**2.34E-01**	**NA**	**-**	**-**	**yes**
Ethane	**74-84-0**	**16**	**16**	**100**	**yes**	**2.41E+03**	**4.08E+02**	**NA**	**-**	**-**	**yes**
Ethylbenzene	**100-41-4**	**16**	**16**	**100**	**yes**	**2.28E+02**	**1.74E+01**	**9.70E-01**	**9.70E-02**	**yes**	**yes**
Ethylene	**74-85-1**	**16**	**16**	**100**	**yes**	**4.19E+00**	**1.17E+00**	**NA**	**-**	**-**	**yes**
Isobutane	**75-28-5**	**16**	**16**	**100**	**yes**	**1.60E+03**	**1.65E+02**	**NA**	**-**	**-**	**yes**
Isobutene/1-Butene	**NA**	**16**	**8**	**50**	**yes**	**6.71E+00**	**2.05E+00**	**NA**	**-**	**-**	**yes**
Isopentane	**78-78-4**	**16**	**16**	**100**	**yes**	**8.32E+02**	**1.14E+02**	**NA**	**-**	**-**	**yes**
Isoprene	**78-79-5**	**16**	**16**	**100**	**yes**	**1.15E+00**	**4.64E-01**	**NA**	**-**	**-**	**yes**
Isopropylbenzene (cumene)	98-82-8	16	14	88	yes	4.85E+00	5.97E-01	4.20E+02	4.20E+01	no	no
m-Diethylbenzene	**141-93-5**	**16**	**16**	**100**	**yes**	**7.08E+00**	**7.98E-01**	**NA**	**-**	**-**	**yes**
Methylcyclohexane	**108-87-2**	**16**	**16**	**100**	**yes**	**7.23E+02**	**8.00E+01**	**NA**	**-**	**-**	**yes**
Methylcyclopentane	**96-37-7**	**16**	**16**	**100**	**yes**	**1.20E+02**	**1.77E+01**	**NA**	**-**	**-**	**yes**
m-Ethyltoluene	**620-14-4**	**16**	**16**	**100**	**yes**	**4.45E+01**	**4.26E+00**	**NA**	**-**	**-**	**yes**
m&p-Xylene	**1330-20-7**	**16**	**16**	**100**	**yes**	**8.84E+02**	**9.47E+01**	**7.30E+02**	**7.30E+01**	**yes**	**yes**
n-Butane	**106-97-8**	**16**	**16**	**100**	**yes**	**1.29E+03**	**1.48E+02**	**NA**	**-**	**-**	**yes**
n-Decane	**124-18-5**	**16**	**16**	**100**	**yes**	**2.08E+02**	**1.89E+01**	**NA**	**-**	**-**	**yes**
n-Dodecane	**112-40-3**	**16**	**16**	**100**	**yes**	**5.15E+01**	**7.71E+00**	**NA**	**-**	**-**	**yes**
n-Heptane	**142-82-5**	**16**	**16**	**100**	**yes**	**3.04E+02**	**3.55E+01**	**NA**	**-**	**-**	**yes**
n-Hexane	**110-54-3**	**16**	**16**	**100**	**yes**	**2.55E+02**	**3.72E+01**	**7.30E+02**	**7.30E+01**	**yes**	**yes**
n-Nonane	**111-84-2**	**16**	**16**	**100**	**yes**	**3.03E+02**	**2.71E+01**	**2.10E+02**	**2.10E+01**	**yes**	**yes**
n-Octane	**111-65-9**	**16**	**16**	**100**	**yes**	**4.17E+02**	**4.10E+01**	**NA**	**-**	**-**	**yes**

Table 2-5

Summary Statistics and Selection of COPCs by Comparision to EPA RSLs[1] Summer 2008 Ambient Air Data Well Completion Operations

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	CAS Number	Number of samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥ 5%?	Maximum Detected Concentration (μg/m^3)	Mean Concentration (μg/m^3)	EPA RSL (μg/m^3)	1/10 EPA RSL (μg/m^3)	Maximum Concentration > 1/10 EPA RSL?	COPC?
n-Pentane	**109-66-0**	**16**	**16**	**100**	**yes**	**5.53E+02**	**1.05E+02**	**1.00E+03**	**1.00E+02**	**yes**	**yes**
n-Propylbenzene	103-65-1	16	16	100	yes	1.20E+01	1.28E+00	1.00E+03	1.00E+02	no	no
n-Tridecane	**629-50-5**	**16**	**16**	**100**	**yes**	**9.05E+00**	**1.64E+00**	**NA**	**-**	**-**	**yes**
n-Undecane	**1120-21-4**	**16**	**16**	**100**	**yes**	**1.21E+02**	**1.36E+01**	**NA**	**-**	**-**	**yes**
o-Ethyltoluene	**611-14-3**	**16**	**16**	**100**	**yes**	**2.92E+01**	**2.77E+00**	**NA**	**-**	**-**	**yes**
o-Xylene	**95-47-6**	**16**	**16**	**100**	**yes**	**1.90E+02**	**1.79E+01**	**730**	**7.30E+01**	**-**	**yes**
p-Diethylbenzene	**105-05-5**	**16**	**13**	**81**	**yes**	**5.01E+00**	**5.45E-01**	**NA**	**-**	**-**	**yes**
p-Ethyltoluene	**622-96-8**	**16**	**16**	**100**	**yes**	**3.22E+01**	**3.10E+00**	**NA**	**-**	**-**	**yes**
Propane	**74-98-6**	**16**	**16**	**100**	**yes**	**4.67E+03**	**4.37E+02**	**NA**	**-**	**-**	**yes**
Propylene	115-07-1	16	16	100	yes	1.94E+00	5.05E-01	3.10E+03	3.10E+02	no	no
Propyne	74-99-7	16	0	0	no	-	-	-	-	-	no
Styrene	100-42-5	16	3	19	yes	5.90E+00	5.57E-01	1.00E+03	1.00E+02	no	no
Toluene	108-88-3	16	16	100	yes	3.19E+02	3.63E+01	5.20E+03	5.20E+02	no	no
trans-2-Butene	**624-64-6**	**16**	**15**	**94**	**yes**	**1.89E+00**	**3.04E-01**	**NA**	**-**	**-**	**yes**
trans-2-Hexene	**4050-45-7**	**16**	**1**	**6**	**yes**	**4.53E-02**	**2.34E-01**	**NA**	**-**	**-**	**yes**
trans-2-Pentene	**646-04-8**	**16**	**14**	**88**	**yes**	**3.05E-01**	**1.07E-01**	**NA**	**-**	**-**	**yes**

Notes:

Bold text indicates contaminant selected as a COPC

μg/m^3: micrograms per cubic meter

CAS: Chemical Abstract Service

COPC: Contaminant of potential concern

EPA: United States Environmental Protection Agency

NA: Not Available

[1]RSL = EPA regional screening levels for ambient air based on exposure of 24 hours per day for 350 days per year for 30 years :
Health effects are not expected to occur at or below the RSL. To select COPCs, maximum detected concentration was compared to 1/10 the RSL to account for additive health effects from multiple chemicals. : http://www.epa.gov/region9/superfund/prg/index.html, May 2010

Table 2-6
Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1] Odor Thresholds[2]
2005-2007 Odor Events
Human Health Risk Assessment
Battlement Mesa HIA

Chemical	CAS Number	Number of Samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥5%?	Maximum Detected Concentration (µg/m^3)	Mean (µg/m3)	EPA RSL (µg/m3)	1/10 EPA RSL (µg/m3)	Maximum Concentration > 1/10 EPA RSL	COPC?	Texas Acute Odor ESL (µg/m^3)
1,1,1-Trichloroethane	71-55-6	28	0	0	no	-	-	-	-	-	no	-
1,1,2,2-Tetrachloroethane	79-34-5	28	0	0	no	-	-	-	-	-	no	-
1,1,2-Trichloroethane	79-00-5	28	0	0	no	-	-	-	-	-	no	-
1,1-Dichloroethane	75-34-3	28	0	0	no	-	-	-	-	-	no	-
1,1-Dichloroethene	75-35-4	28	0	0	no	-	-	-	-	-	no	-
1,2-Dibromoethane	106-93-4	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichlorobenzene	95-50-1	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichloroethane	107-06-2	28	0	0	no	-	-	-	-	-	no	-
1,2-Dichloropropane	78-87-5	28	0	0	no	-	-	-	-	-	no	-
1,3-Dichlorobenzene	541-73-1	28	0	0	no	-	-	-	-	-	no	-
1,4-Dichlorobenzene	106-46-7	28	0	0	no	-	-	-	-	-	no	-
2-Butanone (MEK)	78-93-3	28	20	71	yes	1.00E+01	3.19E+00	5.20E+03	5.20E+02	no	no	3.90E+03
2-Hexanone	591-78-6	28	4	14	yes	2.40E+00	1.47E+00	3.10E+01	3.10E+00	no	no	9.80E+01
4-Methyl-2-pentanone	108-10-1	28	0	0	no	-	-	-	-	-	no	-
Acetone	67-64-1	28	22	79	yes	8.10E+01	2.81E+01	3.20E+04	3.20E+03	no	no	8.50E+03
Benzene	**71-43-2**	**28**	**26**	**93**	**yes**	**1.80E+02**	**3.16E+01**	**3.10E-01**	**3.10E-02**	**yes**	**yes**	**8.60E+03**
Bromodichloromethane	75-27-4	28	0	0	no	-	-	-	-	-	no	-
Bromoform	75-25-2	28	0	0	no	-	-	-	-	-	no	-
Bromomethane	74-83-9	28	0	0	no	-	-	-	-	-	no	-
Carbon Disulfide	75-15-0	28	0	0	no	-	-	-	-	-	no	-
Carbon Tetrachloride	56-23-5	28	0	0	no	-	-	-	-	-	no	-
Chlorobenzene	108-90-7	28	0	0	no	-	-	-	-	-	no	-
Chloroethane	75-00-3	28	0	0	no	-	-	-	-	-	no	-
Chloroform	**67-66-3**	**28**	**1**	**4**	**no**	**1.60E+00**	**1.34E+00**	**1.10E-01**	**1.10E-02**	**yes**	**yes**	**4.20E+05**
Chloromethane	74-87-3	28	1	4	no	2.20E+00	1.37E+00	9.40E+01	9.40E+00	no	no	-
cis-1,2-Dichloroethene	156-59-2	28	0	0	no	-	-	-	-	-	no	-
cis-1,3-Dichloropropene	10061-01-5	28	0	0	no	-	-	-	-	-	no	-
Dibromochloromethane	124-48-1	28	0	0	no	-	-	-	-	-	no	-
Ethylbenzene	**100-41-4**	**28**	**19**	**68**	**yes**	**9.60E+01**	**8.87E+00**	**9.70E-01**	**9.70E-02**	**yes**	**yes**	**2.00E+03**
m,p-Xylenes	**179601-23-1**	**28**	**26**	**93**	**yes**	**1.50E+03**	**1.38E+02**	**7.30E+02**	**7.30E+01**	**yes**	**yes**	**3.50E+02**

Table 2-6
Summary Statistics and Selection of COPCs by Comparison to EPA RSLs[1] Odor Thresholds[2]
2005-2007 Odor Events
Human Health Risk Assessment
Battlement Mesa HIA

Chemical	CAS Number	Number of Samples	Number of Detects	Detection Frequency (%)	Detection frequency ≥5%?	Maximum Detected Concentration (µg/m^3)	Mean (µg/m3)	EPA RSL (µg/m3)	1/10 EPA RSL (µg/m3)	Maximum Concentration > 1/10 EPA RSL	COPC?	Texas Acute Odor ESL (µg/m^3)
Methyl tert-Butyl Ether	1634-04-4	28	0	0	no	-	-	-	-	-	no	-
Methylene chloride	75-09-2	28	0	0	no	-	-	-	-	-	no	-
o-Xylene	**95-47-6**	**28**	**24**	**86**	**yes**	**2.60E+02**	**2.22E+01**	**7.30E+02**	**7.30E+01**	**yes**	**yes**	**1.60E+03**
Styrene	100-42-5	28	0	0	no	-	-	-	-	-	no	-
Tetrachloroethene	127-18-4	28	0	0	no	-	-	-	-	-	no	-
Toluene	**108-88-3**	**28**	**26**	**93**	**yes**	**5.40E+02**	**1.05E+02**	**5.20E+03**	**5.20E+02**	**yes**	**yes**	**6.40E+02**
trans-1,2-Dichloroethene	156-60-5	28	0	0	no	-	-	-	-	-	no	-
trans-1,3-Dichloropropene	10061-02-6	28	0	0	no	-	-	-	-	-	no	-
Trichloroethene	79-01-6	28	0	0	no	-	-	-	-	-	no	-
Trichlorofluoromethane	75-69-4	28	2	7	yes	1.50E+00	1.36E+00	7.30E+02	7.30E+01	no	no	2.80E+04
Trichlorotrifluoroethane	76-13-1	28	0	0	no	-	-	-	-	-	no	-
Vinyl Acetate	108-05-4	28	4	14	yes	1.50E+01	2.60E+00	2.10E+02	2.10E+01	no	no	NA
Vinyl Chloride	75-01-4	28	0	0	no	-	-	-	-	-	no	-

Notes:
Bold text indicates contaminant was selected as a COPC.
µg/m^3: micrograms per cubic meter
CAS: Chemical Abstract Service
COPC: Contaminant of potential concern
EPA: United States Environmental Protection Agency
HIA: Health Impact Assessment
NA: Not Available
[1]RSL = EPA regional screening levels for ambient air based on exposure of 24 hours per day for 350 days per year for 30 years :
Health effects are not expected to occur at or below the RSL. To select COPCs, maximum detected concentration was compared to 1/10 the RSL to account for additive health effects from multiple chemicals. : http://www.epa.gov/region9/superfund/prg/index.html, May 2010
[2]Texas acute odor ESLs are odor based effects screening levels at which 50 percent of human subjects detect an odor (Texas Commission on Environmental Quality 2006).

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
1,1,1-Trichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1,2,2-Tetrachloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1,2-Trichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1-Dichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,1-Dichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2,3-Trimethylbenzene	7	7	100	1.20E-01	1.20E-01	4.40E-02	1.48E-01	9.54E-02	1.48E-01	< 8 observations, Maximum detected value
1,2,4-Trimethylbenzene	7	7	100	1.31E-01	1.31E-01	1.94E-01	8.79E-01	4.24E-01	8.79E-01	< 8 observations, Maximum detected value
1,2-Dibromoethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2-Dichlorobenzene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2-Dichloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,2-Dichloropropane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,3,5-Trimethylbenzene	7	7	100	1.09E-01	1.09E-01	9.50E-02	4.63E-01	2.59E-01	4.63E-01	< 8 observations, Maximum detected value
1,3-Butadiene	7	0	0	1.05E-01	1.05E-01	-	-	-	1.05E-01	Not detected, maximum MRL
1,3-Dichlorobenzene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
1,4-Dichlorobenzene	18	1	6	1.60E+00	2.30E+00	4.60E+00	4.60E+00	1.11E+00	4.60E+00	< 7 detections, maximum detected value
1-Decene	7	0	0	1.15E-01	1.15E-01	-	-	-	1.15E-01	Not detected, maximum MRL
1-Dodecene	7	5	71	2.41E-01	2.41E-01	1.40E-01	8.83E-01	3.05E-01	8.83E-01	< 8 observations, Maximum detected value
1-Heptene	7	7	100	2.24E-01	2.24E-01	4.25E-01	1.28E+00	7.82E-01	1.28E+00	< 8 observations, Maximum detected value
1-Hexene	7	7	100	2.47E-01	2.47E-01	4.93E-02	1.01E-01	7.19E-02	1.01E-01	< 8 observations, Maximum detected value
1-Nonene	7	5	71	1.83E-01	1.83E-01	4.47E-02	1.49E-01	1.05E-01	1.49E-01	< 8 observations, Maximum detected value
1-Octene	7	3	43	1.78E-01	1.78E-01	7.51E-02	1.42E-01	9.53E-02	1.42E-01	< 8 observations, Maximum detected value
1-Pentene	7	7	100	6.88E-02	6.88E-02	7.11E-02	1.50E-01	9.59E-02	1.50E-01	< 8 observations, Maximum detected value
1-Tridecene	7	1	14	2.41E-01	2.41E-01	2.69E-02	2.69E-02	1.07E-01	2.69E-02	< 8 observations, Maximum detected value
1-Undecene	7	0	0	9.75E-02	9.75E-02	-	-	-	9.75E-02	Not detected, maximum MRL
2,2,3-Trimethylpentane	7	7	100	1.81E-01	1.81E-01	9.39E-02	4.29E-01	2.30E-01	4.29E-01	< 8 observations, Maximum detected value
2,2,4-Trimethylpentane	7	1	14	1.28E-01	1.28E-01	2.46E-01	2.46E-01	9.02E-02	2.46E-01	< 8 observations, Maximum detected value
2,2-Dimethylbutane	7	7	100	8.22E-02	8.22E-02	3.88E-01	1.00E+00	5.82E-01	1.00E+00	< 8 observations, Maximum detected value
2,3,4-Trimethylpentane	7	6	86	1.05E-01	1.05E-01	5.48E-02	2.25E-01	1.08E-01	2.25E-01	< 8 observations, Maximum detected value
2,3-Dimethylbutane	7	7	100	1.17E-01	1.17E-01	5.68E-01	1.85E+00	9.75E-01	1.85E+00	< 8 observations, Maximum detected value
2,3-Dimethylpentane	7	7	100	2.28E-01	2.28E-01	3.43E-01	9.48E-01	5.34E-01	9.48E-01	< 8 observations, Maximum detected value
2,4-Dimethylpentane	7	7	100	1.40E-01	1.40E-01	2.14E-01	6.55E-01	3.64E-01	6.55E-01	< 8 observations, Maximum detected value
2-Butanone (MEK)	18	9	50	1.60E+00	2.30E+00	2.10E+00	3.70E+00	1.63E+00	3.26E+00	95% KM UTL
2-Ethyl-1-butene	7	0	0	2.47E-01	2.47E-01	-	-	-	2.47E-01	Not detected, maximum MRL
2-Hexanone	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m³)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
2-Methyl-1-butene	7	5	71	1.15E-01	1.15E-01	6.76E-02	1.38E+00	3.88E-01	1.38E+00	< 8 observations, Maximum detected value
2-Methyl-1-pentene	7	0	0	2.47E-01	2.47E-01	-	-	-	2.47E-01	Not detected, maximum MRL
2-Methyl-2-butene	7	5	71	1.15E-01	1.15E-01	9.23E-02	3.05E-01	1.35E-01	3.05E-01	< 8 observations, Maximum detected value
2-Methylheptane	7	7	100	1.05E-01	1.05E-01	4.41E-01	1.61E+00	9.18E-01	1.61E+00	< 8 observations, Maximum detected value
2-Methylhexane	7	7	100	1.05E-01	1.05E-01	9.83E-01	2.71E+00	1.64E+00	2.71E+00	< 8 observations, Maximum detected value
2-Methylpentane	7	7	100	4.70E-02	4.70E-02	2.73E+00	8.75E+00	4.58E+00	8.75E+00	< 8 observations, Maximum detected value
3-Methyl-1-butene	7	0	0	1.15E-01	1.15E-01	-	-	-	1.15E-01	Not detected, maximum MRL
3-Methylheptane	7	7	100	1.17E-01	1.17E-01	2.98E-01	1.17E+00	7.18E-01	1.17E+00	< 8 observations, Maximum detected value
3-Methylhexane	7	7	100	1.35E-01	1.35E-01	8.02E-01	2.72E+00	1.53E+00	2.72E+00	< 8 observations, Maximum detected value
3-Methylpentane	7	7	100	1.06E-01	1.06E-01	1.38E+00	5.63E+00	2.60E+00	5.63E+00	< 8 observations, Maximum detected value
4-Methyl-1-pentene	7	2	29	2.47E-01	2.47E-01	2.50E-01	7.00E-01	2.24E-01	7.00E-01	< 8 observations, Maximum detected value
4-Methyl-2-pentanone	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Acetone	18	15	83	8.20E+00	1.10E+01	1.00E+01	3.10E+01	1.47E+01	2.96E+01	95% KM UTL
Acetylene	7	7	100	5.85E-02	5.85E-02	1.95E-01	3.03E-01	2.28E-01	3.03E-01	< 8 observations, Maximum detected value
a-Pinene	7	7	100	1.78E-01	1.78E-01	2.23E-01	5.90E-01	3.75E-01	5.90E-01	< 8 observations, Maximum detected value
Benzene	25	8	32	1.28E-01	2.30E+00	8.71E-01	2.70E+00	1.06E+00	1.83E+00	95% KM UTL
b-Pinene	7	5	71	1.11E-01	1.11E-01	9.63E-02	3.72E-01	1.85E-01	3.72E-01	< 8 observations, Maximum detected value
Bromodichloromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Bromoform	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Bromomethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Carbon Disulfide	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Carbon Tetrachloride	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chlorobenzene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chloroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chloroform	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Chloromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
cis-1,2-Dichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
cis-1,3-Dichloropropene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
cis-2-Butene	7	5	71	1.09E-01	1.09E-01	4.59E-02	8.14E-02	5.91E-02	8.14E-02	< 8 observations, Maximum detected value
cis-2-Hexene	7	6	86	2.47E-01	2.47E-01	5.56E-02	2.95E-01	1.69E-01	2.95E-01	< 8 observations, Maximum detected value
cis-2-Pentene	7	2	29	1.09E-01	1.09E-01	3.84E-02	6.07E-02	5.31E-02	6.07E-02	< 8 observations, Maximum detected value
Cyclohexane	7	7	100	1.26E-01	1.26E-01	1.79E+00	7.57E+00	3.32E+00	7.57E+00	< 8 observations, Maximum detected value
Cyclopentane	7	7	100	4.58E-02	4.58E-02	3.27E-01	9.63E-01	5.33E-01	9.63E-01	< 8 observations, Maximum detected value
Cyclopentene	7	7	100	1.11E-01	1.11E-01	1.64E-01	4.72E-01	2.92E-01	4.72E-01	< 8 observations, Maximum detected value

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
Dibromochloromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Ethane	7	7	100	5.54E-02	5.54E-02	3.28E+01	8.30E+01	5.85E+01	8.30E+01	< 8 observations, Maximum detected value
Ethylbenzene	25	7	28	1.14E-01	2.30E+00	1.80E-01	7.05E-01	7.68E-01	6.37E-01	95% KM UTL
Ethylene	7	7	100	4.01E-02	4.01E-02	3.71E-01	9.39E-01	6.48E-01	9.39E-01	< 8 observations, Maximum detected value
Isobutane	7	7	100	4.75E-02	4.75E-02	6.71E+00	2.28E+01	1.29E+01	2.28E+01	< 8 observations, Maximum detected value
Isobutene/1-Butene	7	6	86	8.03E-02	8.03E-02	4.61E+00	1.07E+01	6.08E+00	1.07E+01	< 8 observations, Maximum detected value
Isopentane	7	7	100	1.00E-01	1.00E-01	9.91E+00	2.38E+01	1.52E+01	2.38E+01	< 8 observations, Maximum detected value
Isoprene	7	7	100	1.11E-01	1.11E-01	1.67E-01	1.10E+00	5.45E-01	1.10E+00	< 8 observations, Maximum detected value
Isopropylbenzene	7	3	43	1.75E-01	1.75E-01	5.19E-02	9.06E-02	7.97E-02	9.06E-02	< 8 observations, Maximum detected value
m,p -Xylenes	25	10	40	1.68E-01	2.30E+00	9.88E-01	4.90E+00	1.44E+00	3.68E+00	95% KM UTL
m-Diethylbenzene	7	6	86	9.87E-02	9.87E-02	7.62E-02	4.10E-01	1.95E-01	4.10E-01	< 8 observations, Maximum detected value
Methyl tert-Butyl Ether	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Methylcyclohexane	7	7	100	8.60E-02	8.60E-02	3.44E+00	1.16E+01	6.62E+00	1.16E+01	< 8 observations, Maximum detected value
Methylcyclopentane	7	7	100	7.46E-02	7.46E-02	1.33E+00	5.85E+00	2.65E+00	5.85E+00	< 8 observations, Maximum detected value
Methylene chloride	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
m-Ethyltoluene	7	7	100	8.19E-02	8.19E-02	1.72E-01	6.28E-01	3.32E-01	6.28E-01	< 8 observations, Maximum detected value
n-Butane	7	7	100	6.53E-02	6.53E-02	7.66E+00	2.61E+01	1.39E+01	2.61E+01	< 8 observations, Maximum detected value
n-Decane	7	7	100	1.16E-01	1.16E-01	4.72E-01	1.81E+00	1.06E+00	1.81E+00	< 8 observations, Maximum detected value
n-Dodecane	7	7	100	2.44E-01	2.44E-01	2.34E-01	1.55E+00	6.80E-01	1.55E+00	< 8 observations, Maximum detected value
n-Heptane	7	7	100	1.17E-01	1.17E-01	1.58E+00	5.48E+00	3.00E+00	5.48E+00	< 8 observations, Maximum detected value
n-Hexane	7	7	100	1.35E-01	1.35E-01	2.88E+00	1.25E+01	5.56E+00	1.25E+01	< 8 observations, Maximum detected value
n-Nonane	7	7	100	9.90E-02	9.90E-02	4.34E-01	2.00E+00	1.16E+00	2.00E+00	< 8 observations, Maximum detected value
n-Octane	7	7	100	1.40E-01	1.40E-01	1.00E+00	3.74E+00	2.43E+00	3.74E+00	< 8 observations, Maximum detected value
n-Pentane	7	7	100	5.89E-02	5.89E-02	4.66E+00	1.48E+01	8.26E+00	1.48E+01	< 8 observations, Maximum detected value
n-Propylbenzene	7	6	86	1.04E-01	1.04E-01	8.52E-02	1.79E-01	1.05E-01	1.79E-01	< 8 observations, Maximum detected value
n-Tridecane	7	7	100	2.44E-01	2.44E-01	3.83E-02	3.12E-01	1.49E-01	3.12E-01	< 8 observations, Maximum detected value
n-Undecane	7	7	100	9.87E-02	9.87E-02	7.67E-01	2.17E+00	1.25E+00	2.17E+00	< 8 observations, Maximum detected value
o-Ethyltoluene	7	7	100	1.58E-01	1.58E-01	9.61E-02	3.08E-01	1.94E-01	3.08E-01	< 8 observations, Maximum detected value
o-Xylene	25	7	28	9.22E-02	2.30E+00	2.36E-01	8.25E-01	7.94E-01	7.22E-01	95% KM UTL
p-Diethylbenzene	7	5	71	6.58E-02	6.58E-02	6.69E-02	1.12E-01	7.29E-02	1.12E-01	< 8 observations, Maximum detected value
p-Ethyltoluene	7	7	100	1.42E-01	1.42E-01	9.50E-02	3.60E-01	1.95E-01	3.60E-01	< 8 observations, Maximum detected value
Propane	7	7	100	1.08E-01	1.08E-01	2.01E+01	5.26E+01	3.33E+01	5.26E+01	< 8 observations, Maximum detected value
Propylene	7	7	100	4.02E-02	4.02E-02	2.22E-01	4.34E-01	2.89E-01	4.34E-01	< 8 observations, Maximum detected value
Propyne	7	0	0	9.83E-02	9.83E-02	-	-	-	9.83E-02	Not detected, maximum MRL

Table 2-7
Ambient Air Summary Statistics and BTVs[1] for Background Samples
2005 - 2008
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Number of Samples	Number of detects	Detection frequency (%)	Minimum MRL (µg/m^3)	Maximum MRL (µg/m3)	Minimum Detected value (µg/m3)	Maximum detected value (µg/m3)	Mean (µg/m3)	BTV (µg/m3)	Statistical Basis for BTV
Styrene	25	1	4	1.33E-01	2.30E+00	7.23E-01	7.23E-01	7.31E-01	7.23E-01	< 7 detections, maximum detected value
Tetrachloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Toluene	25	14	56	1.78E-01	2.30E+00	1.81E+00	1.77E+01	2.65E+00	1.49E+01	95% KM UTL
trans-1,2-Dichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
trans-1,3-Dichloropropene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
trans-2-Butene	7	6	86	7.45E-02	7.45E-02	8.26E-02	2.06E-01	1.19E-01	2.06E-01	< 8 observations, Maximum detected value
trans-2-Hexene	7	1	14	2.47E-01	2.47E-01	1.03E-01	1.03E-01	1.20E-01	1.03E-01	< 8 observations, Maximum detected value
trans-2-Pentene	7	5	71	1.09E-01	1.09E-01	5.96E-02	1.27E-01	7.56E-02	1.27E-01	< 8 observations, Maximum detected value
Trichloroethene	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Trichlorofluoromethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Trichlorotrifluoroethane	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL
Vinyl Acetate	18	5	28	1.60E+00	2.30E+00	3.20E+00	7.90E+00	1.78E+00	7.90E+00	< 7 detections, maximum detected value
Vinyl Chloride	18	0	0	1.60E+00	2.30E+00	-	-	-	2.30E+00	Not detected, maximum MRL

Notes:

[1]BTV: Background Threshold Value: BTVs are background contaminant concentrations computed based upon the sampled data collected from the site- specific background locations.

95% KM UTL: 95 percentileKaplan Meier Upper Tolerance Limit

MRL: Method Reporting Limit

Table 2-8
95% UCLs and Selection of EPCs[1]
2005 to 2010 Bell-Melton Ranch Monitoring Station
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Value (µg/m^3)	Mean Value (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
1,2,3-Trimethylbenzene	8.47E-01	8.10E-02	1.01E-01	KM (t)	1.01E-01
1,2,4-Trimethylbenzene	3.09E+00	2.75E-01	3.39E-01	KM (BCA)	3.39E-01
1,3,5-Trimethylbenzene	1.20E+00	1.51E-01	1.78E-01	KM (BCA)	1.78E-01
1,3-Butadiene	1.53E-01	5.58E-02	NC	NC	1.53E-01
1,4-Dichlorobenzene	2.30E+00	9.36E-01	NC	NC	2.30E+00
1-Dodecene	1.02E+00	1.44E-01	1.74E-01	KM (t)	1.74E-01
1-Heptene	2.98E+00	6.30E-01	7.10E-01	KM (BCA)	7.10E-01
1-Hexene	2.77E-01	9.55E-02	9.72E-02	KM (t)	9.72E-02
1-Nonene	4.28E-01	1.07E-01	1.20E-01	(%bootstrap)	1.20E-01
1-Octene	1.37E+00	1.06E-01	1.13E-01	KM (t)	1.13E-01
1-Pentene	3.80E-01	1.04E-01	1.12E-01	KM (BCA)	1.12E-01
1-Tridecene	2.04E-01	1.06E-01	8.89E-02	KM (%bootstrap)	8.89E-02
1-Undecene	1.07E+00	1.21E-01	1.48E-01	KM (t)	1.48E-01
2,2,3-Trimethylpentane	1.64E+00	1.49E-01	1.91E-01	KM (%bootstrap)	1.91E-01
2,2,4-Trimethylpentane	2.48E+00	1.52E-01	2.14E-01	KM (%bootstrap)	2.14E-01
2,2-Dimethylbutane	2.34E+00	6.15E-01	6.76E-01	H-UCL	6.76E-01
2,3,4-Trimethylpentane	1.79E+00	9.21E-02	1.27E+00	KM (%bootstrap)	1.27E+00
2,3-Dimethylbutane	5.05E+00	1.22E+00	1.36E+00	H-UCL	1.36E+00
2,3-Dimethylpentane	2.08E+00	5.26E-01	5.70E-01	H-UCL	5.70E-01
2,4-Dimethylpentane	1.48E+00	3.69E-01	4.06E-01	KM (BCA)	4.06E-01
2-Hexanone	4.40E+00	1.00E+00	NC	NC	4.40E+00
2-Methyl-1-butene	3.94E+01	5.98E-01	1.23E+00	KM (BCA)	1.23E+00
2-Methyl-1-pentene	1.52E-01	9.82E-02	NC	NC	1.52E-01
2-Methyl-2-butene	4.17E-01	8.95E-02	1.07E-01	KM (t)	1.07E-01
2-Methylheptane	2.93E+00	6.28E-01	7.01E-01	H-UCL	7.01E-01
2-Methylhexane	5.71E+00	1.39E+00	1.54E+00	KM (BCA)	1.54E+00
2-Methylpentane	2.20E+01	5.39E+00	5.98E+00	H-UCL	5.98E+00
3-Methyl-1-butene	2.00E-01	6.16E-02	NC	NC	2.00E-01
3-Methylheptane	3.53E+00	4.17E-01	4.55E-01	H-UCL	4.55E-01
3-Methylhexane	4.84E+00	1.11E+00	1.27E+00	KM (BCA)	1.27E+00
3-Methylpentane	1.16E+01	2.80E+00	3.12E+00	H-UCL	3.12E+00
4-Methyl-1-pentene	4.68E+00	1.41E-01	2.28E-01	KM (BCA)	2.28E-01
Acetaldehyde	1.96E+00	7.98E-01	8.74E-01	Student-t	8.74E-01
Acetylene	2.92E+00	6.30E-01	6.97E-01	H-UCL	6.97E-01
a-Pinene	3.37E+00	1.74E-01	2.31E-01	KM (%bootstrap)	2.31E-01
Benzaldehyde	2.04E-01	7.10E-02	9.74E-02	KM (Chebyshev)	9.74E-02
Benzene	1.36E+01	1.47E+00	1.67E+00	KM (BCA)	1.67E+00
b-Pinene	1.43E+00	8.08E-02	1.23E-01	KM (t)	1.23E-01
Butyraldehyde	2.71E-01	6.98E-02	8.11E-02	KM (BCA)	8.11E-02
cis-2-Butene	3.73E-01	6.79E-02	7.95E-02	KM (t)	7.95E-02
cis-2-Hexene	7.00E-01	9.97E-02	1.00E-01	KM (Chebyshev)	1.00E-01
cis-2-Pentene	1.45E-01	5.37E-02	6.12E-02	KM (t)	6.12E-02
Crotonaldehyde	5.53E-01	1.26E-01	2.02E-01	Chebyshev (mean, s	2.02E-01

Table 2-8

95% UCLs and Selection of EPCs[1]

2005 to 2010 Bell-Melton Ranch Monitoring Station

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Value (µg/m^3)	Mean Value (µg/m^3)	95% UCL[2] (µg/m^3)	Statistical Method to Calculate 95% UCL	EPC (µg/m^3)
Cyclopentane	2.94E+00	7.28E-01	8.00E-01	H-UCL	8.00E-01
Cyclopentene	9.58E-01	1.34E-01	1.66E-01	KM (%bootstrap)	1.66E-01
Ethane	4.11E+02	8.00E+01	9.02E+01	H-UCL	9.02E+01
Ethylbenzene	4.34E+00	3.78E-01	3.33E-01	KM (Chebyshev)	4.11E-01
Ethylene	2.94E+00	1.00E+00	1.09E+00	Gamma	1.09E+00
Formaldehyde	1.02E+01	1.17E+00	1.26E+00	H-UCL	1.26E+00
Formaldehyde w/o outlier	2.24E+00	1.02E+00	1.11E+00	Student-t	1.11E+00
Hexaldehyde	1.31E-01	4.21E-02	2.56E-02	KM (Chebyshev)	2.56E-02
Isobutane	1.18E+02	2.34E+01	2.62E+01	Gamma	2.62E+01
Isobutene/1-Butene	1.36E+01	1.29E+00	1.60E+00	KM (% bootstrap)	1.60E+00
Isopentane	1.23E+02	1.97E+01	2.24E+01	KM (BCA)	2.24E+01
Isoprene	3.33E+00	3.13E-01	5.03E-01	KM (Chebyshev)	5.03E-01
Isovaleraldehyde	1.13E-01	5.69E-03	3.29E-02	KM (t)	3.29E-02
m&p-Xylene	1.40E+01	1.69E+00	1.98E+00	KM (BCA)	1.98E+00
m-Diethylbenzene	8.84E-01	9.25E-02	1.18E-01	KM (%bootstrap)	1.18E-01
Methylcyclohexane	2.39E+01	5.38E+00	5.96E+00	Gamma	5.96E+00
Methylcyclopentane	1.04E+01	2.60E+00	2.89E+00	H-UCL	2.89E+00
Methylene Chloride	2.90E+00	9.59E-01	NC	NC	2.90E+00
m-Ethyltoluene	1.63E+00	1.87E-01	2.21E-01	KM (BCA)	2.21E-01
n-Butane	1.57E+02	2.79E+01	3.14E+01	H-UCL	3.14E+01
n-Decane	6.98E+01	1.11E+00	2.24E+00	KM (BCA)	2.24E+00
n-Dodecane	7.14E+01	1.24E+00	3.74E+00	KM (Chebyshev)	3.74E+00
n-Heptane	1.14E+01	2.55E+00	2.85E+00	H-UCL	2.85E+00
n-Hexane	2.50E+01	5.89E+00	6.53E+00	H-UCL	6.53E+00
n-Nonane	3.08E+00	6.36E-01	7.23E-01	KM (BCA)	7.23E-01
n-Octane	6.72E+00	1.45E+00	1.61E+00	H-UCL	1.61E+00
n-Pentane	6.20E+01	1.36E+01	1.50E+01	Gamma	1.50E+01
n-Tridecane	5.68E+00	2.05E-01	2.92E-01	KM (BCA)	2.92E-01
n-Undecane	2.55E+02	2.81E+00	1.15E+01	KM (Chebyshev)	1.15E+01
o-Ethyltoluene	1.44E+00	1.31E-01	1.65E-01	KM (BCA)	1.65E-01
o-Xylene	3.61E+00	4.35E-01	4.03E-01	KM (Chebyshev)	4.94E-01
p-Diethylbenzene	4.20E-01	5.50E-02	7.00E-02	KM (%bootstrap)	7.00E-02
p-Ethyltoluene	1.26E+00	1.33E-01	1.62E-01	KM (BCA)	1.62E-01
Propane	3.16E+02	6.15E+01	6.94E+01	H-UCL	6.94E+01
Tolualdehydes	2.51E-01	8.16E-02	9.32E-02	KM (BCA)	9.32E-02
trans-2-Butene	3.34E+00	1.13E-01	1.74E-01	KM (BCA)	1.74E-01
trans-2-Hexene	3.04E-02	9.83E-02	NC	NC	3.04E-02
trans-2-Pentene	3.18E-01	6.72E-02	8.08E-02	KM (t)	8.08E-02
Valeraldehyde	8.10E-02	2.25E-02	3.49E-02	KM (%bootstrap)	3.49E-02

[1]EPC = Exposure Point Concentration: The lower value between the UCL and maximum detected value.
For contaminants with < 11 detections a UCL was not calculated and the maximum value was used for the EPC

Table 2-8

95% UCLs and Selection of EPCs[1]

2005 to 2010 Bell-Melton Ranch Monitoring Station

Human Health Risk Assessment

Battlement Mesa Health Impact Assessment

Chemical	Maximum Detected Value (µg/m³)	Mean Value (µg/m³)	95% UCL[2] (µg/m³)	Statistical Method to Calculate 95% UCL	EPC (µg/m³)

[2]UCL = Upper Confidence Limit calculated for 2005 - 2010 Bell-Melton Ranch data using EPA's ProUCL v. 4.005 (EPA 2010)
H-UCL = UCL based upon Land's H-statistic
KM (%bootstrap) = UCL based upon Kaplan-Meier estimates using the percentile bootstrap method
KM (chebyshev) UCL based upon Kaplan-Meier estimates using the Chebyshev inequality
KM (t) UCL based upon Kaplan-Meier estimates using the Student's t-distribution cutoff value
KM (BCA) UCL based upon Kaplan-Meier bias-corrected accelerated bootstrap method
NC = Not calculated because less than 10 detected values
Student t: UCL based upon the Student t-distribution cutoff value
Gamma: UCL based upon the Gamma distribution cutoff value.
µg/m³ = micrograms per cubic meter
CAS = Chemical Abstract Service

Table 3-1
Cancer and Non-Cancer Air Intake Values for Chronic Exposures
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Chronic EPC[1] (μg/m³)	Intermediate EPC[2] (μg/m³)	TWA[3] (μg/m³)	Chronic Non-cancer Intake (μg/m³)	TWA Non-cancer Intake (μg/m³)	Chronic Cancer Intake (μg/m³)	TWA Cancer Intake (μg/m³)
1,2,3-Trimethylbenzene	1.01E-01	1.17E+01	4.23E-01	9.68E-02	4.05E-01	4.15E-02	1.74E-01
1,2,4-Trimethylbenzene	3.39E-01	8.30E+01	2.63E+00	3.25E-01	2.53E+00	1.39E-01	1.08E+00
1,3,5-Trimethylbenzene	1.78E-01	7.75E+01	2.33E+00	1.70E-01	2.23E+00	7.30E-02	9.56E-01
1,3-Butadiene	1.53E-01	1.66E-01	1.53E-01	1.47E-01	1.47E-01	6.29E-02	6.30E-02
1,4-Dichlorobenzene	2.30E+00	NM	NC	2.21E+00	2.21E+00	9.45E-01	9.45E-01
1-Dodecene	1.74E-01	6.08E+00	3.37E-01	1.66E-01	3.24E-01	7.13E-02	1.39E-01
1-Heptene	7.10E-01	6.08E+01	2.38E+00	6.80E-01	2.28E+00	2.92E-01	9.77E-01
1-Hexene	9.72E-02	1.63E-01	9.91E-02	9.32E-02	9.50E-02	4.00E-02	4.07E-02
1-Nonene	1.20E-01	1.68E+01	5.83E-01	1.15E-01	5.59E-01	4.94E-02	2.40E-01
1-Octene	1.13E-01	3.16E+00	1.97E-01	1.08E-01	1.89E-01	4.63E-02	8.11E-02
1-Pentene	1.12E-01	3.89E-01	1.20E-01	1.08E-01	1.15E-01	4.62E-02	4.93E-02
1-Tridecene	8.89E-02	3.63E-01	9.65E-02	8.53E-02	9.26E-02	3.65E-02	3.97E-02
1-Undecene	1.48E-01	4.72E+00	2.75E-01	1.42E-01	2.64E-01	6.09E-02	1.13E-01
2,2,3-Trimethylpentane	1.91E-01	2.47E+01	8.73E-01	1.83E-01	8.37E-01	7.84E-02	3.59E-01
2,2,4-Trimethylpentane	2.14E-01	1.98E-01	2.14E-01	2.05E-01	2.05E-01	8.81E-02	8.79E-02
2,2-Dimethylbutane	6.76E-01	4.12E+01	1.80E+00	6.48E-01	1.73E+00	2.78E-01	7.41E-01
2,3,4-Trimethylpentane	1.27E+00	1.21E+00	1.26E+00	1.21E+00	1.21E+00	5.20E-01	5.19E-01
2,3-Dimethylbutane	1.36E+00	6.58E+01	3.15E+00	1.30E+00	3.02E+00	5.59E-01	1.29E+00
2,3-Dimethylpentane	5.70E-01	3.56E+01	1.54E+00	5.47E-01	1.48E+00	2.34E-01	6.35E-01
2,4-Dimethylpentane	4.06E-01	2.36E+01	1.05E+00	3.89E-01	1.01E+00	1.67E-01	4.31E-01
2-Hexanone	4.40E+00	NM	NC	4.22E+00	4.22E+00	1.81E+00	1.81E+00
2-Methyl-1-butene	1.23E+00	1.26E+00	1.23E+00	1.17E+00	1.18E+00	5.03E-01	5.04E-01
2-Methyl-2-butene	1.07E-01	8.43E-02	1.07E-01	1.03E-01	1.02E-01	4.41E-02	4.38E-02
2-Methyl-1-pentene	1.52E-01	3.87E-01	1.59E-01	1.46E-01	1.52E-01	6.25E-02	6.51E-02
2-Methylheptane	7.01E-01	1.46E+02	4.75E+00	6.72E-01	4.55E+00	2.88E-01	1.95E+00
2-Methylhexane	1.54E+00	1.21E+02	4.85E+00	1.48E+00	4.65E+00	6.33E-01	1.99E+00
2-Methylpentane	5.98E+00	2.21E+02	1.20E+01	5.73E+00	1.15E+01	2.46E+00	4.91E+00
3-Methyl-1-butene	2.00E-01	2.49E-01	2.01E-01	1.92E-01	1.93E-01	8.22E-02	8.28E-02
3-Methylheptane	4.55E-01	9.74E+01	3.15E+00	4.36E-01	3.02E+00	1.87E-01	1.29E+00
3-Methylhexane	1.27E+00	1.14E+02	4.40E+00	1.21E+00	4.22E+00	5.21E-01	1.81E+00
3-Methylpentane	3.12E+00	1.29E+02	6.62E+00	2.99E+00	6.35E+00	1.28E+00	2.72E+00
4-Methyl-1-pentene	2.28E-01	9.35E-01	2.47E-01	2.18E-01	2.37E-01	9.36E-02	1.02E-01
Acetaldehyde	8.74E-01	NM	NC	8.38E-01	8.38E-01	3.59E-01	3.59E-01
Acetylene	6.97E-01	8.40E-01	7.01E-01	6.68E-01	6.72E-01	2.86E-01	2.88E-01
a-Pinene	2.31E-01	3.09E+01	1.08E+00	2.21E-01	1.04E+00	9.48E-02	4.45E-01
Benzaldehyde	9.74E-02	NM	NC	9.34E-02	9.34E-02	4.00E-02	4.00E-02
Benzene	1.67E+00	6.85E+01	3.53E+00	1.60E+00	3.38E+00	6.87E-01	1.45E+00
b-Pinene	1.23E-01	8.96E+00	3.69E-01	1.18E-01	3.54E-01	5.07E-02	1.52E-01
Butyraldehyde	8.11E-02	NM	NC	7.78E-02	7.78E-02	3.33E-02	3.30E-02
cis-2-Butene	7.95E-02	1.97E-01	8.28E-02	7.63E-02	7.94E-02	3.27E-02	3.40E-02
cis-2-Hexene	1.00E-01	2.93E-01	1.05E-01	9.59E-02	1.01E-01	4.11E-02	4.33E-02
cis-2-Pentene	6.12E-02	1.48E-01	6.36E-02	5.87E-02	6.10E-02	2.51E-02	2.61E-02
Crotonaldehyde	2.02E-01	NM	NC	1.94E-01	1.94E-01	8.30E-02	8.30E-02
Cyclopentane	8.00E-01	2.23E+01	1.40E+00	7.67E-01	1.34E+00	3.29E-01	5.74E-01
Cyclopentene	1.66E-01	6.51E-01	1.79E-01	1.59E-01	1.72E-01	6.81E-02	7.37E-02
Ethane	9.02E+01	2.41E+03	1.54E+02	8.65E+01	1.48E+02	3.71E+01	6.35E+01
Ethylbenzene	4.11E-01	2.28E+02	6.75E+00	3.94E-01	6.47E+00	1.69E-01	2.77E+00
Ethylene	1.09E+00	4.19E+00	1.17E+00	1.04E+00	1.12E+00	4.46E-01	4.81E-01

Table 3-1
Cancer and Non-Cancer Air Intake Values for Chronic Exposures
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Chronic EPC[1] ($\mu g/m^3$)	Intermediate EPC[2] ($\mu g/m^3$)	TWA[3] ($\mu g/m^3$)	Chronic Non-cancer Intake ($\mu g/m^3$)	TWA Non-cancer Intake ($\mu g/m^3$)	Chronic Cancer Intake ($\mu g/m^3$)	TWA Cancer Intake ($\mu g/m^3$)
Formaldehyde	1.26E+00	NM	NC	1.20E+00	1.20E+00	5.16E-01	5.16E-01
Formaldehyde w/o outlier	1.11E+00	NM	NC	1.06E+00	1.06E+00	4.54E-01	4.54E-01
Hexaldehyde	2.56E-02	NM	NC	2.45E-02	2.45E-02	1.05E-02	1.05E-02
Isobutane	2.62E+01	1.60E+03	7.00E+01	2.51E+01	6.71E+01	1.07E+01	2.87E+01
Isobutene/1-Butene	1.60E+00	6.71E+00	1.74E+00	1.54E+00	1.67E+00	6.58E-01	7.17E-01
Isopentane	2.24E+01	8.32E+02	4.49E+01	2.15E+01	4.31E+01	9.22E+00	1.85E+01
Isoprene	5.03E-01	1.15E+00	5.21E-01	4.82E-01	4.99E-01	2.07E-01	2.14E-01
Isovaleraldehyde	3.29E-02	NM	NC	3.15E-02	3.15E-02	1.35E-02	1.35E-02
m-Diethylbenzene	1.18E-01	7.08E+00	3.11E-01	1.13E-01	2.98E-01	4.84E-02	1.28E-01
Methylcyclohexane	5.96E+00	7.23E+02	2.59E+01	5.72E+00	2.48E+01	2.45E+00	1.06E+01
Methylcyclopentane	2.89E+00	1.20E+02	6.14E+00	2.77E+00	5.89E+00	1.19E+00	2.52E+00
Methylene Chloride	2.90E+00	NM	NC	2.78E+00	4.33E+00	1.19E+00	1.86E+00
m-Ethyltoluene	2.21E-01	4.45E+01	1.45E+00	2.12E-01	1.39E+00	9.07E-02	5.96E-01
m&p-Xylene	1.98E+00	8.84E+02	2.65E+01	1.90E+00	2.54E+01	8.14E-01	1.09E+01
n-Butane	3.14E+01	1.29E+03	6.63E+01	3.01E+01	6.36E+01	1.29E+01	2.72E+01
n-Decane	2.24E+00	2.08E+02	7.96E+00	2.14E+00	7.63E+00	9.19E-01	3.27E+00
n-Dodecane	3.74E+00	5.15E+01	5.07E+00	3.59E+00	4.86E+00	1.54E+00	2.08E+00
n-Heptane	2.85E+00	3.04E+02	1.12E+01	2.73E+00	1.08E+01	1.17E+00	4.61E+00
n-Hexane	6.53E+00	2.55E+02	1.34E+01	6.26E+00	1.29E+01	2.68E+00	5.52E+00
n-Nonane	7.23E-01	3.03E+02	9.11E+00	6.93E-01	8.74E+00	2.97E-01	3.75E+00
n-Octane	1.16E+00	4.17E+02	1.27E+01	1.11E+00	1.22E+01	4.77E-01	5.23E+00
n-Pentane	1.50E+01	5.53E+02	3.00E+01	1.44E+01	2.87E+01	6.18E+00	1.23E+01
n-Tridecane	2.92E-01	9.05E+00	5.36E-01	2.80E-01	5.14E-01	1.20E-01	2.20E-01
n-Undecane	1.15E+01	1.21E+02	1.45E+01	1.10E+01	1.39E+01	4.73E+00	5.97E+00
o-Ethyltoluene	1.65E-01	2.92E+01	9.71E-01	1.59E-01	9.31E-01	6.80E-02	3.99E-01
o-Xylene	4.94E-01	1.90E+02	5.77E+00	4.74E-01	5.53E+00	2.03E-01	2.37E+00
p-Diethylbenzene	7.00E-02	5.01E+00	2.07E-01	6.72E-02	1.99E-01	2.88E-02	8.52E-02
p-Ethyltoluene	1.62E-01	3.22E+01	1.05E+00	1.56E-01	1.01E+00	6.67E-02	4.33E-01
Propane	6.94E+01	4.67E+03	1.97E+02	6.65E+01	1.89E+02	2.85E+01	8.11E+01
Tolualdehydes	9.32E-02	NM	NC	8.94E-02	7.74E-02	3.83E-02	3.32E-02
trans-2-Butene	1.74E-01	1.89E+00	2.22E-01	1.67E-01	2.13E-01	7.16E-02	9.12E-02
trans-2-Hexene	3.04E-02	4.53E-02	3.08E-02	2.92E-02	2.95E-02	1.25E-02	1.27E-02
trans-2-Pentene	8.08E-02	3.05E-01	8.70E-02	7.74E-02	8.34E-02	3.32E-02	3.58E-02
Valeraldehyde	3.49E-02	NM	NC	3.35E-02	3.35E-02	1.44E-02	1.44E-02

Notes:

$\mu g/m^3$: micrograms per cubic meter

EPC: Exposure Concentration

NC: Not calculated

NM: Not measured

TWA: Time weighted average

[1]EPC for chronic exposure (30 year duration) of all Battlement Mesa residents from 2005 to 2010 Bell Melton Ranch Data (Table 2-8)

[2]EPC for intermediate 10 month exposure of Battlement Mesa residents living adjacent to a well pad from 2008 Well completion data (Maximum value Table 2-5)

[3]TWA for a chronic 30 year duration for Battlement Mesa residents living adjacent to a well pad calculated from chronic (350 months) and intermediate (10 months) EPCs.

Table 3-2
EPCs, Dermal Permeability Constants and Surface Water Intakes for Acute Exposure of Child Resident
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	EPC[1] (mg/L)	[2]PC (cm/hr)	Dermal Intake (mg/kg-day)
Benzene	1.70E-02	0.11	2.00E-03
Ethylbenzene	8.30E-03	1.38	1.23E-02
m&p-Xylene	5.60E-02	0.08	4.79E-03
o-Xylene	2.00E-02	0.08	1.71E-03
Toluene	4.50E-02	1.01	4.86E-02

Notes:

[1]EPCs from URS (2008). Second Quarter 2008 Report: Operational and Environmental Monitoring within a Three-Mile Radius of Project Rulison, Noble Energy, Williams, and EnCana

[2]PC: permeability constants: EPA EPA/600/8-91/011B 1992, Dermal Exposure Assessment: Principles and Applications
cm/hr: centimeters per hour
mg/kg-day: mg per kilogram per day
mg/L: Milligrams per Liter

Table 4-1
Cancer and Non-Cancer Inhalation Toxicity Values
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Available Toxicity Factors	RfC - chronic (mg/m^3)	Source	RfC - acute (mg/m^3)	Source	IUR ($1/(\mu g/m^3)$)	Source
1,2,3-Trimethylbenzene	nc	7.00E-03	based on 1,2,4-TMB	NA	NA	NA	NA
1,2,4-Trimethylbenzene	nc	7.00E-03	PPTRV	NA	NA	NA	NA
1,3,5-Trimethylbenzene	nc	7.00E-03	based on 1,2,4-TMB	NA	NA	NA	NA
1,3-Butadiene	c/nc	2.00E-03	ATW-IRIS	NA	NA	3.00E-05	ATW-IRIS
1,4-Dichlorobenzene	c/nc	8.00E-01	ATW-IRIS	1.20E+01	ATW-MRL	1.10E-05	ATW-CAL
2-Hexanone	nc	3.00E-02	ATW-IRIS	NA	NA	NA	NA
Acetaldehyde	c/nc	9.00E-03	ATW-IRIS	NA	NA	2.20E-06	ATW-IRIS
Benzene	c/nc	3.00E-02	ATW-ATSDR	2.90E-02	ATW-MRL	7.80E-06	ATW-IRIS
Chloroform	nc	9.80E-02	ATW-ATSDR	4.90E-01	ATW-MRL	2.30E-05	IRIS
Crotonaldehyde	c	NA	NA	NA	NA	5.43E-04	HEAST
Ethylbenzene	c/nc	1.00E+00	ATW-ATSDR	4.30E+01	ATW-MRL	2.50E-06	ATW-CAL
Formaldehyde	c/nc	9.80E-03	ATW-ATSDR	4.90E-02	ATSDR-MRL	1.30E-05	ATW-IRIS
Methylcyclohexane	nc	3.01E+00	HEAST	NA	NA	NA	NA
Methylene Chloride	c/nc	1.00E+00	ATW-ATSDR	2.10E+00	ATW-MRL	4.70E-07	ATW-IRIS
m-Xylene/p-Xylene	nc	1.00E-01	ATW-IRIS	8.70E+00	ATW-MRL	NA	NA
n-Hexane	nc	7.00E-01	ATW-IRIS	NA	NA	NA	NA
n-Nonane	nc	2.00E-01	PPTRV	NA	NA	NA	NA
n-Pentane	nc	1.00E+00	PPTRV	NA	NA	NA	NA
o-Xylene	nc	7.00E-01	CAL	NA	NA	NA	NA
Toluene	nc	5.00E+00	ATW-IRIS	3.80E+00	ATW-MRL	NA	NA

Notes:

µg/m3 = microgram per cubic meter

ATSDR-MRL: Agency for Toxic Substances Disease Registry Minimal Risk Level for Hazardous Substances, 2009

ATW-CAL: Value from EPA's Air Toxic Web-Site searched on 7/28/10. ATW obtained value from CAL.

ATW-IRIS: Value from EPA's Air Toxic Web-Site searched on 7/28/10. ATW obtained value from IRIS.

ATW-MRL: Value from EPA's Air Toxic Web-Site searched on 7/28/10. ATW obtained value from ATSDR MRL.

c = IUR for cancer available, nc = RfC for non-cancer effects available , c/nc = both are available

CAL: California EPA Office of Environmental Health Hazard Assessment Toxicity Criteria Database searched 7/28/10

CAS = Chemical Abstract Service

HEAST: EPA Health Effects Assessment Summary Tables 1997

IRIS: Value from EPA integrated risk information system searched on 7/28/10

IUR = incremental unit risk

mg/m3 = milligram per cubic meter

NA = Not available

PPTRV: EPA's Provisional Peer-Reviewed Toxicity Values from May 2010 risk screening level table

RfC = Reference concentration

Table 4-2
Contaminants of Potential Concern for without Toxicity Values
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Contaminant	CAS Number	Contaminant	CAS Number
1-Dodecene	112-41-4	cis-2-Butene	590-18-1
1-Heptene	592-76-7	cis-2-Hexene	7688-21-3
1-Hexene	592-41-6	cis-2-Pentene	627-20-3
1-Nonene	124-11-8	Cyclopentane	287-92-3
1-Octene	111-66-0	Cyclopentene	142-29-0
1-Pentene	109-67-1	Ethane	74-84-0
1-Tridecene	2437-56-1	Ethylene	74-85-1
1-Undecene	821-95-4	Hexaldehyde	66-25-1
2,2,3-Trimethylpentane	564-02-3	Isobutane	75-28-5
2,2,4-Trimethylpentane	540-84-1	Isobutene/1-Butene	115-11-7 / 106-98-9
2,2-Dimethylbutane	75-83-2	Isopentane	78-78-4
2,3,4-Trimethylpentane	565-75-3	Isoprene	78-79-5
2,3-Dimethylbutane	79-29-8	Isovaleraldehyde	590-86-3
2,3-Dimethylpentane	565-59-3	m-Diethylbenzene	141-93-5
2,4-Dimethylpentane	108-08-7	Methylcyclopentane	96-37-7
2-Methyl-1-butene	563-46-2	m-Ethyltoluene	620-14-4
2-Methyl-2-butene	513-35-9	n-Butane	106-97-8
2-Methyl-2-butene	513-35-9	n-Decane	124-18-5
2-Methylheptane	592-27-8	n-Dodecane	112-40-3
2-Methylhexane	591-76-4	n-Heptane	142-82-5
2-Methylpentane	107-83-5	n-Octane	111-65-9
3-Methyl-1-butene	563-45-1	n-Tridecane	629-50-5
3-Methylheptane	589-81-1	n-Undecane	1120-21-4
3-Methylhexane	589-34-4	o-Ethyltoluene	611-14-3
3-Methylpentane	96-14-0	p-Diethylbenzene	105-05-5
4-Methyl-1-pentene	691-37-2	p-Ethyltoluene	622-96-8
Acetylene	74-86-2	Propane	74-98-6
a-Pinene	80-56-8	Tolualdehydes	NA
Benzaldehyde	100-52-7	trans-2-Butene	624-64-6
b-Pinene	127-91-3	trans-2-Hexene	4050-45-7
Butyraldehyde	123-72-8	trans-2-Pentene	4050-45-7
		Valeraldehyde	110-62-3

Table 4-3
Oral/Dermal Non-cancer Toxicity Factors
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	Available Toxicity Values	RfD-acute (mg/kg-day)	Source	RFD-intermediate (mg/kg-day)	Source	RfD-chronic (mg/kg-day)	Source
Benzene	c/nc	NA	NA	NA	NA	4.00E-03	IRIS
Ethylbenzene	c/nc	NA	NA	5.00E-01	ATSDR-MRL	-	-
m&p-Xylene	nc	1.00E+00	ATSDR-MRL	-	-	-	-
o-Xylene	nc	1.00E+00	from m&p-xylene	-	-	-	-
Toluene	nc	8.00E-01	ATSDR-MRL	-	-	-	-

NA = Not available
- = Not applicable
c = carcinogen
c = Slope factor for cancer available, nc = RfD for non-cancer effects available , c/nc = both are available
RfD = Reference Dose
mg/kg-day = millgrams per kilogram per day
CAS = Chemical Abstract Service
IRIS: Value from EPA integrated risk information system searched on 7/28/10
ATSDR-MRL: Agency for Toxic Substances Disease Registry Minimal Risk Level for Hazardous Substances, 2009

Table 5-1
Chronic Risk Characterization for all Battlement Mesa Residents - 30 year Duration
Human Health Risk Assessment
Health Impact Assessment

	Non-Cancer Hazards			***Cancer Risks***			
Chemical	**RfC - chronic (μg/m^3)**	**Chronic Non-Cancer Intake (μg/m^3)**	**HQ**	**EPA WOE**	**IUR (1/(μg/m3)**	**Chronic Cancer Intake (μg/m^3)**	**Cancer Risk**
1,2,3-Trimethylbenzene	7.00E+00	9.68E-02	1.38E-02	-	-	-	-
1,2,4-Trimethylbenzene	7.00E+00	3.25E-01	4.65E-02	D	-	-	-
1,3,5-Trimethylbenzene	7.00E+00	1.70E-01	2.43E-02	-	-	-	-
1,3-Butadiene	2.00E+00	1.47E-01	7.35E-02	A	3.00E-05	6.29E-02	1.89E-06
1,4-Dichlorobenzene	8.00E+02	2.21E+00	2.76E-03	C	1.10E-05	9.45E-01	1.04E-05
2-Hexanone	3.00E+01	4.22E+00	1.41E-01	D	-	-	-
Acetaldehyde	9.00E+00	8.30E-01	9.22E-02	B2	2.20E-06	3.59E-01	7.90E-07
Benzene	3.00E+01	1.60E+00	5.33E-02	A	7.80E-06	6.87E-01	5.36E-06
Crotonaldehyde	-	-	-	C	5.43E-04	8.30E-02	4.51E-05
Ethylbenzene	1.00E+03	3.94E-01	3.94E-04	D	2.50E-06	1.69E-01	4.23E-07
Formaldehyde	9.80E+00	1.20E+00	1.22E-01	B1	1.30E-05	5.16E-01	6.70E-06
Methylcyclohexane	3.01E+03	5.72E+00	1.90E-03	-	-	-	-
Methylene Chloride	1.00E+03	2.78E+00	2.78E-03	B2	4.70E-07	1.19E+00	5.59E-07
Hazard Index (HI)			**6.E-01**	**Total Cancer Risk**			**7.1E-05**

Notes:

μg/m^3: michrograms per cubic meter

EPA: Environmental Protection Agency

HQ: Hazard Quotient

IUR: Incremental Unit Risk

RfC: Reference Concentration

WOE: Weight of Evidence: A - known human carcinogen; B1&B2 probable human carcinogen;
C-possible human carcinogen; D-Not enough evidence to classify carcinogencity

Table 5-2
Comparison of EPCs to BTVs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS	BTV	EPC Bell-Melton Ranch 2005-2010 (μg/m^3)	EPC> BTV?	Maximum Detected Concentration 2008 Well Completion (μg/m^3)	Maximum Detected Concentration > BTV?
1-Dodecene	112-41-4	8.83E-01	1.74E-01	no	6.08E+00	yes
1-Heptene	592-76-7	1.28E+00	7.10E-01	no	6.08E+01	yes
1-Hexene	592-41-6	1.01E-01	9.72E-02	no	1.63E-01	yes
1-Nonene	124-11-8	1.49E-01	1.20E-01	no	1.68E+01	yes
1-Octene	111-66-0	1.42E-01	1.13E-01	no	3.16E+00	yes
1-Pentene	109-67-1	1.50E-01	1.12E-01	no	3.89E-01	yes
1-Tridecene	2437-56-1	2.69E-02	8.89E-02	yes	3.63E-01	yes
1-Undecene	821-95-4	9.75E-02	1.48E-01	yes	4.72E+00	yes
2,2,3-Trimethylpentane	564-02-3	4.29E-01	1.91E-01	no	2.47E+01	yes
2,2,4-Trimethylpentane	540-84-1	2.46E-01	2.14E-01	no	1.98E-01	no
2,2-Dimethylbutane	75-83-2	1.00E+00	6.76E-01	no	4.12E+01	yes
2,3,4-Trimethylpentane	565-75-3	2.25E-01	1.27E+00	yes	1.21E+00	yes
2,3-Dimethylbutane	79-29-8	1.85E+00	1.36E+00	no	6.58E+01	yes
2,3-Dimethylpentane	565-59-3	9.48E-01	5.70E-01	no	3.56E+01	yes
2,4-Dimethylpentane	108-08-7	6.55E-01	4.06E-01	no	2.36E+01	yes
2-Methyl-1-butene	563-46-2	1.38E+00	1.23E+00	no	1.26E+00	no
2-Methyl-1-pentene	763-29-1	2.47E-01	1.52E-01	no	8.43E-02	no
2-Methyl-2-butene	513-35-9	3.05E-01	1.07E-01	no	3.87E-01	yes
2-Methylheptane	592-27-8	1.61E+00	7.01E-01	no	1.46E+02	yes
2-Methylhexane	591-76-4	2.71E+00	1.54E+00	no	1.21E+02	yes
2-Methylpentane	107-83-5	8.75E+00	5.98E+00	no	2.21E+02	yes
3-Methyl-1-butene	563-45-1	1.15E-01	9.44E-02	no	2.49E-01	yes
3-Methylheptane	589-81-1	1.17E+00	4.55E-01	no	9.74E+01	yes
3-Methylhexane	589-34-4	2.72E+00	1.27E+00	no	1.14E+02	yes
3-Methylpentane	96-14-0	5.63E+00	3.12E+00	no	1.29E+02	yes
4-Methyl-1-pentene	691-37-2	7.00E-01	2.28E-01	no	9.35E-01	yes
Acetylene	74-86-2	3.03E-01	6.97E-01	yes	8.40E-01	yes
a-Pinene	80-56-8	5.90E-01	2.31E-01	no	3.09E+01	yes
b-Pinene	127-91-3	3.72E-01	1.23E-01	no	8.96E+00	yes
cis-2-Butene	590-18-1	8.14E-02	7.95E-02	no	1.97E-01	yes
cis-2-Hexene	7688-21-3	2.95E-01	1.00E-01	no	2.93E-01	no
cis-2-Pentene	627-20-3	6.07E-02	6.12E-02	yes	1.48E-01	yes
Cyclopentane	287-92-3	9.63E-01	8.00E-01	no	2.23E+01	yes
Cyclopentene	142-29-0	4.72E-01	1.66E-01	no	6.51E-01	yes
Ethane	74-84-0	8.30E+01	9.02E+01	yes	2.41E+03	yes
Ethylene	74-85-1	9.39E-01	1.09E+00	yes	4.19E+00	yes
Isobutane	75-28-5	2.28E+01	2.62E+01	yes	1.60E+03	yes
Isobutene/1-Butene	115-11-7 / 106-98-9	1.07E+01	1.60E+00	no	6.71E+00	no
Isopentane	78-78-4	2.38E+01	2.24E+01	no	8.32E+02	yes
Isoprene	78-79-5	1.10E+00	5.03E-01	no	1.15E+00	yes
m-Diethylbenzene	141-93-5	4.10E-01	1.18E-01	no	7.08E+00	yes
Methylcyclopentane	96-37-7	5.85E+00	2.89E+00	no	1.20E+02	yes
m-Ethyltoluene	620-14-4	6.28E-01	2.21E-01	no	4.45E+01	yes

Table 5-2
Comparison of EPCs to BTVs
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS	BTV	EPC Bell-Melton Ranch 2005-2010 (µg/m³)	EPC> BTV?	Maximum Detected Concentration 2008 Well Completion (µg/m³)	Maximum Detected Concentration > BTV?
n-Butane	106-97-8	2.61E+01	3.14E+01	yes	1.29E+03	yes
n-Decane	124-18-5	1.81E+00	2.24E+00	yes	2.08E+02	yes
n-Dodecane	112-40-3	1.55E+00	3.74E+00	yes	5.15E+01	yes
n-Heptane	142-82-5	5.48E+00	2.85E+00	no	3.04E+02	yes
n-Octane	111-65-9	3.74E+00	1.61E+00	no	4.17E+02	yes
n-Tridecane	629-50-5	3.12E-01	2.92E-01	no	9.05E+00	yes
n-Undecane	1120-21-4	2.17E+00	1.15E+01	yes	1.21E+02	yes
o-Ethyltoluene	611-14-3	3.08E-01	1.65E-01	no	2.92E+01	yes
p-Diethylbenzene	105-05-5	1.12E-01	7.00E-02	no	5.01E+00	yes
p-Ethyltoluene	622-96-8	3.60E-01	1.62E-01	no	3.22E+01	yes
Propane	74-98-6	5.26E+01	6.94E+01	yes	4.67E+03	yes
trans-2-Butene	624-64-6	2.06E-01	1.74E-01	no	1.89E+00	yes
trans-2-Hexene	4050-45-7	1.03E-01	3.04E-02	no	4.53E-02	no
trans-2-Pentene	4050-45-7	1.27E-01	8.08E-02	no	3.05E-01	yes

Notes
BTV: Background Threshold Value
EPC: Exposure Point Concentration
CAS: Chemical Abstract Service
µg/m³: micrograms per cubic meter

Table 5-3

Chronic Risk Characterization for Residents Living Adjacent to a Well Pad - 30 Year Duration

Human Health Risk Assessment

Health Impact Assessment

	Non-Cancer Hazards			*Cancer Risks*			
Chemical	**RfC - chronic (µg/m^3)**	**TWA Inon-Cancer Intake (µg/m^3)**	**HQ**	**EPA WOE**	**IUR (1/(µg/m3)**	**TWA Cancer Intake (µg/m^3)**	**Cancer Risk**
1,2,3-Trimethylbenzene	7.00E+00	4.05E-01	5.79E-02	-	-	-	-
1,2,4-Trimethylbenzene	7.00E+00	2.53E+00	3.61E-01	D	-	-	-
1,3,5-Trimethylbenzene	7.00E+00	2.23E+00	3.19E-01	-	-	-	-
1,3-Butadiene	2.00E+00	1.47E-01	7.35E-02	A	3.00E-05	6.30E-02	1.89E-06
1,4-Dichlorobenzene	8.00E+02	2.21E+00	2.76E-03	C	1.10E-05	9.45E-01	1.04E-05
2-Hexanone	3.00E+01	4.22E+00	1.41E-01	D	-	-	-
Acetaldehyde	9.00E+00	8.38E-01	9.31E-02	B2	2.20E-06	3.59E-01	7.90E-07
Benzene	3.00E+01	3.38E+00	1.13E-01	A	7.80E-06	1.45E+00	1.13E-05
Crotonaldehyde	-	-	-	C	5.43E-04	8.30E-02	4.51E-05
Ethylbenzene	1.00E+03	6.47E+00	6.47E-03	D	2.50E-06	2.77E+00	6.93E-06
Formaldehyde	9.80E+00	1.20E+00	1.22E-01	B1	1.30E-05	5.16E-01	6.70E-06
Methylcyclohexane	3.01E+03	2.48E+01	8.24E-03	-	-	-	-
Methylene Chloride	1.00E+03	4.33E+00	4.33E-03	B2	4.70E-07	1.86E+00	8.74E-07
m&p-Xylene	1.00E+02	2.54E+01	2.54E-01	D	-	-	-
n-Hexane	7.00E+02	1.29E+01	1.84E-02	D	-	-	-
n-Nonane	2.00E+02	8.74E+00	4.37E-02	-	-	-	-
n-Pentane	1.00E+03	2.87E+01	2.87E-02	-	-	-	-
o-Xylene	7.00E+02	5.53E+00	7.91E-03	D	-	-	-
Hazard Index (HI)			**2.E+00**	**Total Cancer Risk**			**8.3E-05**

Notes:

µg/m^3: micrograms per cubic meter

EPA: Environmental Protection Agency

HQ: Hazard Quotient

IUR: Incremental Unit Risk

RfC: Reference Concentration

TWA: Time weighted average

WOE: Weight of Evidence: A - known human carcinogen; B1&B2 probable human carcinogen; C-possible human carcinogen; D-Not enough evidence to classify carcinogencity

Table 5-4
Acute Risk Characterization for Child Resident Living Adjacent to Well Pad - 7-day Duration
Human Health Risk Assessement
Health Impact Assessment

Chemical	Primary target system	RfC - acute ($\mu g/m^3$)	Acute Intake ($\mu g/m^3$)	HQ
Ambient Air				
1,2,3-Trimethylbenzene	Neurologic, Respiratory, Immunologic	7.00E+00	1.17E+01	1.67E+00
1,2,4-Trimethylbenzene	Neurologic, Respiratory, Immunologic	7.00E+00	8.30E+01	1.19E+01
1,3,5-Trimethylbenzene	Neurologic, Respiratory, Immunologic	7.00E+00	7.75E+01	1.11E+01
1,3-Butadiene	Reproductive	2.00E+00	1.66E-01	8.29E-02
2-Hexanone	Neurologic	3.00E+01	4.22E+00	1.41E-01
Acetaldehyde	Respiratory	9.00E+00	1.96E+00	2.18E-01
Benzene	Immunologic	2.90E+01	1.80E+02	6.21E+00
Chloroform	Neurologic	4.90E+02	1.60E+00	3.27E-03
Ethylbenzene	Developmental	4.30E+04	9.60E+01	2.23E-03
Formaldehyde	Respiratory	4.90E+01	1.02E+01	2.08E-01
Methylcyclohexane	Renal	3.01E+03	7.23E+02	2.40E-01
m&p-Xylene	Neurologic	8.70E+03	1.50E+03	1.72E-01
n-Hexane	Neurologic	7.00E+02	2.55E+02	3.64E-01
n-Nonane	Neurologic	2.00E+02	3.03E+02	1.51E+00
n-Pentane	Neurologic	1.00E+03	5.53E+02	5.53E-01
o-Xylene	Neurologic	7.00E+02	2.60E+02	3.71E-01
Toluene	Neurological and Respiratory	3.80E+03	5.40E+02	1.42E-01
Hazard Index (HI)				***3.47E+01***
		RfD - acute (mg/kg-day)	**Acute Intake (mg/kg-day)**	**HQ**
Surface Water				
Benzene	Immunologic	4.00E-03	2.00E-03	5.00E-01
Ethylbenzene	Developmental	5.00E-01	1.23E-02	2.45E-02
m&p-Xylene	Neurologic	1.00E+00	4.79E-03	4.79E-03
o-Xylene	Neurologic	1.00E+00	1.71E-03	1.71E-03
Toluene	Neurological and Respiratory	8.00E-01	4.86E-02	6.08E-02
Hazard Index (HI)				***5.92E-01***
Ambient Air and Surface Water				
Total Hazard Index (HI)				**4.E+01**

Notes:

$\mu g/m^3$: michrograms per cubic meter

EPA: Environmental Protection Agency

HQ: Hazard Quotient

mg/kg-day: milligrams per kilogram per day

RfC: Reference Concentration

RfD: Reference Dose

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
#1 diesel	8008-20-6
#2 Diesel	68476-34-6
(sulfonic acids, petroleum, calcium salts)	61789-86-4
1,2 benzanthracene	56-55-3
1,2-benzphenanthrene	218-01-9
2-Aminoethanol	141-43-5
2-ethoxyethanol	110-80-5
2-methyl-4-isothiazolin-3-one	2682-20-40
2-pentanone, 4 -methyl(hexone)	108101
5-cholro-2-methyl-4-isothiazolin-3-one	26172-55-4
acenaphthene	83-32-9
Additives	proprietary
aliminum oxide	1344-28-1
aliphatic glyicdyl ether	2461-15-6
Aliphatic petroleum distallates	64742-89-8
alkali carbonates	584-08-7
alkoxylated long-chain alkyl amine	proprietary
alkyd resin	Not listed
Alkyl (C12-16) dimethylbenzylammonium chloride	68424-85-1
aluminum	7429-90-5
aluminum stearate	68442-97-7
Amino Methylene Phosphonic Acid Salt	proprietary
amino silane	1760-24-3
ammonium sulfate	7783-20-2
amorphous fumed silica	112945-52-5
anthracene	120-12-7
antioxidant	trade secret
argon	7440-37-1
aromatic petroleum distallates	64742-96-6
asphalt	8052-42-4
attaclay	8031-18-3
barium sulfate	7727-43-7
bentonite	1302-78-9
benzo(a)pyrene	50-32-8
benzo(b)fluoranthene	205-99-2
benzo(g,h,i)perylene	191-24-2
benzo(J)fluoranthene	205-82-3
benzo(K)fluoranthene	207-08-9
benzyldimethlamine	103-83-3
bisphenol A	80-05-7
bisphenol'A'/epichlorohydrin based epoxy	25068-38-6
boric acid	10043-35-3
calcium aluminate	12042783
calcium aluminate /iron oxide	12068358
calcium carbonate	471-34-1
calcium carbonate	1317-65-3
calcium fluoride	7789755
calcium hydroxide	01305-62-0

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
calcium hypochlorite	7778-54-3
calcium oxide	1305-78-8
calcium oxide, magnesium oxide, potassium sulfate, sodium sulfate	1003
calcium silicates	various
calcium sulfate	13397245
carbon	7440-44-0
carbon black	1333-86-4
carbon dioxide	124-38-9
carbon monoxide	0630-08-0
cellulose	65996-61-4
chlorinated paraffin	Not listed
chromium	7440-47-3
chromium (VI) as Cr	7440-47-3
Copper	7440-50-8
corrosion inhibitor	mixture
crystalline silica (cristobalite)	14464-46-1
crystalline silica (quartz)	14808-60-7
dibenz(A,H)anthracene	53-70-3
dibenzo(a)pyrene	189-55-9
dibenzo(a,e)pyrene	192-65-4
dibenzo(a,h)pyrene	189-64-0
dibutyl phthalate	84-74-2
diethylene glycol	111-46-6
diethylene glycol monoethyl ether	111-90-0
dipentamethylene thiuram tetrasulfide	120-54-7
dipotassium phosphate	2139900
dipropylene glycol	34590948
di-tocopherol	59-02-9
epoxy resin	25085-99-8
ethanol	64-17-5
ethyl acetate	141-78-6
ethyl ether	60-29-7
ethyl mercaptan	75-08-1
ethyl silicate	78-10-4
ethylene glycol	107-21-1
ethylene glycol monobutyl ether	111-76-2
ethylene glycol monoethyl ether acetate	111-15-9
ethylene glycol monomethyl ether	109-86-4
feldspar	Not listed
ferric oxide hydroxide	51274-00-0
fluoranthene	206-44-0
fluorene	86-73-7
fluorides	7789-75-5
fumed silica	67762-90-7
gasoline	mixture
Glutaraldehyde	111-30-8
glycerine (glycerol)	56-81-5

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
glycerol	56-81-5
glycol ether EB acetate	112-07-2
graphite	7782-42-5
gypsum	777-8-18-9
heavy aromatic naphtha	68603-08-7
helium	7440-59-7
highly refined base oils	mixture
highly refined mineral oil C15-C50	mixture
highly solvent-refinded base oils	64741-88-4
	64742-01-4
hydrocarbon propellant	684 76-86-8
Hydrochloric acid	7647-01-0
hydrogen	133-74-0
hydrogen sulfide	7783-06-4
hydrosulferized kerosene C9-16	64742-81-0
hydrotreated distallate, light C9-16	64742-47-8
hydrotreated heavy naphtha (petroleum(	64742489
hydrous alluminum silicate	Not listed
indeno (1,2,3-cd) pyrene	193-39-5
iron	7439-89-6
iron oxides	65996-74-9
isohexane isomers	107-83-5
Isopropanol	67-63-0
isopropyl acetate	108-21-4
lead chromate	1344372
leonardite	1414-93-6
lithium compounds	554-13-2
lithium sterate soap	7620-77-1
lubicant base oil	various
magnesite	1309-48-4
magnesium	7439954
magnesium carbonate	546-93-0
magnesium oxide	1309-58-4
manganese	7439-96-5
mercaptobenzothiazole	149-30-4
metallic coating	mixture
Methanaminium, N N N trimethyl-,chloride	75-57-0
methane	0074-82-8
Methanol	67-56-1
methyl n-amyl ketone	110-43-0
methyl n-propyl ketone	107-87-9
mica	12001-26-2
mineral oil	8042-47-5
Mineral oil, petroleum distallates, hydrotreated (severe) heavy naphthenic; (mineral oil)	64742525
Mineral oil, petroleum distallates, hydrotreated (severe) light naphthenic; (mineral oil petroleum distallates)	64742536
mineral silicates	1332-58-7

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
mineral spirits	8052-41-3
mineral spirits (F)	64742-88-7
modified aliphatic amine	Not listed
molybdenum	7439-98-7
mono ammonium phosphate	7733-76-1
N-aminoethypiperazine	140-31-8
Naphthalene	91-20-3
n-butanol	71-36-3
nickel	7440-02-0
nitrogen	7727-37-9
non-phenol ethoyxalates	Not listed
nonyl phenol	25154-52-3
nonylphenol ethoxylates	9016-45-9
nut shells	NA
octyl alcohol	111-87-5
oil mists	mixture
organic cobalt compounds	various
organophillic clay	71011-26-2
partially hydrolized polyacrylamide	Not listed
perchloroethylene	127-18-4
petroleum base oil	64742-65-0
Petroleum Grease Mixture	64742-52-5, 7620-77-1, 68783-36-8, Mixture
petroleum product additive	Not listed
phenanthrene	85-01-8
phosphated polyester	proprietary
phosphorous (yellow)	7723-14-0
poly[oxyethylene(dimethylimino)ethylene(dimethyleimino)ethylenedichloride	31512-74-0
polyamide resin	68410-23-1
polyanionic carboxymethyl cellulose	Not listed
polyethelene co-polymer	Not listed
polyethylene	9002884
polyethylene or polyethylene-butene copolymer or polyethylene-hekene copolymer	9002883
polyethylene-butene	25087347
polyethylene-hexene	25213029
Polytef [USAN]	9002-84-0
polyvinyl chloride	Not listed
Polyvinyl Chloride Resin	non/haz
portland cement	65997-15-1
potassium acid fluoride	7789-29-9
potassium aluminum silicate (potassium feldspar)	68476255
potassium borate	1332-77-0
potassium pentaborate	11128-29-3
potassium silicate	1312761
proprietary additives	proprietary

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
proprietary pigment (nuisance dust)	proprietary
propylene carbonate	108-32-7
PVC resin	9002-86-2
pyrene	129-00-0
red dye	4477-79-6
red iron oxide	1309-37-1
refined coal tar pitch (contains PAH's)	65996-93-2
silica (precipitated)	112926-00-8
silica amorphous	7631-86-9
silica, crystalline, quartz	148-06-60-7
silica, crystalline, tridymite	15468-32-3
silicic acid, disodium salt (sodium silicate)	6834920
silicon	7440-21-3
silicon fluid (poly (dimethylsiloxane), dimethyl	63148629
silicone oil	63148-57-2
slag coal	Not listed
sodium carbonate	497-19-8
sodium acid pyrophosphate	7758-16-9
sodium bicarbonate	7447-40-7
sodium carbomethyl starch	9063-38-1
sodium chloride	7647-14-5
sodium fluoride	7681-49-4
sodium hydroxide	1310-73-2
sodium silicate	1344-09-8
soft/hard wood sawdust ex W red cedar	mixture
soluble barium compound	Not listed
subtilisin	1/1/9014
sulfamic acids	5329-14-6
sulfur	7404-34-9
talc (respirable dust)	14807-96-9
talc [JAN]	14807-96-6
tetrahydrofuran	109-99-9
thiocarbamates	Not listed
tin	7440-31-5
titanium	12719-90-5
titanium dioxide	13463-67-7
triclosan	3380-34-5
triethylenetetramine	112-24-3
Triisopropanolamine	122-20-3
vanadium	1314-62-1
violet dye	81-48-1
yellow pigment	5468-75-7
zinc	1314-13-2
zinc compound	proprietary
Zinc dialkyldithiophosphate	68649-42-3
zinc oxide	1314-13-2
zirconium	12004-83-0
Zirconium acetate lactate ammonium complex	68909-34-2

Table 6-1
Chemicals Identified from Antero's MSDS
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Chemical	CAS Number
zirconium dioxide (zirconium silicate)	7440677
zirconium silicate	14940-68-2

Table 7-1
Summary of Risk Characterization
Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

Exposure Scenario	Exposure	Hazard Index (HI)	Cancer Risk
All Battlement Mesa Residents - 30 years	Chronic	1	7.1E-05
Residents living near a well pad - 30 years	Chronic	2	8.3E-05
Child Resident living near a well pad - 7 days			
-Ambient Air Exposure Pathway[1]	Acute	35	-
-Surface Water Exposure Pathway	Acute	0.6	-
'-Ambient Air plus Surface Water Pathways	Acute	40	-

[1]Also applies to adult residents for 7-day acute exposure

Figure 2-1
Temporal Trends of BTEX at Bell-Melton Monitoring Station - 2005 to 2010

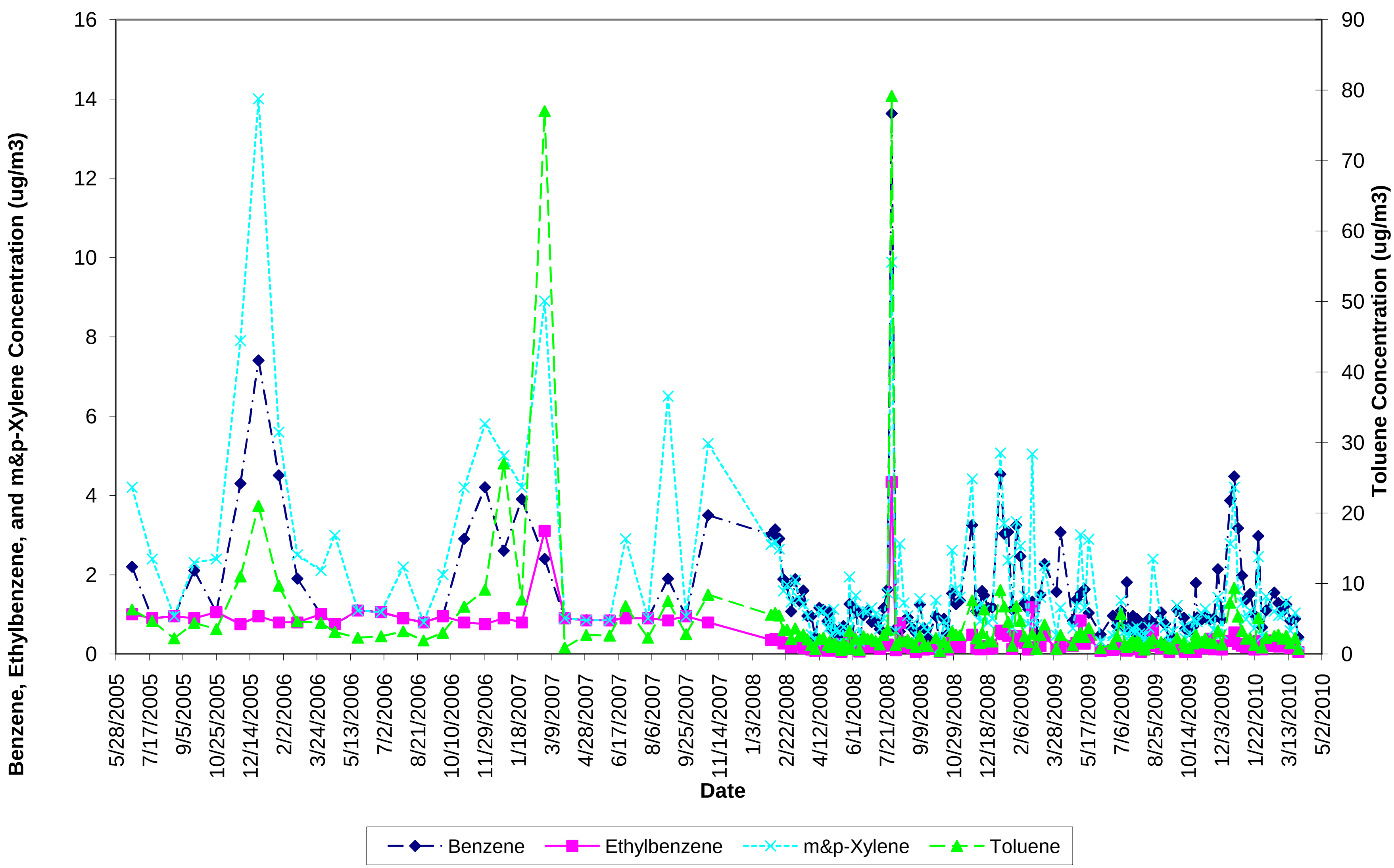
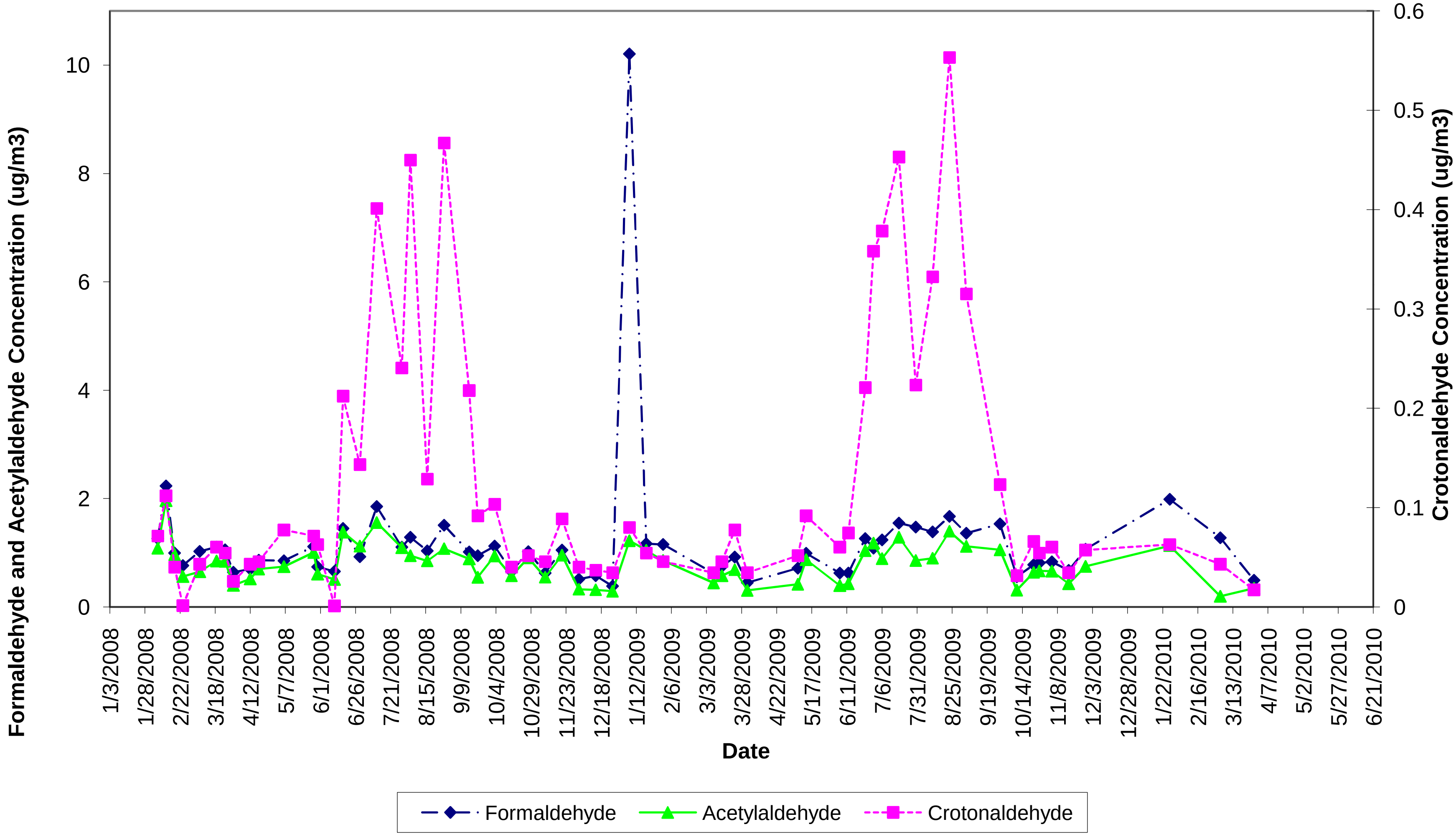


Figure 2-2
Temporal Trends for Carbonyls
Bell Melton Ranch Monitoring Station



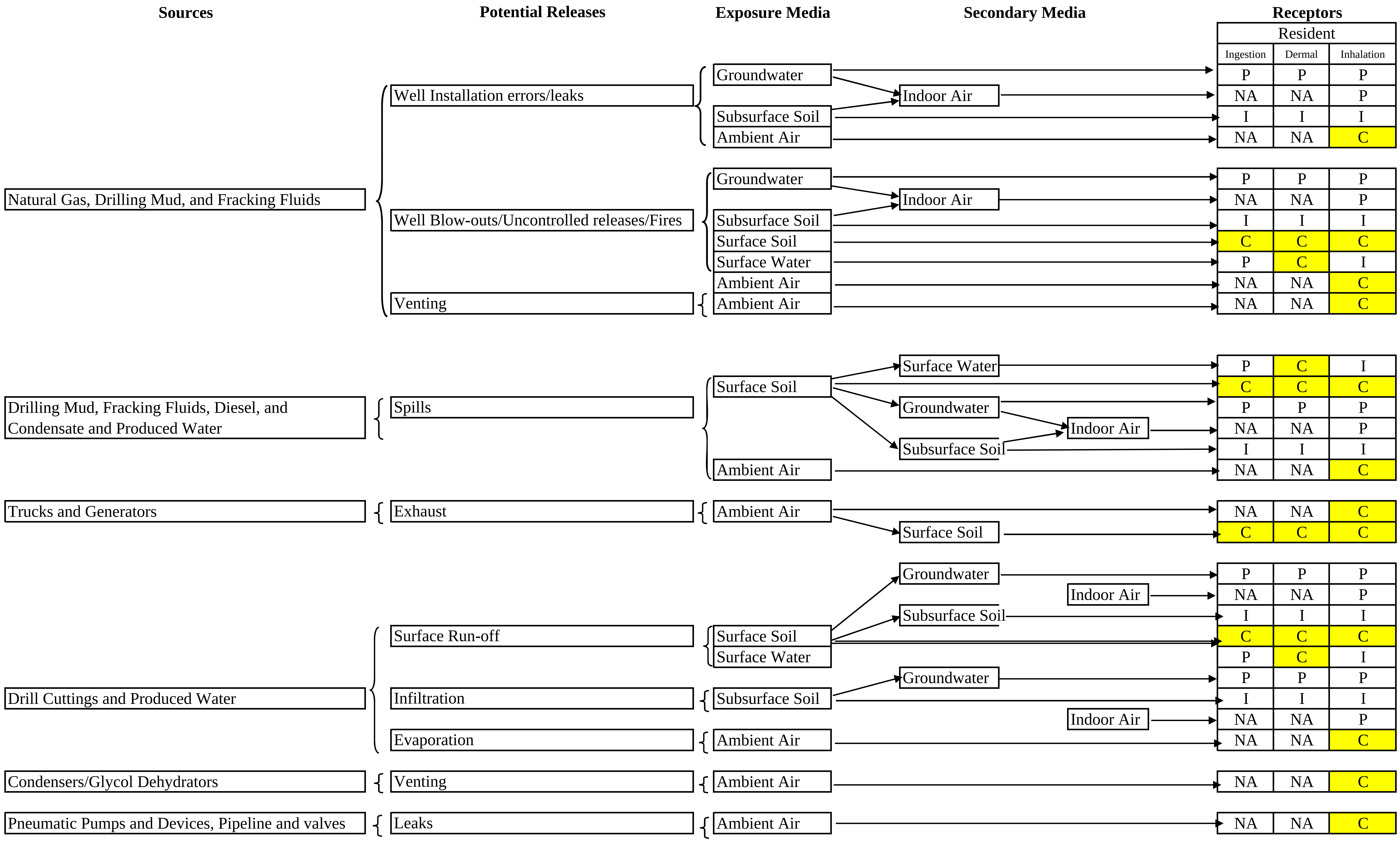


Figure 3-2: Conceptual Site Model for Battlement Mesa Health Impact Assessment
C = Complete Pathway I = Incomplete Pathway P = Potential Pathway NA = Not Applicable

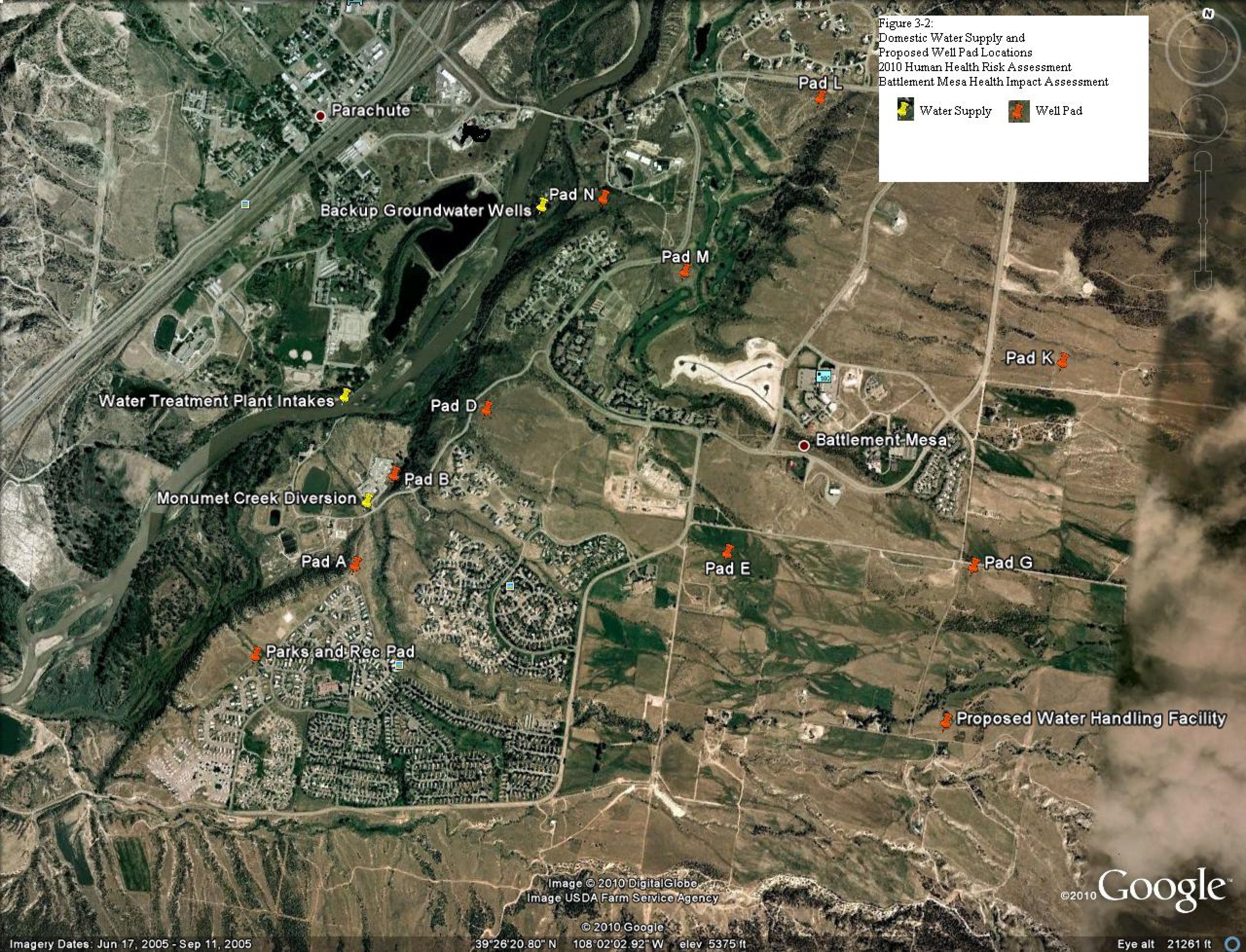


Figure 3-2:
Domestic Water Supply and
Proposed Well Pad Locations
2010 Human Health Risk Assessment
Battlement Mesa Health Impact Assessment
Water Supply
Well Pad
Parachute
Pad L
Pad N
Backup Groundwater Wells
Pad M
Pad K
Water Treatment Plant Intakes
Pad D
Battlement Mesa
Pad B
Monumet Creek Diversion
Pad A
Pad E
Pad G
Parks and Rec Pad
Proposed Water Handling Facility
Image © 2010 DigitalGlobe
Image USDA Farm Service Agency
© 2010 Google
©2010 Google
Imagery Dates: Jun 17, 2005 - Sep 11, 2005
39°26'20.80" N 108°02'02.92" W elev 5375 ft
Eye alt 21261 ft

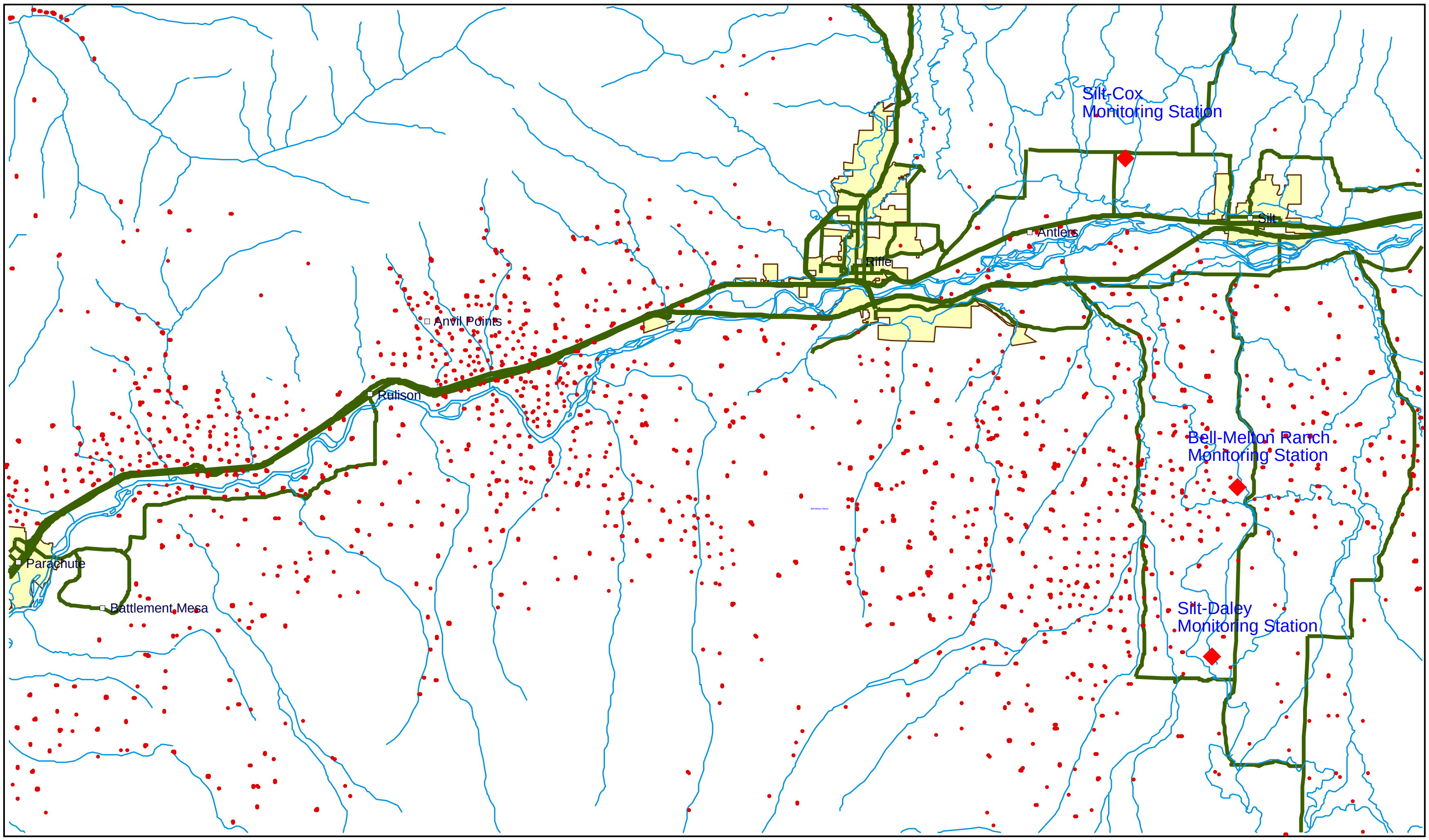


Figure 3-3: Locations of Baseline and Bell-Melton Ranch Monitoring Stations
2010 Human Health Risk Assessment
Battlement Mesa Health Impact Assessment

● = Natural gas or oil well ■ = Monitoring Station ▬ = Road

BATTLEMENT CONCERNED CITIZENS

Battlement Mesa, Colorado

November 6, 2009

Garfield County Dept. of Public Health
195 W. 14th Street
Rifle, CO 81650

Dear Ms. Meisner and Mr. Rada:

On behalf of the Battlement Concerned Citizens (BCC), a committee of the Grand Valley Citizens Alliance, we thank you for the opportunity to discuss the special public health concerns associated with natural gas development within the Battlement Mesa Planned Unit Development (PUD). We appreciate talking to public health officials who understand and appreciate the potentially serious health hazards from the drilling industry.

To be sure, drilling up to 200 wells, with some rigs planned within 400 feet of homes, has raised considerable health concerns within the community. Within two weeks in September, BCC members garnered over 400 signatures from Battlement Mesa residents on a petition to the Board of County Commission (BOCC), the Colorado Oil and Gas Conservation Commission (COGCC), and the Colorado Department of Public Health and Environment (CDPHE). That petition asked that these agencies defer any permitting decision until a thorough study of the public health, safety and welfare concerns has been completed.

In our discussion with you, BCC members stressed that Battlement Mesa is a unique community and therefore, a special health baseline study is warranted before drilling within the PUD continues from the Williams Production well pad or is expanded with Antero's Comprehensive Drilling Plan (CDP).

As noted in our discussion last week:

- Battlement Mesa has approximately 5000 residents, many of whom are seniors with existing health problems and compromised immune systems. Also included are three schools with about 600 students and Mesa Vista Assisted Living facility with 35 to 45 elderly citizens with 6 of them currently on oxygen.
- Because of the unknown chemical compositions used in drilling practices, oil-and-gas exploration operations within Battlement Mesa could expose a large number of vulnerable people to potentially long-term adverse health and environmental impacts -- making sick people sicker

- There are currently no effective means of monitoring drilling chemical use and its impacts on air and water quality within the Battlement community
- Data from the air quality study that was completed in 2008 was used by Dr. Russ Walker to show there are real hazards from drilling operations in close proximity to humans. Drs. Walker and Teresa Coons also went on to make a series of recommendations to protect public health based on the study data.

On behalf of Battlement Mesa citizens, BCC members have requested the county and state to conduct a "Health Impact Assessment" (HIA) before a Special Use Permit (SUP) is approved to **any** company drilling within the Battlement Mesa PUD.

We feel these subjects should be addressed in a Battlement HIA:

- The baseline health study should be specific to Battlement Mesa and it's population
- Conduct baseline monitoring of air and water quality within the Battlement PUD before any drilling operations continue
- Conduct a comprehensive and continuous air, water, and soil quality monitoring system at all well sites during all phases of operation
- Establish a medical monitoring system to identify any changes in baseline data or trends and/or anomalies in medical practices
- Require full disclosure of materials used in drilling and fracturing processes to health officials and scientists conducting these studies
- Test whether a buffer zone of not less than one thousand feet between any well operation and any residence, business, or public building will protect health standards

Recent COGCC Rule Amendments encourage responsible energy development and inter-agency collaboration. The CDPHE has the authority to participate in the permit review process and recommend additional measures to protect public health. In short, Garfield County has an opportunity to communicate with both state agencies to request additional public or environmental protections. Certainly, Battlement Mesa's unique situation requires additional oversight and analysis – and provides an opportunity for agencies to collaborate on a detailed HIA -- possibly the first such study conducted in the state in regards to energy development in an established residential area of people with compromised health issues.

Funding sources are many. For instance, the Robert Wood Johnson Foundation and the Pew Charitable Trusts are currently welcoming HIA proposals from local and state agencies, non-profit organizations, and business interests. We also feel that other sources of funding should be pursued. Recently Garfield County received an additional approximately $8 million in severance tax revenue from the state. Some of those funds, as well as monies from the Energy Mitigation Fund could be utilized. Also, if any funds are generated from fines to energy operators for violations of county regulations, those monies should also be considered. It may also be appropriate to require any organization seeking county approval for gas drilling or exploration operations in the PUD to participate in the cost of an HIA as a condition of the application process. The CDPHE might also participate in such a project – either financially or otherwise.

Natural gas is an important domestic energy that merits responsible development. However, some of its development practices remain unsafe and there are particular areas where drilling proposals deserve additional scrutiny and oversight. Since our community will need additional levels of protection when so many wells are to be developed, we believe the people of Battlement Mesa deserve a public health risk and baseline environmental study to ensure public health protection during all stages of energy development.

We appreciate that you will take our concerns to the appropriate members of the BOCC, COGCC, and CDPHE and we look forward to further discussion with you regarding the HIA process.

Thank you for your consideration.

Battlement Concerned Citizens

Bob Arrington
285-9757
baar@rof.net

Dave Devanney, Co-Chair
285-2263
dgdevanney@comcast.net

Ron Galterio, Co-Chair
285-0243
mrgalterio@aol.com

SURFACE USE AGREEMENT

This Surface Use Agreement ("Agreement") is entered into and made effective this 15th day of January, 2009 ("Effective Date") by and between Battlement Mesa Partners, LLC a Colorado limited liability company d/b/a Battlement Mesa Company, and Battlement Mesa Land Investments, LLC, Battlement Mesa Land Investments Parcel 1 LLC, Battlement Mesa Land Investments Parcel 2 LLC, Battlement Mesa Land Investments Parcel 3 LLC, Battlement Mesa Land Investments Parcel 6 LLC, Battlement Mesa Land Investments Parcel 7 LLC, Battlement Mesa Land Investments Parcel OHS LLC, Battlement Mesa Land Investments Parcel 5-1, TRK3 and 4 LLC, Battlement Mesa Land Investments Parcel 5-2, TRK 5 LLC, Battlement Mesa Land Investments Parcel 5-2, TRK 6 LLC, Battlement Mesa Land Investments Parcel Fairways LLC, Green Head Investments 1 LLC, Burning Rock B2L2 LLC, MCV2 Church Site LLC, Battlement Mesa Golf Course, LLC, Saddleback Village Convenience Center, LLC, Willow Park Apartments LLC, Battlement Mesa Land Investments Parcel 1-A, LLC, Paradise Valley Minerals LLC, Battlement Mesa Land Investments Town Center 1 LLC, Battlement Mesa Land Investments Town Center 2 LLC, Battlement Mesa Land Investments Town Center 3 LLC, Battlement Mesa Plaza Town Center, LLC, Battlement Mesa Land Investments Parcel 5-1, TRK 2 LLC, Battlement Mesa Land Investments OES LLC, Battlement Mesa RV Park LLC, Battlement Mesa RV Storage LLC, Battlement Mesa Office I LLC, Modular Homes LLC, Tamarisk Village Pads, LLC, Willow Ridge at Battlement Mesa LLC, , Battlement Mesa Parcel 5 LLC, Battlement Mesa Lot Holdings LLC, whose address is 73 G Sipprelle Drive, Battlement Mesa Colorado 81635 hereinafter, collectively, called "Owner", Exxon Mobil Corporation hereinafter called "ExxonMobil", and Antero Resources Piceance Corporation, 1625 Seventeenth Street, Suite 300, Denver, Colorado 80202, hereinafter called "Operator." Owner and Operator may be referred to individually as a "Party" and collectively as the "Parties."

WHEREAS, the Owner owns portions of the surface of a tract of land described in the attached Exhibit A located in Garfield County, Colorado, identified as a part of Battlement Mesa PUD, hereinafter referred to as the "Property" and currently is in the process of developing the same for residential and commercial uses;

WHEREAS, the Property is subject to a surface use agreement with predecessor of ExxonMobil dated December 12, 1989 ("BMP-ExxonMobil SUA") which agreement reserved to ExxonMobil the right to use portions of the Property to develop its mineral interest underlying the Property;

WHEREAS, Operator holds valid and subsisting oil and gas leasehold rights underlying portions of the Property from both ExxonMobil, Owner and other parties, and, as such has the right to reasonable use of the surface of the Property to explore for, develop, and produce certain of the oil, gas and other hydrocarbons ("Oil and Gas") that underlie the Property; and,

WHEREAS, the Parties desire to enter into this Agreement to supersede in part the BMP-ExxonMobil SUA and to set forth their understanding of the rights and obligations of the Parties concerning operations on and development of the Property and to provide for the coexistence and joint development of the surface estate and the Oil and Gas estate and to delineate the process through which the two estates will be developed; and

WHEREAS, it is the intent of the Parties that all of the existing owners of the surface of the Property be included in this Agreement, and for that purpose and to the best of the Owners' knowledge, all of the entities related to Battlement Mesa Partners LLC that have an ownership interest in the surface estate in the Property are listed in the first attestation paragraph above. To the extent it is later determined that entities that have an ownership interest in the Property and that are related to Battlement Mesa Partners LLC are not parties to this agreement, Owner shall cause those omitted entities to ratify and endorse this Agreement when they are subsequently identified;

NOW, THEREFORE, in consideration of the mutual promises contained herein, and ten dollars ($10.00) and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, the Parties agree as follows:

1. Grant of Easement. Owner hereby grants to Operator a right-of-way and easement on, over, through, under and across the Property for the purpose of drilling, completing, operating and producing gas wells, conducting reservoir fracture stimulation operations, re-completing and monitoring wells therefore, together with the right-of-way and easement on, over, through and across the Property necessary to construct operate, maintain and repair (including but not limited to) access roads, fluid retention reservoirs, well sites, tank batteries, compressors, electrical lines, facilities, pipelines for handling both production produced from the Property, as well as that produced from other lands which Owner may not have an interest, which may be necessary for Operator to have a continuous and efficient pipeline system, pigging facilities, tanks, water discharge, and any other actions deemed necessary by Operator for its operations. Operator shall provide, within ninety (90) days of the execution of this Agreement, legal descriptions of the pipeline easements granted herein as well as envelopes for Wellsite Locations and their access roads. These legal descriptions are to be provided by Schmueser, Gordon, Meyer, or an engineering firm selected by the agreement of Owner and Operator.

2. Conformance with Exhibit B. Operator shall locate and stake the proposed placement of all Wellsite Locations, all access roads, and all gas-gathering lines, as depicted on Exhibit B for inspection by Owner at leas[redacted] calendar days prior to any construction operations for such proposed surface activity. Owner may inspect the staked locations and their boundaries to determine whether they conform to the locations as depicted on Exhibit B. Within [redacted] calendar days of having been notified of such staking, Owner may object to the staked locations and their boundaries on the grounds that they do not conform to the locations as depicted on Exhibit B. If Owner objects, Operator shall either re-stake the locations if it does not actually conform to the survey, or confirm that it does actually conform with to the locations as depicted on Exhibit B. If Owner does not object within [redacted] calendar days after having received the initial notice, then it will be deemed to have waived any objection to the staked locations.

REDACTED

3. Wellsite Locations. Exhibit B depicts locations of the planned well sites and central-water handling and treatment facilities ("Wellsite Locations") to be used by the

Operator to develop the Oil and Gas estate. Operator agrees to restrict its Oil and Gas Operations to the easements for the Wellsite Locations shown on Exhibits B. "Oil and Gas Operations" are defined to include, but are not limited to, drilling, completion, and maintenance of wells and equipment, production operations, workovers, well recompletions and deepenings, fracturing, twinning and the drilling of replacement wells and the location of associated Oil and Gas production equipment. Specific operational requirements applying to individual Wellsite Locations are shown in Exhibit C. Any material deviation from the planned location of the Wellsite Locations, as shown in Exhibits B will require Owner's prior written approval, which approval will not be unreasonably withheld. "Material Deviation" is defined as any proposed surface use or occupancy by Operator outside the boundaries of the Wellsite Locations identified on Exhibit B.

a. Operator shall locate, build, repair, and maintain tanks, separators, treaters, dehydrators, and all other associated oil and gas drilling and production equipment and facilities, and wellhead compressors, only within the Wellsite Locations shown on Exhibit B. Operator shall have the right to install, replace, operate and maintain equipment on Wellsite Locations. Operator shall only be permitted to have a repair and maintenance facility at the central water handling and treatment facilities located at Wellsite Location F, with use of such facility limited to operations conducting under this Agreement and conditioned upon the requirements specified on Exhibit C.

b. Without waiving its right to use the full dimensions of the Wellsite Location as described in Exhibit B, Operator shall use good faith efforts to construct the Wellsite Locations to be as small as reasonably feasible for drilling and completion activities and will attempt to reclaim the Wellsite Locations to an area no larger than is necessary to support production equipment and future workover and recompletion or re-drilling activity.

c. Supporting facilities that may be located on Wellsite Locations include but are not limited to, closed mud systems, well head equipment, lines to carry condensate, gas and water, tanks, dehydrators, treaters, and any other facilities related to Oil and Gas Operations and deemed necessary by Operator. It is expressly understood that no centralized compressors will be located on the Property, except that wellhead compression will be permitted subject to the noise abatement requirements provided for hereinafter.

d. Central water handling and treatment facilities are permitted to be located on the Property as identified on Exhibit B. Owner agrees to cooperate with Operator in obtaining necessary approvals for such facilities.

e. Any valve sites, exposed pipeline structures, wellhead compressor housing, permanent tanks intended to contain hydrocarbon substances or produced water installed during Oil and Gas Operations on the Wellsite Location shall all be low profile when technically feasible and painted with color tones, matched to the surrounding landscape as per COGCC Series 804 rule on Visual Impact Mitigation. Owner reserves the right to select the hue and surface finish at the time of the initial installation of surface facilities. Owner and Operator shall jointly and in good faith cooperate to take mutually acceptable measures to protect the residential character of Property outside of the Wellsite Locations.

f. All wellheads or production facilities shall be located pursuant to COGCC rules applicable at the time they are installed and as shown on Exhibit B. COGCC regulations shall specify the required setbacks from any designated boundary line in the Battlement Mesa PUD or a designated outside activity area.

g. Operator, at its sole cost, risk and expense, will be responsible to obtain any governmental required approvals related to the Wellsite Locations. Owner agrees to cooperate with Operator to obtain any governmental required approvals. If Operator is precluded from obtaining required governmental approvals for any Wellsite Location, Owner agrees to work in good faith with Operator to locate a suitable replacement location.

4. Access Roads. Exhibit B depicts the approximate locations of the planned access roads ("Access Roads") to be used by the Operator to develop the Oil and Gas estate. Operator agrees to restrict its Oil and Gas Operations to the easements for the Access Roads shown on Exhibits B. Any material deviation from the planned location of the Access Roads, as shown in Exhibits B will require Owner's prior written approval, which approval will not be unreasonably withheld. "Material Deviation" is defined as any proposed surface use or occupancy by Operator outside the boundaries of the Access Roads identified on Exhibit B.

a. Access Roads constructed by Operator shall be no greater than 20 feet wide, gated and maintained in a good visual condition and in conformity with applicable state and local standards for oil and gas operations, including grading for proper drainage. Such road construction and maintenance shall be at the sole risk, cost and expense of Operator. Operator shall monitor the condition of the Access Roads and in those situations where warranted, apply dust suppressants such as water, soil tack, and/or magnesium chloride solution. Vehicle speed in excess of 20 miles per hour is prohibited. Operator will at least annually forward a "NOTICE TO ALL CONTRACTORS" regarding driving and traffic law adherence and a policy of discipline up to and including removal of the offending party from activities conducted under this Agreement for violators.

b. If Operator or its vendors cause damage to a road that is jointly used by Operator, its vendors and the persons residing within the Battlement Mesa PUD, Operator, as its sole cost, shall promptly repair any damage which it causes which is a direct result of its use of the road. Operator agrees to bear all expenses to remove mud, gravel and sand in a manner that will cause such roads to be returned to the condition of such roads before being impacted by Operator's Oil and Gas Operations.

c. The Parties agree to conduct their respective operations in a manner which minimizes interference with or delay of the ongoing operations of the other.

d. No employee (acting in an official capacity for Operator and not as a public person), agent, vendor, vendor's employee, consultant or any other person authorized by Operator to be on the Property shall bring alcohol, drugs, firearms, or animals upon the Property at any time. All gates and Access Roads on and at the Wellsite Locations and such other facilities as agreed to by the Parties will be kept closed when not in use in by Operator and Operator shall take all reasonable steps to keep the area served by the roadway as secure as possible.

e. Operator, at its sole cost, risk and expense, will be responsible to obtain any governmental required approvals related to the Access Roads. Owner agrees to cooperate with Operator to obtain any governmental required approvals. Owner agrees to cooperate with Owner in securing any and all such required approvals.

f. Authorized agents of Owner may utilize Access Roads, provided that such use does not interfere with Operator's ongoing activities on the Wellsite Locations.

5. Pipelines. Exhibit B depicts the locations of the planned gas gathering line ("Pipeline Easements") to be used only by the Operator to develop the Oil and Gas estate. Operator agrees to restrict its Oil and Gas Operations to the areas shown on Exhibits B. Any material deviation from the planned location of the Pipeline Easements, as shown in Exhibits B will require Owner's prior written approval, which approval will not be unreasonably withheld. "Material Deviation" is defined as any proposed surface use or occupancy by Operator outside the boundaries of the Pipeline Easements identified on Exhibit B.

a. Pipeline Easements shall consist of a 25-foot permanent easement and a temporary 50-foot construction easement and be for the use of Operator for the installation, operation, maintenance and repair of wells, utility lines, flowlines, pipelines, and appurtenant equipment that will be used to produce, gather, measure, treat, transport or distribute oil, gas, liquid hydrocarbons, and water, whether treated or untreated. Operator, its successors, assigns, affiliated companies, parent companies, and subsidiaries, may use any of the flowlines and pipelines located in the easements to produce, gather, transport or distribute oil, gas, liquid hydrocarbons and water.

b. Operator has the right to construct, use, repair, maintain and replace flowlines, pipelines and utility lines providing service to wells and facilities as shown on Exhibit B.

c. Gas gathering lines shall be installed at depths not less than approximately 48 inches below the surface of the ground, except in those areas shown on Exhibit B where Owner and Operator agree to install them at a greater or lesser depth to accommodate storm sewer lines, sewer lines, water lines or other similar gravity-dependent facilities ("Gravity Dependent Facilities"). Additionally, Operator shall bury its gas gathering lines at a greater or lesser depth at such points indicated on Exhibit B as necessary to provide Owner with access roads to its development property and avoid existing structures. Operator will consult with Owner prior to installing the gas gathering lines to agree upon a burial depth necessary to avoid Owner's existing and anticipated utilities, access to its property and structures. Owner and Operator shall each consult in good faith to reasonably and mutually accommodate each other's economic interests in the Property and the underlying oil and gas leases.

d. In the event Owner desires to have existing gas gathering lines (or such other lines or utilities as Operator may have installed) redesigned or relocated due to Owner's development plans, Operator shall review Owner's detailed drawings and attempt to accommodate redesign or relocation of the gas gathering lines at Owner's expense. Locations of gas gathering line easements and depth of pipeline installation may be changed by mutual agreement of the Parties; provided, however, all costs and expenses of such relocations shall be borne by the Party requesting the relocation. In the event that the parties agree to the relocation of a pipeline or gathering line at the Owner's request, the Operator shall provide Owner with a written estimate of the relocation costs. Owner shall remit fifty percent (50%) of the amount of the estimate to the Operator 30 days prior to commencement of the relocation operations and the remaining 50% upon completion of the work and the submission of an itemized invoice as provided hereinafter. The final amount due shall be adjusted up or down upon completion of the work and after an itemized statement is provided to Owner.

e. Operator shall compact all trenches related to any phase of drilling and/or pipeline construction to no less than 95% SPD; provided that compaction shall be 100% SPD for all trenches which are in areas designated for public or private roads or paved trails.

f. Owner may cross gas gathering line easements affirmed or granted herein to install, operate and maintain streets, curbs, gutters, sidewalks, utility service lines, cables or facilities, including those for water, gas, sewer, electricity, telephone, television, and fiber optics, provided that Owner shall use its best efforts to minimize interference with Operator's use of the easements affirmed or granted herein, and provided further that 1) any such crossing shall be at substantially right angles to the easements affirmed or granted herein, if reasonably possible; 2) if any such streets, curbs, gutters, sidewalks lines, cables or facilities are laid substantially parallel to gathering lines or pipelines, they shall be located at a minimum horizontal distance of five feet from any gathering line or pipeline; and, 3) any lines, cables or facilities that cross gathering lines or pipelines shall be separated vertically by a minimum distance of two (2) feet center-to-center.

g. Owner, its agents, representatives, successors and assigns may use easements for other utilities, access and roadways as deemed necessary by the Owner; provided that utilities shall have a horizontal separation of at least five (5) feet (center to center) and a vertical separation of at least two (2) feet (center-to-center).

h. Within ninety (90) days following completion of construction of any working segment of pipeline or ancillary facilities, Operator shall, at its sole cost, provide Owner with as-built drawings of the completed pipeline segment or ancillary facilities.

i. Operator, at its sole cost, risk and expense, will be responsible to obtain any governmental required approvals related to the Pipeline Easements. Owner agrees to cooperate with Operator to obtain any governmental required approvals.

j. Pipelines serving each Wellsite Location shall be completed contemporaneously with the commencement of oil and gas operations at the respective Wellsite Locations A, B, C, D, E, L and M, on a location by location basis.

k. In the event Operator desires to permit a third party to utilize Operator's Pipeline Easements, which utilization is not in connection with Operator's Oil and Gas Operations, Operator shall obtain the permission of Owner to such use. Operator acknowledges that Owner may require compensation and other considerations for the grant of this permission.

l. Operator acknowledges this grant of pipeline easements is reflective of its agreement with Owner to greatly reduce or eliminate trucking at Battlement Mesa PUD by the transportation of oil, gas, liquid hydrocarbons and water by pipeline in its Oil and Gas Operations from the Wellsite Locations to the central water handling and treatment facility shown on Exhibit B.

m. If Owner intends to construct any improvements in any of the pipeline or access easements described in this Agreement that would potentially interfere with Operator's access to or use of such easement, Owner shall provide at least 180 days' Notice to Operator (the "Notice Period") of such intended activity. Notice shall be given in writing and shall be specific enough to allow Operator to determine the extent to which such activity would potentially interfere with Operator's use of any easement. Operator may construct pipelines or other facilities as provided in the Agreement, in such easements during the Notice Period without interference from Owner's activities. If Operator has not constructed pipelines or facilities in such easement during the Notice Period, and Owner has subsequently built improvements in such easement after the end of the Notice Period, then Operator may construct pipelines or facilities in such easement, but Operator shall be required to pay for actual damages to the improvements constructed in such easement that are caused by Operator's subsequent construction of pipelines or facilities in such easement. If Owner gives Notice, but has not constructed any improvements in the easements for which it has given Notice under this Paragraph by the end of 365 days from the date of such Notice, then such Notice shall be deemed to have lapsed, and the parties' relative rights in such easements shall return to the status quo that existed prior to the Owners' giving of Notice.

n. In the event Operator's Oil and Gas Operations impact the Battlement Mesa Golf Course, Operator agrees to restore that part of the golf course to its pre-impacted condition as soon as possible. In this restoration, Operator will work with the golf course superintendent to assume that all necessary steps are taken to return it to its pre-impacted condition. Operator agrees to utilize and pay for the golf course maintenance staff and/or its designated vendors as well as all materials required. Operator shall also pay for any revenue loss caused by its incursion into the golf course. [redacted]

REDACTED

o. At such time as pipe is laid in the pipeline easements, it shall not be removed except for the purpose of repair. Upon the termination of Operator's Oil and Gas Operations, the pipelines shall be left in place and abandoned by Operator.

6. Power/Telephone/Transformers. Only power lines, transformers and data transmission lines necessary for the operation of wells drilled on the Wellsite Location, or production equipment ancillary thereto, may be installed on the Wellsite Location or in the easement of any Access Road or Pipeline Easement. No power line, data transmission line or transformers will be permitted outside of Wellsite Location, Access Road or Pipeline Easement shown Exhibit B.

7. Hours of Operation. There will be no time of day restrictions with regard to drilling, completing, re-completing, workover, reservoir fracture stimulation operations. With respect to other routine ongoing maintenance, development and production operations, Operator agrees to limit such activities (except in the case of emergency) to between the hours of 7:00 AM to 8:00 PM.

8. Noise Abatement. Stationary engines and their exhausts shall be located and oriented to direct noise away from the homes closest to Wellsite Locations as set forth by COGCC Series 802.e rule. Equipment initially installed on Wellsite Locations shall be modern and well maintained. Operator will evaluate noise generation from equipment and require contractors to refit mufflers etc. in situations where the volume of sound produced may exceed applicable standards. Operator shall at all times maintain compliance with applicable Colorado Oil and Gas Conservation Commission ("COGCC") rules and regulations pertaining to noise reduction standards in Residential/ Agricultural/Rural areas and employ best management practices as set out in the COGCC Series 802 Noise Abatement Rule. Neither Operator nor its vendors shall be permitted to utilize engine braking on the Property.

9. Lighting Abatement. If a drilling rig is within 1,000 feet of an occupied dwelling, Operator and its subcontractors will align the drilling rig lighting equipment to minimize the proportion of the lights that are directed toward the dwelling and will install lighting shield devices on all of the more conspicuous lights. Lighting shall

be directed inward and downward except as deemed necessary by Operator to illuminate other areas for safety reasons. Operator shall use appropriate technology to minimize light pollution emanating from the Property including, but not limited to, utilization of low density sodium vapor lighting.

10. Air Emissions and Odor Abatement. Operator will utilize mats, soil tack and/or liquid dust suppressants as necessary to mitigate fugitive dust emissions from Wellsite Locations. Completion processes shall be designed to consolidate the number of hydraulic fracture stimulation flow-back events. No flaring of wells shall be permitted within 2,000 feet of an occupied dwelling, except in the event of emergency. Operator may flare a well within 2,000 feet of an occupied dwelling if such flaring is conducted utilizing flare suppression containment. Glycol dehydrators, tanks, treaters, and flares shall comply with applicable CDPHE and COGCC regulations governing VOC emissions.

Operator's operations shall be in compliance with the applicable Colorado Department of Public Health and Environment Air Quality Control Commission Regulations, including, but not limited to, the Regulation No. 2 requirement that no oil or gas operation may cause or allow the emission of odorous air from any single source that is detectible after the odorous air has been diluted with seven or more volumes of odor-free air. These measurements shall be made outside the property line of the property from which the emission originates.

11. Noxious Weed Management. Operator shall maintain a noxious weed management plan consistent with the requirements of Garfield County, Colorado and the COGCC Series 1003.f. and 1004.e. rules on noxious weed management.

12. Visual Impact Mitigation and Reclamation of Wellsite Locations. Operator agrees to construct each Wellsite Location to mitigate visual impacts, including specific Wellsite Location requirements described in Exhibit C. As soon as reasonably feasible (and consistent with best practices and growing seasons), Operator shall commence interim and final reclamation operations as per COGCC Series 1003 and 1004 rules. The timing to begin such reclamation operations will be determined in good faith negotiations between Operator and Owner, The reclamation standards are set forth in the attached Exhibit D, Reclamation Plan.

13. Environment and Safety. Operator will comply with all applicable COGCC, Colorado Department of Public Health and Environment (CDPHE), Environmental Protection Agency (EPA) spill control, cleanup, and reporting requirements, the Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA"), The Resource Conservation and Recovery Act ("RCRA") the Oil Pollution Act ("OPA") and the Clean Water Act.

   a. Sanitary facilities will be on site at all times during drilling, testing and completion operations. Sewage will be placed in a portable chemical toilet. The toilet will be replaced periodically utilizing a licensed contractor. Toilet contents will be delivered to local wastewater treatment facilities in accordance with state and county regulations. Disposal will be in accordance with the State of Colorado and Garfield County rules and regulations regarding sewage treatment and disposal.

b. All refuse, trash and other solid waste, (including cans, paper, cable, etc.) generated during drilling, testing and completion operations will be contained in enclosed receptacles, removed from the location promptly, and hauled to an authorized disposal site.

c. Immediately after completion of construction, all debris and other waste materials will be cleaned up and removed from the location.

d. All project-related activities involving hazardous materials use will be conducted in a manner that minimizes potential environmental impacts. Operator shall maintain a file of current Material Safety Data Sheets (MSDS) for all chemicals, compounds, and/or substances that are used in the course of site preparation, drilling operations, production operations and reclamation. Compliance with the foregoing will be governed by the rules and regulations of the Colorado Oil and Gas Conservation Commission.

e. Any spills of oil, gas, or any other potentially hazardous substance shall be reported to (and within the timeframes specified by) local authorities, state authorities, federal authorities, and other responsible parties as required under EPA regulations – 40 CFR part 110, Discharge of Oil regulation, and 40 CFR part 112, Oil Pollution Prevention regulation, and COGCC and CDPHE spill reporting requirements. Such event shall be mitigated immediately, as appropriate, through cleanup or removal to an approved disposal site.

f. Operator will implement a spill prevention, control and counter measure control plan (SPCC). No hazardous materials in toxic concentrations will be permanently stored on any Wellsite Location. Hazardous materials for use in the production of oil, gas or water will be allowed but will be stored and in use in reasonable quantities necessary for Operator's activities on such Wellsite Location. No bulk storage of hazardous materials is allowed.

g. Operator shall ensure that all personnel and contractors employed in operations shall receive appropriate training in safety and environmental protection practices as required by state and federal laws and regulations.

h. Operator shall not house employees on the Property on a temporary or permanent basis without the express written consent of Owner. Notwithstanding the foregoing, Operator is permitted to allow key personnel to reside temporarily on Wellsite Locations provided such personnel are, in Operator's and Owner's jointly held opinion, necessary to maintain a safe operation.

i. The Operator will conduct and maintain its operations in a safe manner and protect the public from any hazardous conditions. In the event of an emergency, Operator will take immediate appropriate action to safeguard life and prevent significant environmental degradation.

14. Emergency Communications. Operator will comply with all local, state and federal reporting requirements in all emergency situations. Emergency contact information

shall be posted in a conspicuous location on the Property. In the event of an emergency requiring communication with the community, Operator will coordinate with the Garfield County Emergency Communications Authority to immediately contact surface owners living within 1,000 feet of such emergency. Further, Operator shall immediately contact Owner's representative advising of that emergency situation

15. Operator's Sole Risk; Insurance.

a. Operator shall conduct all operations on the Property at its sole risk, cost and expense. Operator assumes all risk and liability of any nature incident to, occasioned by or resulting in any manner, directly or indirectly, from Operator's operations hereunder.

REDACTED

b. Operator shall carry no less than [redacted] in general liability limits for any one occurrence and [redacted] in the aggregate, and shall name the Owner as an additional insured with respect to the liabilities assumed hereunder.

16. Surface Damage Payments. Operator shall conduct berming and landscaping at the Wellsite Locations as described in Exhibit C. The referenced berming and landscaping is not intended to waive any right or remedies the Owner may have, including the right to damages, if it is determined that the conduct of Operator, or its agents, employees, successors or assigns exceeds the scope of the those rights granted herein or Operator is in breach of its duties under this Agreement.

17. Owners' Utilities. To the degree that Operator requires any utility lines (i.e. communication, electric, etc) to service any of the facilities depicted on Exhibit B, Operator agrees to locate such utility lines underground at Operator's cost.

18. Compliance with Colorado Oil and Gas Conservation Rules and Regulations. Operator agrees to comply with all of the applicable rules and regulations of the COGCC concerning the development of the Property for oil and gas exploration, drilling, production and the Property's reclamation. Provided, however, that Operator has complied with applicable requirements of the COGCC Regulations for well permitting, Owner agrees, for itself, its successors and assigns, that it shall execute written waivers to allow the COGCC to issue permits to drill wells in the Wellsite Locations shown on Exhibit B, including without limitation, waivers of any setback requirements imposed by the COGCC's High Density Development Area regulations.

19. Indemnification. All use and occupancy of the surface of the Property of Owner, its successors and assigns, by Operator, its agents, employees, contractors, subcontractors, representatives, agents or assigns, shall be at the sole risk of Operator. Operator hereby agrees to indemnify, defend and hold harmless Owner, its employees, customers, golfers, agents, guests, successors and assigns from and against any and all losses, costs, damages, claims awards, attorneys fees (including Owner's attorneys fees and litigation expense, provided such fees and expenses are reasonable), expenses, demands, judgments or liabilities resulting from injuries or death of any person whomsoever, or losses, damages, destruction, pollution, hazardous material spills, discharges to any of Owner's or any third parties'

property whatsoever caused by Operator's oil and gas activities and operations at and below the surface of Battlement Mesa PUD, or by Operator's agents, representatives, contractors, and employees. Specifically excepted from Operator's foregoing indemnity in favor of the Owner shall be those losses suffered by Owner (or other third parties) that are caused by the negligence or fault of the Owner, or Owner's agents, contractors, subcontractors, representatives, or assigns. Operator further agrees to indemnify, hold harmless and defend Owner, its employees, agents, subcontractors, representatives, successors and assigns from any liability which may be asserted or determined by any individual, legal entity, county, state or federal agency based upon a violation of any of the provisions of CERCLA, RCRA, OPA, the Clean Water Act or common law resulting from the actions or inactions of the Operator on the Property.

20. No liens. Operator shall keep the Property free and clear of any and all liens for labor or work performed by it or its contractors and subcontractors upon the Property relating to its oil and gas exploration, development or production operations or for materials furnished thereto. Notwithstanding the above, Operator may contest the validity of any alleged lien, including the enforcement thereof. Operator agrees to pay any and all property taxes, assessments, governmental charges imposed upon its interest in the Property and upon any building, structure or other improvements, equipment or personal property placed or erected upon the Property.

21. Term. This Agreement will remain in effect for as long as Operator, its successors, or assigns is utilizing the easements granted under this Agreement, with no inactivity of greater than 24 continuous months (excluding event of force majeure).

22. BMP-ExxonMobil SUA Superseded in Part. Operator and ExxonMobil acknowledge that Owner is in the process of developing the Battlement Mesa PUD. ExxonMobil, Operator and Owner agree: (i) that future Wellsite Locations, wells and/or production facilities shall be placed; and (ii) that the real estate situated in Battlement Mesa PUD shall be developed, in a manner consistent with this Agreement. To the extent this Agreement is in conflict with the BMP-ExxonMobil SUA, this Agreement will prevail as among the parties. It is expressly understood and agreed that ExxonMobil is joining in this agreement solely for the purpose of being bound by this paragraph, and, paragraphs 23 to 24 and paragraph 26 below, and that the other terms and conditions of this agreement shall be between Owner and Operator, and shall not be applicable to ExxonMobil.

23. Successors and Assigns. This Agreement is binding upon the successors, heirs and assigns of Owner, Operator and ExxonMobil.

24. Counterparts/Facsimile Signatures. The Parties may execute this Agreement in any number of counterparts, each of which shall be deemed an original instrument, but all of which together shall constitute but one and the same instrument. The Parties agree that facsimile signatures are binding.

25. Breach. The Parties acknowledge that, in the event of a violation of this Agreement by either party, the breaching Party shall pay any actual damages found by the trier of fact to have been caused by such breach. In any litigation related to this

Agreement, the prevailing party shall be awarded its costs and fees, including without limitation, reasonable expert fees and reasonable attorney fees.

26. Notices. Any notice or other communication required or permitted under this Agreement shall be sufficient if deposited in the U. S. Mail, postage prepaid, or sent via expedited delivery service, with proof of delivery, or by facsimile transmission with proof of receipt by the notified party, addressed as follows:

If to Operator:

Antero Resources Piceance Corporation

[redacted]

If to Owner:

Battlement Mesa Partners, LLC

[redacted] 35

[redacted]

REDACTED

If to ExxonMobil:

Exxon Mobil Corporation

[redacted]

27. Annual Consultation with Owner. Operator agrees to meet annually with Owner at a mutually agreeable time and place to discuss Operator's planned upcoming year's Oil and Gas Operations including, but not limited to, drilling activity. Ten days prior to this meeting, Operator shall provide to Owner in writing its planned scheduled activities. Operator agrees to provide Owner written notice, immediately, of any change to Operator's stated schedule at any time such change is made. Further, at this meeting, Operator and Owner shall address Owner's concerns about past, present and the proposed future Oil and Gas Operations at Battlement Mesa PUD.

This Agreement may be amended only by means of a mutually executed written letter agreement.

IN WITNESS WHEREOF, this instrument is executed as of the date first above written.

OWNER: Battlement Mesa Partners, LLC

OWNERS:
Battlement Mesa Land Investments, LLC
Battlement Mesa Land Investments Parcel 1 LLC
Battlement Mesa Land Investments Parcel 2 LLC
Battlement Mesa Land Investments Parcel 3 LLC
Battlement Mesa Land Investments Parcel 6 LLC
Battlement Mesa Land Investments Parcel 7 LLC
Battlement Mesa Land Investments Parcel OHS LLC
Battlement Mesa Land Investments Parcel 5-1, TRK3 and 4 LLC
Battlement Mesa Land Investments Parcel 5-2, TRK 5 LLC
Battlement Mesa Land Investments Parcel 5-2, TRK 6 LLC
Battlement Mesa Land Investments Parcel Fairways LLC
Green Head Investments 1 LLC
Burning Rock B2L2 LLC
MCV2 Church Site LLC
Battlement Mesa Golf Course, LLC
Saddleback Village Convenience Center, LLC
Willow Park Apartments LLC
Battlement Mesa Land Investments Parcel 1-A, LLC
Paradise Valley Minerals LLC
Battlement Mesa Land Investments Town Center 1 LLC
Battlement Mesa Land Investments Town Center 2 LLC
Battlement Mesa Land Investments Town Center 3 LLC
Battlement Mesa Plaza Town Center, LLC
Battlement Mesa Land Investments Parcel 5-1, TRK 2 LLC
Battlement Mesa Land Investments OES LLC
Battlement Mesa RV Park LLC
Battlement Mesa RV Storage LLC
Battlement Mesa Office I LLC
Modular Homes LLC
Tamarisk Village Pads, LLC
Willow Ridge at Battlement Mesa LLC

Battlement Mesa Parcel 5 LLC
Battlement Mesa Lot Holdings LLC

Battlement Mesa Partners LLC

____________________ 3-2-09

Name: Eric Schmela
Title: Authorized Agent

OPERATOR: Antero Resources Piceance Corporation

Name: Brian A. Kuhn
Title: Vice President

EXXON MOBIL CORPORATION:

Name: John C. Rothwell
Title: Agent and Attorney-in-Fact

ACKNOWLEDGMENTS

STATE OF COLORADO §
§
COUNTY OF DENVER §

The foregoing instrument was acknowledged before me on this 2nd day of March, 2009, by Eric Schmela, Authorized Agent for Battlement Mesa Partners, LLC a Colorado limited liability company d/b/a Battlement Mesa Company, and Battlement Mesa Land Investments, LLC, Battlement Mesa Land Investments Parcel 1 LLC, Battlement Mesa Land Investments Parcel 2 LLC, Battlement Mesa Land Investments Parcel 3 LLC, Battlement Mesa Land Investments Parcel 6 LLC, Battlement Mesa Land Investments Parcel 7 LLC, Battlement Mesa Land Investments Parcel OHS LLC, Battlement Mesa Land Investments Parcel 5-1, TRK3 and 4 LLC, Battlement Mesa Land Investments Parcel 5-2, TRK 5 LLC, Battlement Mesa Land Investments Parcel 5-2, TRK 6 LLC, Battlement Mesa Land Investments Parcel Fairways LLC, Green Head Investments 1 LLC, Burning Rock B2L2 LLC, MCV2 Church Site LLC, Battlement Mesa Golf Course, LLC, Saddleback Village Convenience Center, LLC, Willow Park Apartments LLC, Battlement Mesa Land Investments Parcel 1-A, LLC, Paradise Valley Minerals LLC, Battlement Mesa Land Investments Town Center 1 LLC, Battlement Mesa Land Investments Town Center 2 LLC, Battlement Mesa Land Investments Town Center 3 LLC, Battlement Mesa Plaza Town Center, LLC, Battlement Mesa Land Investments Parcel 5-1, TRK 2 LLC, Battlement Mesa Land Investments OES LLC, Battlement Mesa RV Park LLC, Battlement Mesa RV Storage LLC, Battlement Mesa Office I LLC, Modular Homes LLC, Tamarisk Village Pads, LLC, Willow Ridge at Battlement Mesa LLC, , Battlement Mesa Parcel 5 LLC, Battlement Mesa Lot Holdings LLC, on behalf of said entities.

My Commission Expires:

____

Shelley K. Leo
Notary Public, State of Colorado

NOTARY PUBLIC
SHELLEY K. LEO
STATE OF COLORADO
My Commission Expires 09/21/2012

STATE OF TEXAS §
§
COUNTY OF HARRIS §

The foregoing instrument was acknowledged before me on this 17 day of March, 2009, by John C. Rothwell, Agent and Attorney-in-fact for EXXON MOBIL CORPORATION, a New Jersey corporation, on behalf of said corporation.

My Commission Expires:

LAVERA JOHNSON
Notary Public
State of Texas
Comm. Exp. 10-06-2010

Notary Public, State of Texas

STATE OF COLORADO §
§
COUNTY OF DENVER §

The foregoing instrument was acknowledged before me on this 14th day of April, 2009, by Brian A. Kuhn, Vice President, for ANTERO RESOURCES PICEANCE CORPORATION, on behalf of said corporation.

My Commission Expires:
8/3/11

Notary Public, State of Colorado

KELLY HUFFMAN
NOTARY PUBLIC
STATE OF COLORADO
MY COMMISSION EXPIRES 08/03/2011

Wellsite Location A

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Exhibit A

Description of Battlement Mesa PUD

EXHIBIT A

LEGAL DESCRIPTION

A parcel of land lying in Sections 5, 6, 7, 8, 9, 10, 16, 17, 18, and 19, Township 7 South, Range 95 West and Sections 13 and 24, Township 7 South, Range 96 West, of the Sixth Principal Meridian, County of Garfield, State of Colorado, more particularly described as follows:

Beginning at the East 1/4 Corner of Section 5, Township 7 South, Range 95 West;
Thence along the East line of Section 5 South 00°15'43" West a distance of 1628.34 feet, to the Southeast Corner of the N1/2 NE1/4 SE1/4 SE1/4 of Said Section 5;
Thence along the South line of the N1/2 NE1/4 SE1/4 SE1/4 North 87°19'30" West a distance of 664.56 feet, to the Southwest Corner of said N1/2 NE1/4 SE1/4 SE1/4;
Thence along the West line of the N1/2 NE1/4 SE1/4 SE1/4 of Section 5, North 00°23'16" East a distance of 324.34 feet to the Northwest Corner of said NE1/4 SE1/4 SE1/4;
Thence along the North line of the SE1/4 SE1/4 of said Section 5, North 87°26'14" West a distance of 663.79 feet, to the Northwest Corner of said SE1/4 SE1/4;
Thence along the West line of SE1/4 SE1/4 of said Section 5, South 00°30'52" West a distance of 1292.05 feet to the Southwest Corner of said SE1/4 SE1/4;
Thence along the South line of said Section 5, South 86°59'25" East a distance of 1333.74 feet to the Southeast Corner of said Section 5;
Thence along the North line of Section 9, Township 7 South, Range 95 West, South 87°59'43" East a distance of 1326.37 feet, to the Northeast Corner of the NW1/4 NW1/4 of said Section 9;
Thence along the East line of the NW1/4 NW1/4 of said Section 9, South 01°02'26" West a distance of 1301.45 feet to the Southeast Corner of said NW1/4 NW1/4;
Thence along the North line of the SE1/4 NW1/4 of said Section 9, South 88°02'23" East a distance of 1324.35 feet to the Northeast Corner of said SE1/4 NW1/4;
Thence along the North line of the SW1/4 NE1/4 of said Section 9, South 88°35'51" East a distance of 1275.60 feet, to the Northeast Corner of said SW1/4 NE1/4;
Thence along the West line of the NE1/4 NE1/4 of said Section 9, North 01°04'15" East a distance of 1311.84 feet to the Northwest Corner of said NE1/4 NE1/4;
Thence along the North line of said Section 9, South

89°06'43" East a distance of 1274.26 feet to the Northeast Corner of said Section 9;
Thence along the East line of said Section 9, South 01°00'49" West a distance of 1323.29 feet, to the Southeast Corner of the NE1/4 NE1/4 of said Section 9;
Thence along the North line of the SW1/4 NW1/4 of Section 10, Township 7 South, Range 95 West, South 88°46'55" East a distance of 631.29 feet to a point on the North line of the said SW1/4 NW1/4, 687 feet West of the Northeast Corner of said SW1/4 NW1/4, said point being the Northwest Corner of that parcel of land described in Document Number 198564 as recorded in Book 302 at Page 200 of the records of the Clerk and Recorder of Garfield County;
Thence along the boundary of said parcel the following five (5) courses:

(1) South 00°49'34" West a distance of 221.67 feet;
(2) South 48°09'56" East a distance of 361.92 feet to a point 456.00 feet, as measured at right angles, southerly from the North line of the SW1/4 NW1/4 of said Section 10;
(3) South 89°17'47" East a distance of 166.55 feet;
(4) South 00°49'34" West a distance of 201.43 feet;
(5) South 89°17'47" East a distance of 246.37 feet;

to a point on the East line of said SW1/4 NW1/4 655 feet South of the Northeast Corner of said SW1/4 NW1/4;
Thence departing said parcel boundary along the East line of the SW1/4 NW1/4 of said Section 10, South 00°54'36" West a distance of 667.20 feet to the Southeast Corner of said SW1/4 NW1/4;
Thence along the East line of the NW1/4 SW1/4 of said Section 10, South 00°54'38" West a distance of 1335.11 feet to the Southeast Corner of said NW1/4 SW1/4;
Thence along the South line of the NW1/4 SW1/4 of said Section 10, North 89°11'04" West a distance of 1323.06 feet to the Southwest Corner of said NW1/4 SW1/4;
Thence along the South line of the N1/2 SE1/4 of Section 9, Township 7 South, Range 95 West, North 87°19'11" West a distance of 2557.45 feet to the Southwest Corner of said N1/2 SE1/4;
Thence along the South line of the N1/2 SW1/4 of Section 9, North 88°38'08" West a distance of 2654.44 feet to the Southwest Corner of said N1/2 SW1/4;
Thence along the South line of the NE1/4 SE1/4 of Section 8, Township 7 South, Range 95 West, North 88°43'49" West a distance of 1331.33 feet to the Southwest Corner of said NE1/4 SE1/4 of Section 8;
Thence along the West line of the SE1/4 SE1/4 of Section 8, South 01°20'14" West a distance of 1316.23 feet to the

Southwest Corner of said SE1/4 SE1/4 of Section 8;

Thence along the East line of the W1/2 NE1/4 of Section 17, South 01°00'57" West a distance of 2639.16 feet to the Southeast Corner of said W1/2 NE1/4 of Section 17;

Thence along the North line of the NE1/4 SE1/4 of Section 17, South 88°46'04" East a distance of 1324.13 feet to the E1/4 Corner of Section 17;

Thence along the Easterly line of the NE1/4 SE1/4 of Section 17, South 01°01'24" West a distance of 1320.50 feet to the Southeast Corner of the NE1/4 SE1/4 of Section 17;

Thence along the North line of the SW1/4 SW1/4 of Section 16, Township 7 South, Range 95 West, South 87°41'13" East a distance of 1330.94 feet to the Northeast Corner of said SW1/4 SW1/4;

Thence along the East line of the SW1/4 SW1/4 of Section 16, South 01°03'30" West a distance of 1322.00 feet to the Southeast Corner of said SW1/4 SW1/4;

Thence along the South line of said Section 16 North 87°37'18" West a distance of 1330.20 feet to the Southwest Corner of said Section 16;

Thence along the South line of Section 17, Township 7 South, Range 95 West, North 88°44'01" West a distance of 1984.49 feet to the Southwest Corner of the E1/2 SW1/4 SE1/4;

Thence along the West line of the E1/2 SW1/4 SE1/4, North 00°59'11" East, a distance of 1319.91 feet to the Northwest Corner of said E1/2 SW1/4 SE1/4;

Thence along the South line of the NW1/4 SE1/4 of said Section 17, North 88°45'02" West a distance of 661.78 feet to the Southwest Corner of said NW1/4 SE1/4;

Thence along the South line of the NE1/4 SW1/4, North 88°45'02" West a distance of 1158.58 feet to a point 10 rods East of the Southwest Corner of said NE1/4 SW1/4;

Thence North 01°03'04" East a distance of 131.93 feet;

Thence North 88°43'44" West a distance of 165.63 feet;

Thence North 00°55'58" East a distance of 527.66 feet, along the West line of the NE1/4 SW1/4 to the Northeast Corner of the S1/2 NW1/4 SW1/4;

Thence North 88°45'33" West 1324.42 feet to the Northeast Corner of the E1/2 SE1/4, NE1/4 SE1/4 of Section 18, Township 7 South, Range 95 West;

Thence along the North line of the E1/2 SE1/4 NE1/4 SE1/4 of said Section 18, North 88°24'33" West a distance of 329.86 feet to the Northwest Corner of said E1/2 SE1/4 NE1/4 SE1/4;

Thence along the West line of the E1/2 SE1/4 NE1/4 SE1/4 of said Section 18, South 00°53'57" West a distance of 659.61 feet to the Southwest Corner of said E1/2 SE1/4 NE1/4 SE1/4;

Thence along the South line of the NE1/4 SE1/4 of said Section 18, North 88°26'07" West a distance of 989.84 feet to the Southwest Corner of said NE1/4 SE1/4;
Thence along the East line of the SW1/4 SE1/4 of said Section 18, South 00°55'21" West a distance of 1320.46 feet to the Southeast Corner of said SW1/4 SE1/4;
Thence along the East line of the W1/2 NE1/4 of Section 19, Township 7 South, Range 95 West, South 01°06'34" West a distance of 2642.06 feet to the Southeast Corner of said W1/2 NE1/4;
Thence along the South line of the NE1/4 of Section 19, North 88°41'12" West a distance of 1329.89 feet to the Southwest Corner of said NE1/4;
Thence continuing Westerly along the South line of the NW1/4 of said Section 19, North 88°41'12" West 2570.38 feet to the Southwest Corner of said NW1/4 of Section 19;
Thence continuing Westerly along the South line of the NE1/4 of Section 24, Township 7 South, Range 96 West, North 89°32'43" West a distance of 2673.12 feet to the Southwest Corner of said NE1/4;
Thence along the West line of said NE1/4, North 00°23'55" West 1023.06 feet;
Thence North 01°25'42" East 229.60 feet;
Thence North 66°31'04" West 236.83 feet;
Thence North 34°29'42" East 1613.03 feet;
Thence North 88°52'30" West 202.82 feet;
Thence North 00°00'00" East 461.13 feet;
Thence North 81°10'00" West 955.94 feet to the centerline of the Colorado River;
Thence along said center the following courses and distances;

North 26°28'25" East 232.98 feet;
North 30°21'25" East 206.15 feet;
North 35°25'25" East 644.58 feet;
North 29°37'25" East 829.36 feet;
North 40°24'25" East 99.86 feet;
North 36°27'25" East 350.05 feet;
North 34°54'25" East 163.27 feet;
North 31°12'21" East 266.75 feet;
North 50°36'25" East 886.79 feet;
North 72°21'50" East 390.96 feet;
North 76°17'12" East 151.22 feet;
North 77°41'27" East 463.54 feet;
North 79°53'07" East 281.99 feet;
North 79°01'50" East 87.91 feet;
North 62°57'39" East 257.89 feet;
North 27°17'27" East 312.44 feet;
North 40°46'59" East 326.43 feet;
North 24°17'40" East 197.27 feet;

North 32°26'39" East 124.13 feet;
North 60°01'18" East 109.42 feet;
North 74°02'49" East 226.07 feet;
North 78°19'08" East 154.17 feet;
North 50°40'20" East 444.46 feet;
North 35°52'21" East 149.32 feet;
North 26°41'02" East 150.34 feet;
North 14°13'25" East 511.69 feet;
North 24°54'46" East 241.07 feet;
North 14°40'02" East 996.76 feet;
North 04°23'25" West 274.60 feet;
North 08°35'04" East 215.19 feet;
North 20°08'11" East 79.88 feet;
North 32°27'48" East 71.69 feet;

Thence leaving said Colorado River centerline South 81°08'11" East 526.15 feet;
Thence North 01°04'10" East a distance of 485.22 feet;
Thence South 88°24'36" East a distance of 83.00 feet;
Thence North 53°18'25" East a distance of 635.50 feet to the southerly Right-Of-Way of the existing County Road;
Thence along said Right-Of-Way South 43°14'11" East a distance of 55.74 feet;
Thence continuing along said Right-Of-Way South 34°04'07" East 107.02 feet;
Thence continuing along said Right-Of-Way South 15°35'44" East 66.56 feet;
Thence North 72°19'16" West a distance of 13.56 feet;
Thence South 79°47'18" West a distance of 24.89 feet;
Thence South 37°23'26" West a distance of 108.52 feet;
Thence South 06°07'27" West a distance of 83.52 feet;
Thence North 88°48'43" East a distance of 85.28 feet to the westerly Right-Of-Way of the existing County Road;
Thence along said Right-Of-Way the following courses and distances: South 10°31'10" East a distance of 50.84 feet;
Thence 244.26 feet along the arc of a curve to the left having a radius of 1611.94 feet, the chord of said curve bears South 02°50'01" East a distance of 244.03 feet;
Thence 331.22 feet along the arc of a curve to the left having a radius of 270.10 feet the chord of said curve bears South 42°18'20" East 310.85 feet;
Thence South 77°25'36" East a distance of 249.91 feet;
Thence South 82°00'16" East 142.25 feet;
Thence leaving said County Road Right-Of-Way North 13°52'58" East a distance of 60.00 feet;
Thence South 76°07'01" East a distance of 196.00 feet;

Thence South 66°03'01" East a distance of 92.80 feet;
Thence North 64°50'00" East a distance of 12.20 feet;
Thence South 86°44'06" East a distance of 201.00 feet;
Thence North 01°36'29" East a distance of 650.00 feet;
Thence North 86°44'01" West a distance of 359.65 feet;
Thence North 01°36'06" East a distance of 469.21 feet;
Thence North 01°32'15" East a distance of 568.40 feet;
Thence North 01°39'14" East a distance of 355.62 feet;
Thence North 85°59'03" West a distance of 597.54 feet to the centerline of the Colorado River;
Thence along said centerline the following courses and distances:

North 30°34'03" East 126.48 feet;
North 11°14'23" East 262.86 feet;
North 03°21'52" East 244.98 feet;
North 06°43'43" East 149.36 feet;
North 09°50'22" West 130.18 feet;
North 15°44'44" West 249.17 feet;
North 23°23'56" East 595.97 feet;
North 29°30'40" East 146.50 feet;
North 43°21'22" East 437.13 feet;
North 53°22'38" East 517.59 feet;
North 60°37'24" East 639.69 feet;
North 58°44'59" East 242.35 feet;
North 68°18'39" East 236.76 feet;
North 74°06'42" East 340.87 feet;
North 86°52'08" East 446.66 feet;
North 88°43'46" East 270.56 feet;
South 83°05'32" East 198.26 feet;
North 78°27'53" East 618.98 feet;
North 76°29'45" East 483.05 feet;
North 49°07'36" East 593.26 feet;

Thence leaving said Colorado River centerline South 87°53'37" East a distance of 2282.68 feet along the North line of the SE1/4 of said Section 5, Township 7 South, Range 95 West of the Sixth Principal Meridian to the point of beginning.

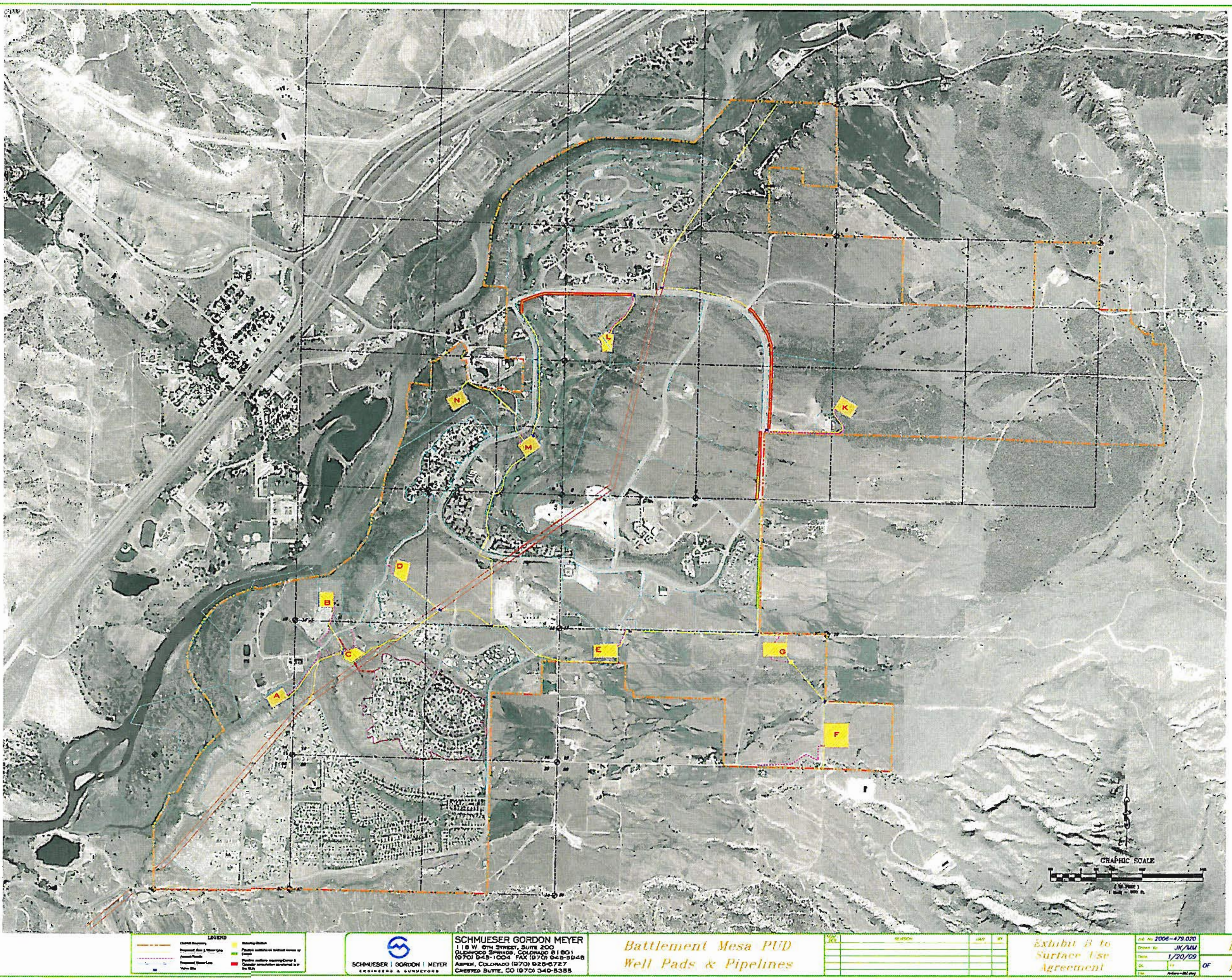
Wellsite Location B

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Exhibit B

Map Depicting General Location of
Wellsite Locations, Access Roads and Pipeline Easements

(Plat follows)



SCHMUESER | GORDON | MEYER
ENGINEERS & SURVEYORS

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CRESTED BUTTE, CO (970) 349-5355

Battlement Mesa PUD
Well Pads & Pipelines

Exhibit B to Surface Use Agreement

Job No. 2006-479.020
Drawn by JK/MM
Date 1/20/09

1 OF 1

Exhibit C

Specific Operational Requirements
For
Wellsite Locations, Access Roads and Pipeline Easements

Wellsite Location A

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated1/20/09, including berming the access road into the Wellsite Location.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will be oriented in a southwesterly direction. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the southwest, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting.

3. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, Soiltac or its equivalent and/or liquid dust suppressants.

4. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

5. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

6. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

Wellsite Location B

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated1/20/09, including berming the access road into the Wellsite Location.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will be oriented in a northerly direction. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the north, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting.

3. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soiltac and/or liquid dust suppressants.

4. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

5. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

6. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

Wellsite Location C

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location C

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09 and the Schematic, Light Exposure and Planting plans dated 1/19/09 prepared by Design Workshop for this pad, including berming the access road into the Wellsite Location. Operator reserves the right to make minor adjustments to number, size and variety of plants, subject to Operator's obtaining Owner's written consent to same, which consent shall not be unreasonably withheld.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will be oriented in a westerly direction as set forth in the above referenced Light Exposure plan. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the west, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting.

3. Landscaping Plan. Operator agrees to landscape the Wellsite Location pursuant to the above referenced Planting Plan. Operator agrees to commence with such landscaping work as soon as initial dirt work at the site commences and complete the same prior to commencement of drilling activity at the Wellsite Location, taking into consideration the growing season. Operator will be responsible for maintaining such landscaping, including but not limited to installing irrigation.

4. Power at Site. Provided electrical power can be accessed under commercially reasonable terms from the local power distribution company servicing the area of the Wellsite Location, Operator shall only use electricity to power its drilling rigs at the site. To the extent third-party contractor equipment has the provisions to utilize electrical power, Operator shall require such third-party contractors to only use electricity to power its equipment at the site In emergency situations, Operator shall be permitted to utilize non-electric generators until such time as electrical power can be restored. Provided, however, these emergency generators shall be positioned in such a manner as to minimize noise impacts on the adjacent residences.

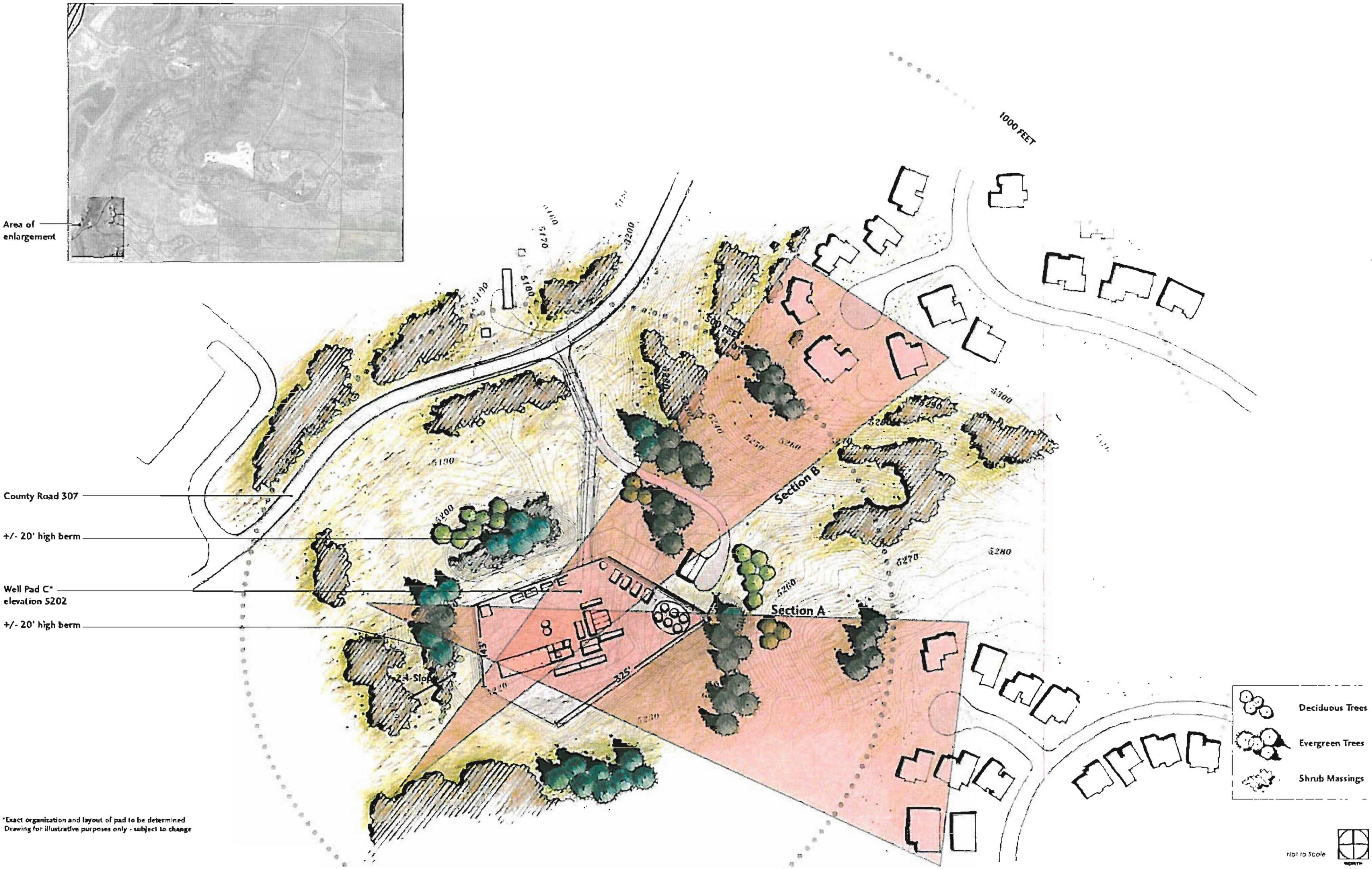
5. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soiltac and/or liquid dust suppressants.

6. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

7. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

8. Irrigation Water. If Operator chooses to purchase water from the Consolidated Metro District to provide its irrigation water, the cost of any tap will be at Operator's sole expense.

9. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.



*Exact organization and layout of pad to be determined
Drawing for illustrative purposes only - subject to change

BATTLEMENT MESA PARACHUTE, COLORADO

ANTERO RESOURCES

01/19/09 SCHEMATIC DESIGN: PAD C

DESIGNWORKSHOP

Not to Scale

Battlement Mesa PARACHUTE, COLORADO

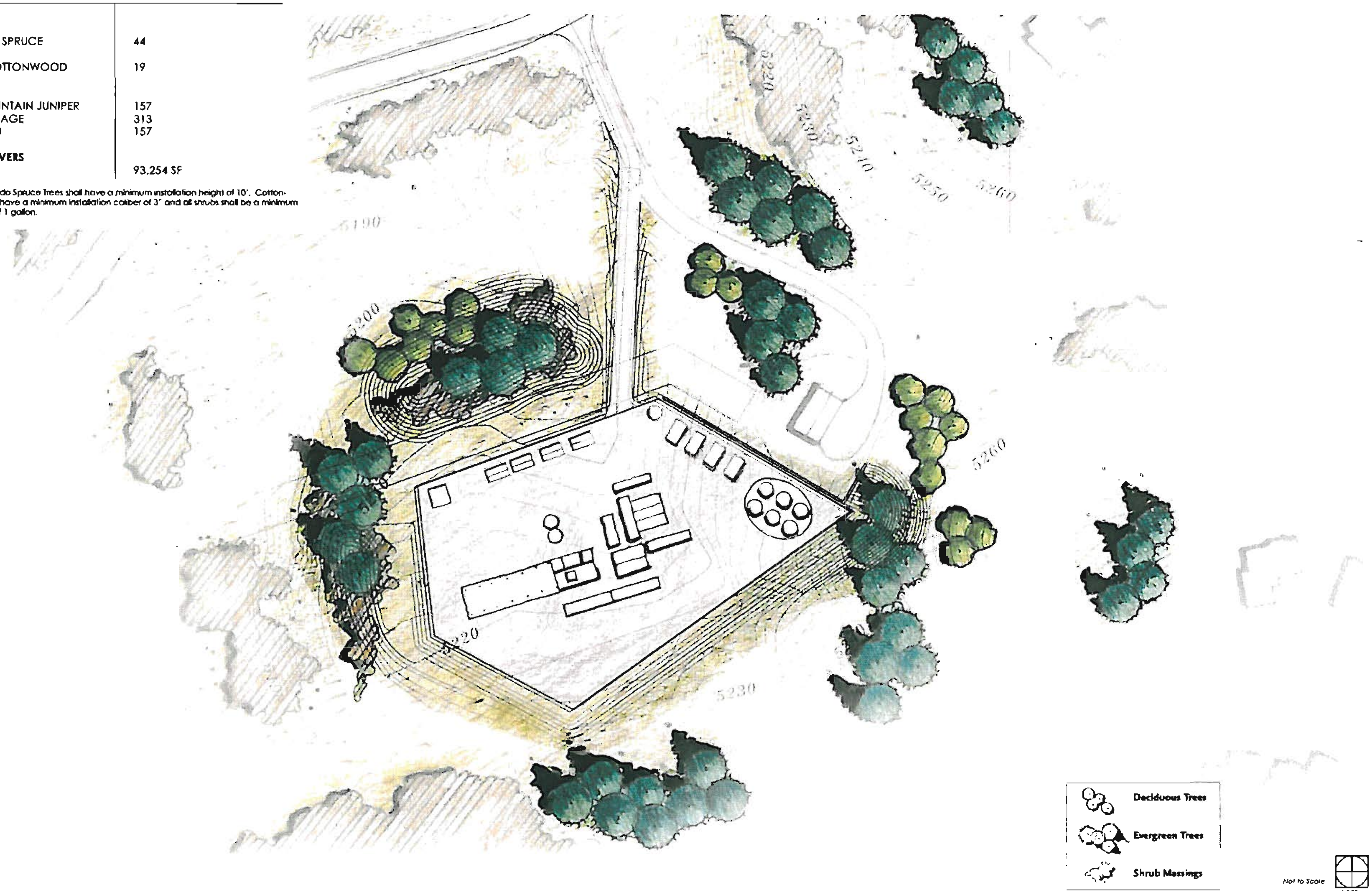
01/19/09 LIGHT EXPOSURE: PAD C

ANTERO RESOURCES

DESIGNWORKSHOP

PLANT TYPE	QUANTITY
TREES	
COLORADO SPRUCE	44
WESTERN COTTONWOOD	19
SHRUBS	
ROCKY MOUNTAIN JUNIPER	157
MOUNTAIN SAGE	313
RABBITBRUSH	157
GROUNDCOVERS	
SEEDMIX	93,254 SF

*Note: All Colorado Spruce Trees shall have a minimum installation height of 10'. Cottonwood trees shall have a minimum installation caliber of 3" and all shrubs shall be a minimum installation size of 1 gallon.



BATTLEMENT MESA PARACHUTE, COLORADO

01/19/09 PLANTING PLAN: PAD C

ANTERO RESOURCES

DESIGNWORKSHOP

Wellsite Location D

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location D

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09 and the Schematic, Light Exposure and Planting plans dated 1/19/09 by Design Workshop for this pad, including berming the access road into the Wellsite Location. Operator reserve the right to make minor adjustments to number size and variety of plants, subject to Operator's obtaining Owner's written consent to same, which consent shall not be unreasonably withheld.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will be oriented in a northwesterly direction as set forth in the above referenced Light Exposure plan. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the northwest, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting, where feasible.

3. Landscaping Plan. Operator agrees to landscape the Wellsite Location pursuant to the above referenced Planting Plan. Operator agrees to commence with such landscaping work as soon as initial dirt work at the site commences and complete the same prior to commencement of drilling activity at the Wellsite Location, taking into consideration the growing season. Operator will be responsible for maintaining such landscaping, including but not limited to installing irrigation.

4. Power at Site. Provided electrical power can be accessed under commercially reasonable terms from the local power distribution company servicing the area of the Wellsite Location, Operator shall only use electricity to power its drilling rigs at the site. To the extent third-party contractor equipment has the provisions to utilize electrical power, Operator shall require such third-party contractors to only use electricity to power its equipment at the site In emergency situations, Operator shall be permitted to utilize non-electric generators until such time as electrical power can be restored. Provided, however, these emergency generators shall be positioned in such a manner as to minimize noise impacts on the adjacent residences.

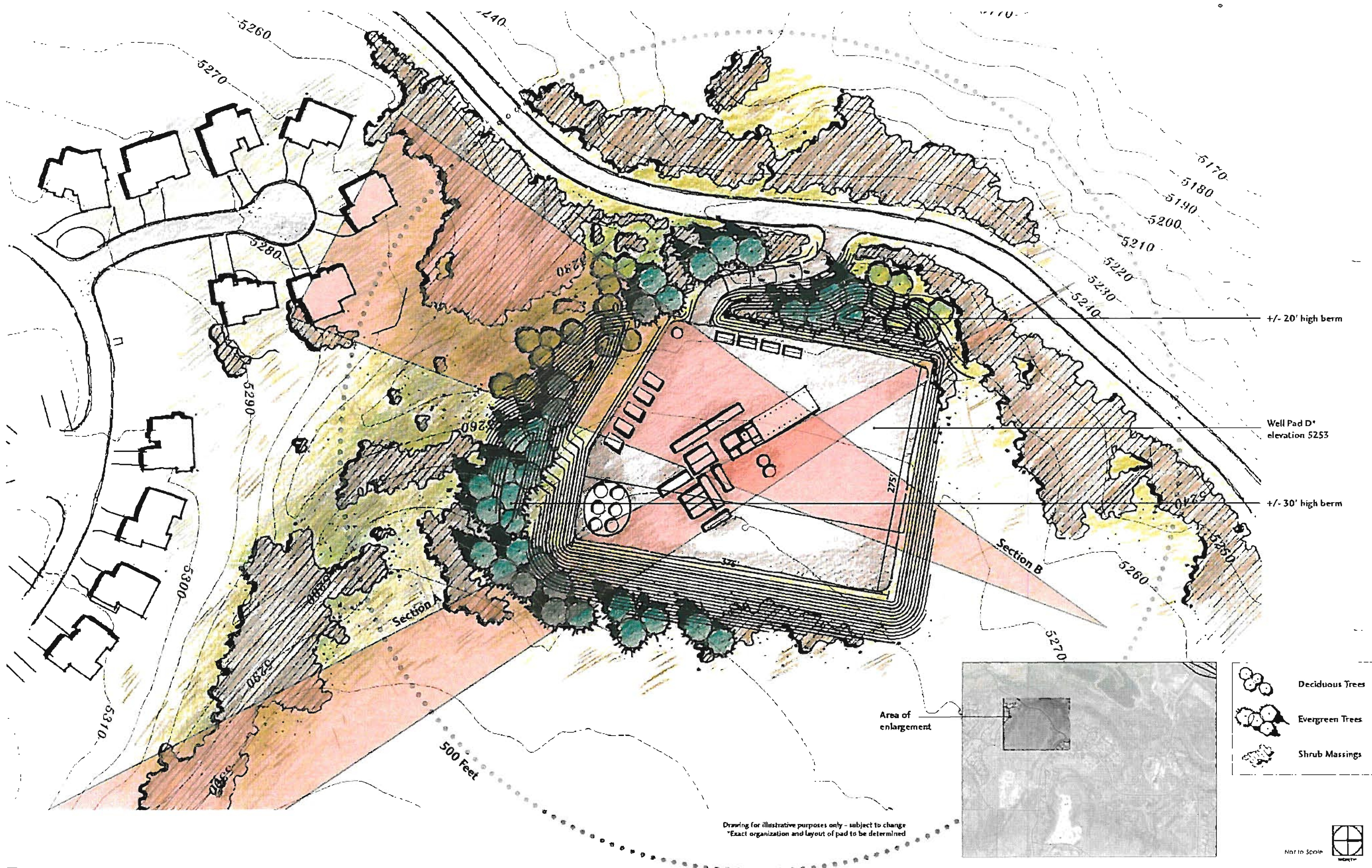
5. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soiltac and/or liquid dust suppressants.

6. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

7. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

8. Irrigation Water. If Operator chooses to purchase water from the Consolidated Metro District to provide its irrigation water, the cost of any tap will be at Operator's expense.

9. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.



BATTLEMENT MESA PARACHUTE, COLORADO

01/19/09

SCHEMATIC DESIGN: PAD D

ANTERO RESOURCES

DESIGNWORKSHOP

BATTLEMENT MESA PARACHUTE, COLORADO

01/19/09 LIGHT EXPOSURE: PAD D

ANTERO RESOURCES

DESIGNWORKSHOP

PLANT TYPE	QUANTITY
TREES	
COLORADO SPRUCE	35
WESTERN COTTONWOOD	20
SHRUBS	
ROCKY MOUNTAIN JUNIPER	198
MOUNTAIN SAGE	395
RABBITBRUSH	198
GROUNDCOVERS	
SEEDMIX	82,935 SF

*Note: All Colorado Spruce Trees shall have a minimum installation height of 10', Cottonwood trees shall have a minimum installation caliber of 3" and all shrubs shall be a minimum installation size of 1 gallon.

BATTLEMENT MESA PARACHUTE, COLORADO

01/19/09 PLANTING PLAN: PAD D

ANTERO RESOURCES

DESIGNWORKSHOP

Wellsite Location E

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location E

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09, including berming the access road into the Wellsite Location.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will most likely be oriented in a westerly direction. Focus of lighting will be downward and directed, where applicable, away from residences. If this light orientation becomes a nuisance to the residences in the vicinity of Wellsite Location E, Operator and Owner will cooperate to reasonably mitigate the effects related to lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting.

3. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soil tack and/or liquid dust suppressants.

4. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

5. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

6. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

Wellsite Location F

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location F

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09, including berming the access road into the Wellsite Location. Operator agrees to utilize this Wellsite Location as a centralized fluid gathering site, Operator agrees to use all best visual resource management practices when implementing odor control and spill prevention measures and will do so in accordance with all COGCC regulations and/or guidelines.

2. Lighting. If Operator utilizes this Wellsite Location as a drilling location, all lights on the Wellsite Location above the top level of the berm will most likely be oriented in a southerly direction. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the south, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting

3. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the site, These efforts shall include, but not be limited to, the use as options of mats, soil tack and/or liquid dust suppressants.

4. Storage and Parking. Operator agrees this site may be used for storage or parking of any property required by Operator for its drilling, development and production activities conducted pursuant to this Agreement.

5. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

Wellsite Location G

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location G

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09 including berming the access road into the Wellsite Location.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will most likely be oriented in a westerly direction. Focus of lighting will be downward and directed, where applicable, away from residences. If this light orientation becomes a nuisance to the residences in the vicinity of Wellsite Location G, Operator and Owner will cooperate to reasonably mitigate the effects related to lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting.

3. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soil tack and/or liquid dust suppressants.

4. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

5. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

6. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

Wellsite Location K

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location K

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09, including berming the access road into the Wellsite Location. If Operator utilizes this Wellsite Location as a drilling location, Operator agrees to build and maintain the Wellsite Location in accordance to Operator's highest standards during the drilling and completion phase, during the production phase (interim reclamation), and during the final reclamation phase. These standards are to meet or exceed all COGCC well-site regulations and/or guidelines. If Operator utilizes this Wellsite Location as a centralized fluid gathering site, Operator agrees to use all best management practices when implementing odor control and spill prevention measures and will do so in accordance with all COGCC regulations and/or guidelines. If Operator fails to utilize this site within three (3) years from the date of the Effective Date, Operator agrees to release this site from the potential of its development as a Wellsite Location.

2. Lighting. If Operator utilizes this Wellsite Location as a drilling location, all lights on the Wellsite Location above the top level of the berm will most likely be oriented in an easterly direction. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the east, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting.

3. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soil tack and/or liquid dust suppressants.

4. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

5. Storage and Parking. Operator agrees this site may be used for storage or parking of any property required by Operator for its drilling, development and production activities conducted pursuant to this Agreement.

6. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a

conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

Wellsite Location L

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location L
Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09and the Schematic, Light Exposure and Planting plans dated 1/19/09 prepared by Design Workshop, including berming the access road into the Wellsite Location, screening the valve sites and mitigating the impact of the Access Road entry way. Operator reserves the right to make minor adjustments to number, size and variety of plants, subject to Operator's obtaining Owner's written consent to same, which consent shall not be unreasonably withheld.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will be oriented in a southerly direction as set forth in the above referenced Light Exposure plan. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the south, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding the color of the surrounding landscape on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting, where feasible.

3. Landscaping Plan. Operator agrees to landscape the Wellsite Location pursuant to the above referenced Planting Plan. Operator agrees to commence with such landscaping work as soon as initial dirt work at the site commences and complete the same prior to commencement of drilling activity at the Wellsite Location, taking into consideration the growing season. Operator will be responsible for maintaining such landscaping, including but not limited to installing irrigation.

4. Power at Site. Provided electrical power can be accessed under commercially reasonable terms from the local power distribution company servicing the area of the Wellsite Location, Operator shall only use electricity to power its drilling rigs at the site. To the extent third-party contractor equipment has the provisions to utilize electrical power, Operator shall require such third-party contractors to only use electricity to power its equipment at the site In emergency situations, Operator shall be permitted to utilize non-electric generators until such time as electrical power can be restored. Provided, however, these emergency generators shall be positioned in such a manner as to minimize noise impacts on the adjacent residences.

5. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soil tack and/or liquid dust suppressants.

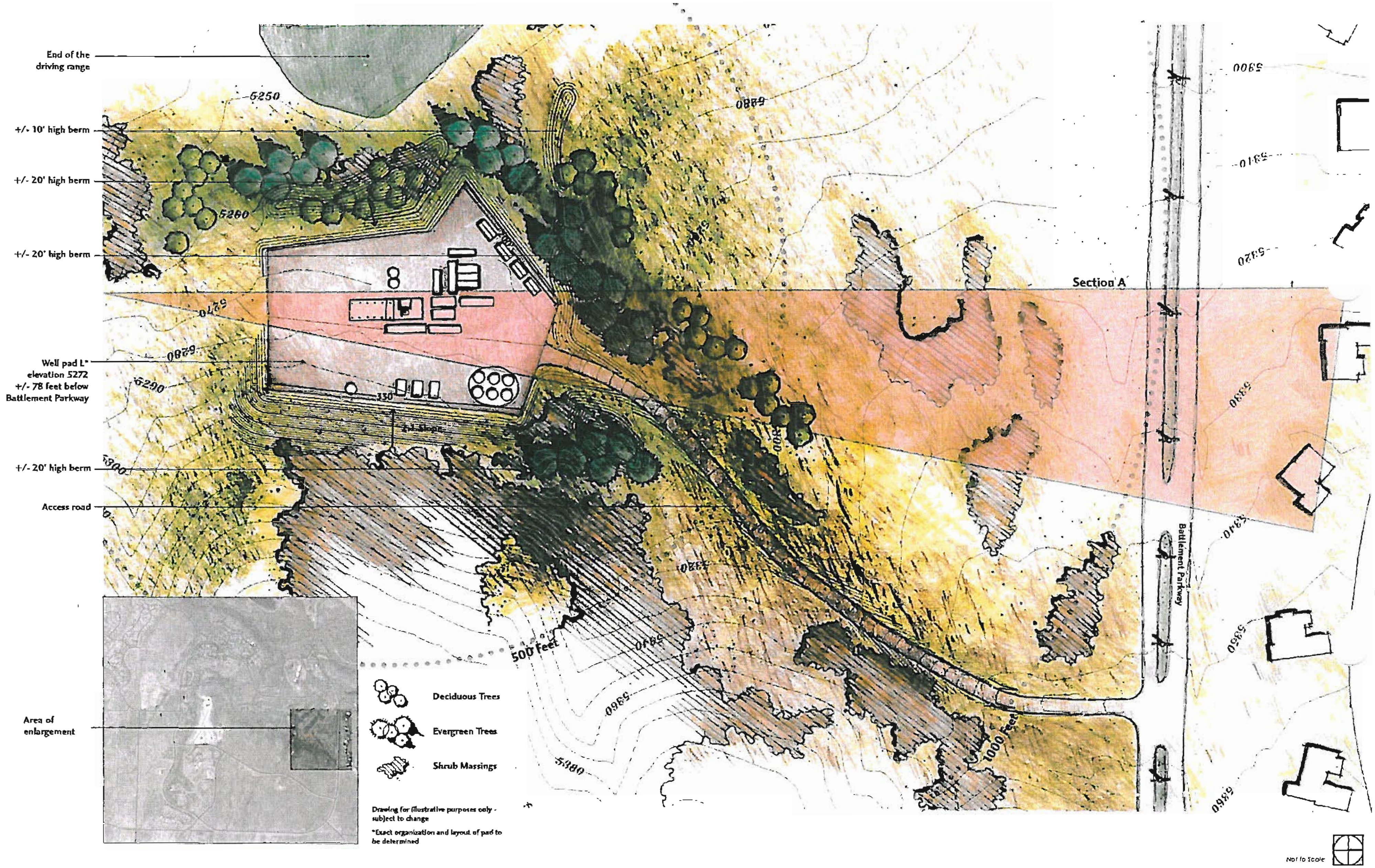
6. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

7. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

8. Irrigation Water. Owner shall provide Operator with access to the golf course irrigation system as well as a water supply to facilitate the irrigation and maintenance of the landscaping to be performed by Operator pursuant to paragraph five (5) above. Operator agrees to provide metering of the water utilized if requested in writing by Owner.

9. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

10. Consultation with Owner and Golf Course Operator. Operator agrees to consult with the Owner and the Golf Course Operator regarding mitigation of Oil and Gas Operations on the use and enjoyment of the golf course.



BATTLEMENT MESA PARACHUTE, COLORADO

ANTERO RESOURCES

01/19/09 SCHEMATIC DESIGN: PAD L

DESIGNWORKSHOP

Not to Scale

BATTLEMENT MESA PARACHUTE, COLORADO

01/19/09 LIGHT EXPOSURE: PAD L

ANTERO RESOURCES

DESIGNWORKSHOP

Wellsite Location M

Schematic prepared by Schmueser Gordon Meyer dated 1/20/09 is redacted

Wellsite Location M

Specific Operational Requirements

1. Visual Impact Mitigation. At Operator's sole expense, the Wellsite Location will be constructed to the ground level as depicted on the attached schematics created by Schmueser Gordon Meyer dated 1/20/09 and the Schematic, Light Exposure and Planting plans dated 1/19/09 prepared by Design Workshop, including berming the access road into the Wellsite Location. Operator reserves the right to make minor adjustments to number, size and variety of plants, subject to Operator's obtaining Owner's written consent to same, which consent shall not be unreasonably withheld.

2. Lighting. All lights on the Wellsite Location above the top level of the berm will be oriented in an easterly direction as set forth in the above referenced Light Exposure plan. Focus of lighting will be downward and directed, where applicable, away from residences. If for safety reasons, Operator deems it unreasonable to orient the lighting to the east, Owner will be notified and both will cooperate to reasonably mitigate the effects related to such reorientation of the lighting, including utilizing shrouding on three sides of the drilling rig on site as a mitigation measure, and the utilization of low density sodium vapor lighting, where feasible.

3. Bike Path Relocation. At Operator's sole expense, the current bike path will be relocated and reconnected with the existing bike path as shown on the attached plat in consultation with the Battlement Mesa Homeowners Association. The relocated bike path will be similar in width and constructed with similar materials as the existing bike path.

4. Golf Cart Path Relocation. At Operator's sole expense, the existing golf cart path located on the northeast side of the Wellsite Location will be relocated in consultation with the current owner of golf course. The relocated golf cart path will be similar in width and constructed with similar materials as the existing golf course path. If requested by the owner of the golf course, a safety fence will be installed on the edge of the golf cart path along areas of steep slope. This fencing shall consist of a split rail or other appropriate form of fencing (of similar expense) sufficient to protect persons in the area while not unnecessarily detracting from the natural setting of the golf course.

5. Landscaping Plan. Operator agrees to landscape the Wellsite Location pursuant to the attached schematic created by Schmueser Gordon Meyer dated 10/27/08 and the above referenced Planting Plan created by Design Workshop. Operator agrees to commence with such landscaping work as soon as initial dirt work at the site commences and complete the same prior to commencement of drilling activity at the Wellsite Location, taking into consideration the growing season. Operator will be responsible for maintaining such landscaping, including but not limited to installing irrigation. Operator also agrees to utilize such materials in the ditch

constituting a part of this Wellsite Location as to cause it be natural in appearance and in harmony with its surroundings.

6. Power at Site. Provided electrical power can be accessed under commercially reasonable terms from the local power distribution company servicing the area of the Wellsite Location, Operator shall only use electricity to power its drilling rigs at the site. To the extent third-party contractor equipment has the provisions to utilize electrical power, Operator shall require such third-party contractors to only use electricity to power its equipment at the site In emergency situations, Operator shall be permitted to utilize non-electric generators until such time as electrical power can be restored. Provided, however, these emergency generators shall be positioned in such a manner as to minimize noise impacts on the adjacent residences.

7. Dust Suppression. Operator shall utilize its best efforts at all times to suppress all dust emissions from the Wellsite Location, These efforts shall include, but not be limited to, the use as options of mats, soil tack and/or liquid dust suppressants.

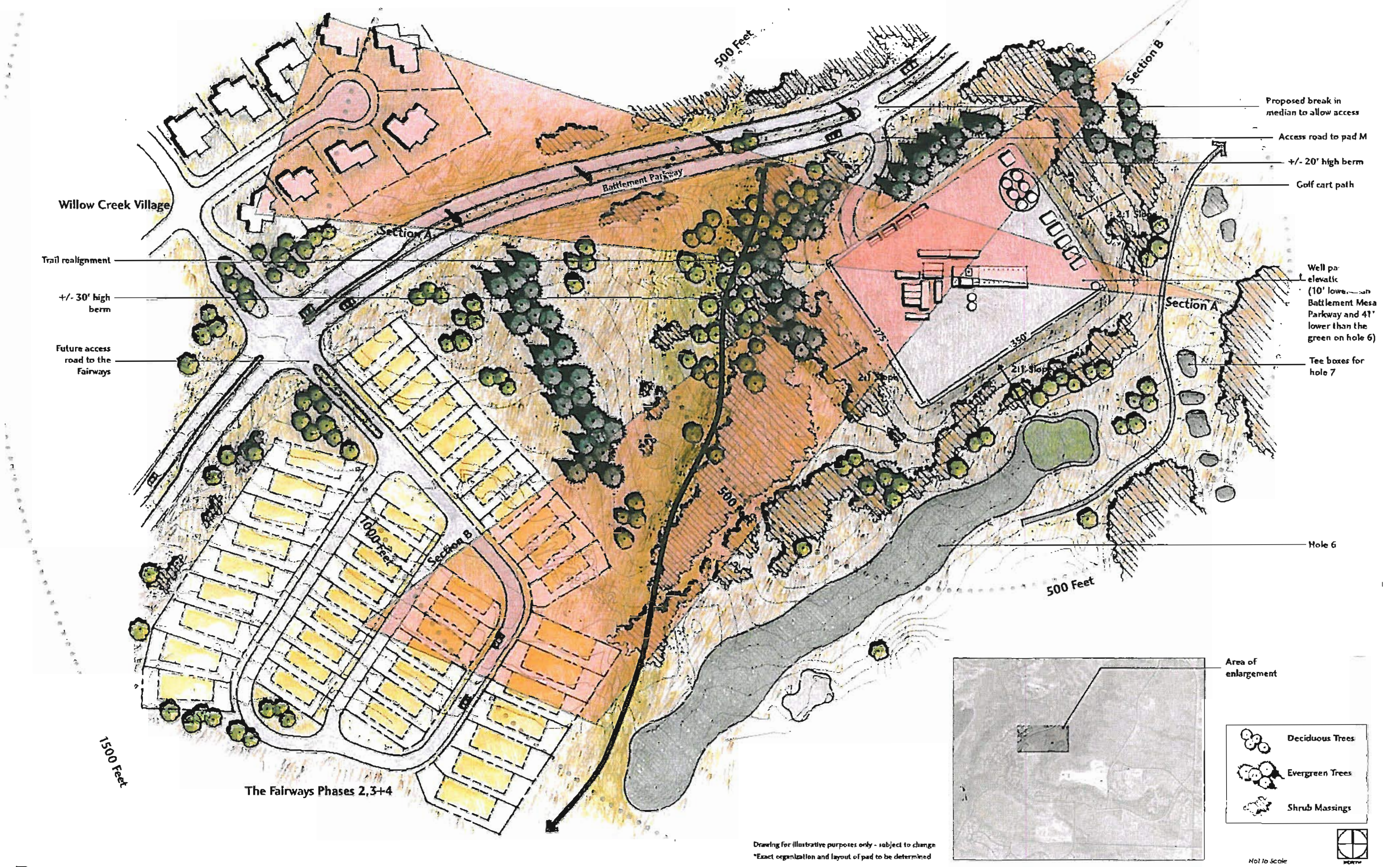
8. Wellhead Compression Housing. To the extent in Operator's opinion wellhead compression is necessary, Operator shall house all noise-related compression equipment in a structure that provides a high level of noise suppression available through the utilization of best management practices.

9. Storage and Parking. Operator agrees this site will not be used for storage or parking of any property other than that immediately required by Operator for its drilling, development and production activities.

10. Irrigation Water. Owner shall provide Operator with access to the golf course irrigation system as well as a water supply to facilitate the irrigation and maintenance of the landscaping to be performed by Operator pursuant to paragraph five (5) above.

11. Surface Use Agreement. These provisions incorporate and, at the same time, shall be considered a part of the SUA and all of its various exhibits. To the extent a conflict in the terms of this document and the SUA occurs, those terms more protective of the environmental and community interests of Owner and Battlement Mesa PUD shall control.

12. Consultation with Owner and Golf Course Operator. Operator agrees to consult with the Owner and Golf Course Operator regarding mitigation of Oil and Gas Operations on the use and enjoyment of the golf course.



BATTLEMENT MESA PARACHUTE, COLORADO

ANTERO RESOURCES

01/19/09 SCHEMATIC DESIGN: PAD M

DESIGNWORKSHOP

BATTLEMENT MESA PARACHUTE, COLORADO

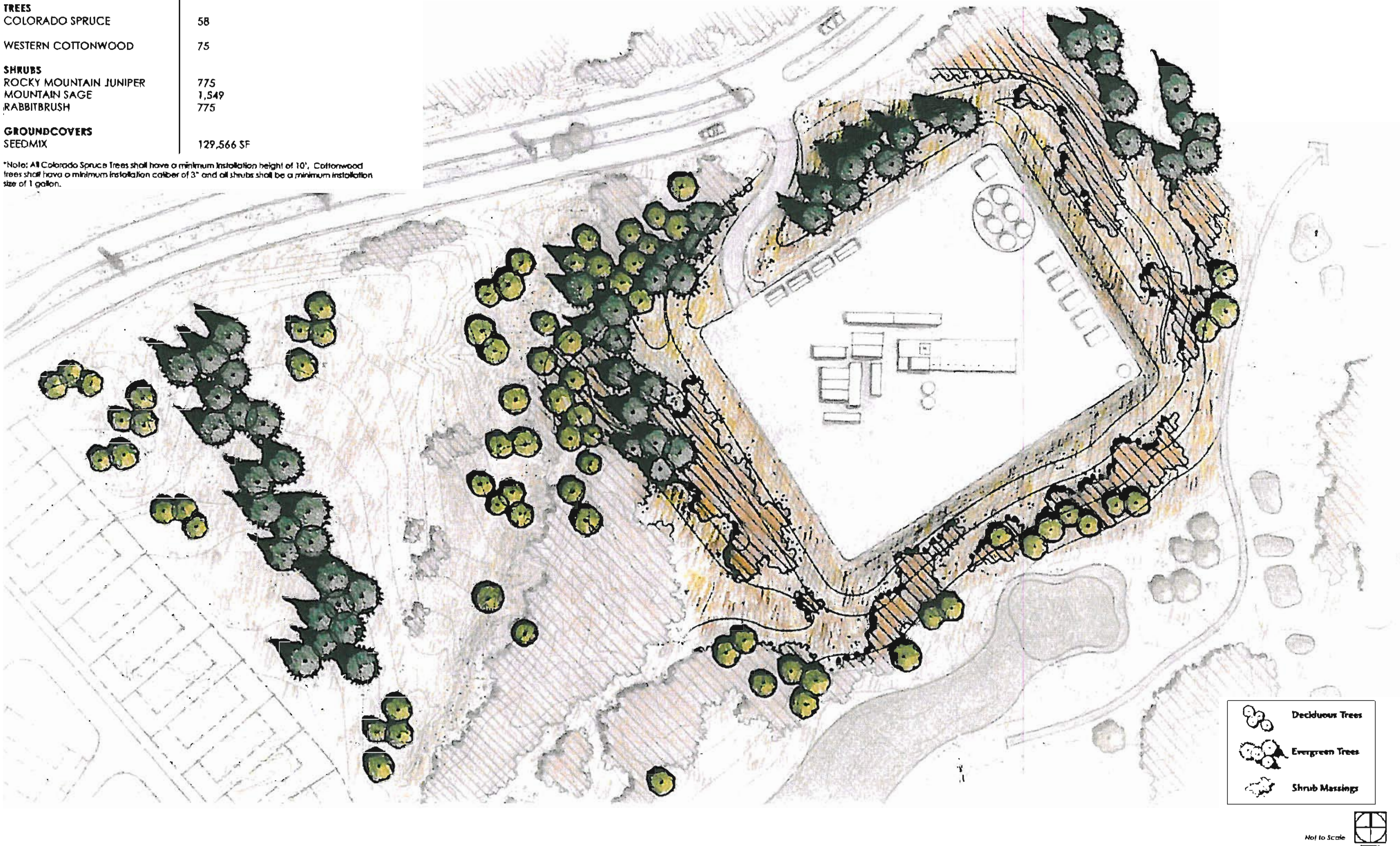
ANTERO RESOURCES

01/19/09 LIGHT EXPOSURE: PAD M

Not to Scale DESIGNWORKSHOP

PLANT TYPE	QUANTITY
TREES	
COLORADO SPRUCE	58
WESTERN COTTONWOOD	75
SHRUBS	
ROCKY MOUNTAIN JUNIPER	775
MOUNTAIN SAGE	1,549
RABBITBRUSH	775
GROUNDCOVERS	
SEEDMIX	129,566 SF

*Note: All Colorado Spruce Trees shall have a minimum installation height of 10'. Cottonwood trees shall have a minimum installation caliber of 3" and all shrubs shall be a minimum installation size of 1 gallon.



BATTLEMENT MESA PARACHUTE, COLORADO

ANTERO RESOURCES

01/19/09 PLANTING PLAN: PAD M

DESIGNWORKSHOP

Exhibit D

Reclamation Plan

AFFECTED COMMUNITIES/HABITATS

The affected community and habitats of each Wellsite Location and the Pipeline Easements will be established. Site vegetation may consist of sagebrush and grasses.

PRE-DISTURBANCE INVENTORY AND SITE PLANNING

Location plats for each Wellsite Location, Access Roads and Pipeline Easements will be created along with a legal description. The vegetation reference area will be identified for each will be documented by photographs.

Site planning and proposed fencing of disturbed areas will be documented.

TOPSOIL AND SUBSOIL DETERMINATION AND SALVAGE

An inspection of the soils at the proposed Wellsite Location, Access Roads and Pipeline Easements will be conducted. Immediately after soil samples are collected they will be placed in a cooler to preserve nitrate/nitrogen levels. Soil samples will be submitted to a lab for analysis of the following parameters:

- soil texture
- pH
- sodium absorption ratio
- electrical conductivity
- saturation percentage
- selenium
- nitrogen content
- phosphorus content
- potassium content
- cation exchange capacity
- organic matter content

The soil series and soil horizons will be identified for each well pad.

GUIDELINES FOR TOPSOIL AND SUBSOIL STRIPPING

The soil color differences and a slight texture difference will be identified for each soil series. The A horizon should be stripped to a depth as per the COGCC Series 1003 rule and stockpiled as topsoil separately. Soil salvaged in this manner will help assure a substantial volume of favorable growth media.

SOIL STOCKPILING

The stockpiled soil material not utilized in berming, wellpad construction and Access Roads for and to the various Wellsites shall be located on Wellsite F as indicated on the Schmueser Gordon Meyer schematics dated 1/20/09 and, where applicable, Design Workshop.

TEMPORARY REVEGETATION EFFORTS

The soil stockpile, as well as cut and fill slopes, will be seeded immediately after the well pad disturbance. The seed mixture will consist of grass species which appear on the BLM list of recommended seed mixes. The seed mixture may be hand broadcast and drag harrowed and/or hand raked to get good soil contact.

SOIL AMENDMENTS AND FERTILIZERS

The results of the soil inspection will be used to determine the appropriate soil amendments and fertilizers and the depth of their application.

STABILIZATION AND INTERIM RECLAMATION

Interim reclamation will be performed in accordance with COGCC Series 1003 rules. The objectives of stabilization and interim reclamation will be as follows:

1. Stabilization of the disturbed areas will be conducted by providing wind and water erosion control to reduce soil loss.

2. Utilize the prescribed seed mixture and additional vegetation practices as described below to establish a self-sustaining vegetative rangeland cover.

Operator shall utilize irrigation as necessary during the course of interim reclamation measures to assist in the establishment of plant life at the site consistent with good reclamation practice.

All interim reclamation shall be consistent with Exhibit C Wellsite requirements.

BACKFILLING, GRADING, AND RE-CONTOURING

Reclaimed areas will be sloped to 3:1 or less. A flat area will be maintained for well servicing and potential future additional drilling efforts. Further drill pad reduction may be possible based on landowner requirements and/or site conditions.

TOPSOIL REPLACEMENT

Soil salvaged when the wells are drilled will be redistributed over the soil surface after subsoil has been replaced and additional backfilling, grading, and re-contouring steps have been completed as described below. Soil will be replaced by using front-end loaders, trackhoes, and dozers. Soil will not be replaced when it is excessively wet and frozen so as to jeopardize soil structure.

SEEDBED PREPARATION/SOIL TILLAGE

Seedbed preparation and soil tillage will be completed after the application of subsoil, topsoil, and any soil amendments. Soil tillage will be to a minimum depth of 4" utilizing a disk, chisel plow, or harrow. Seedbed preparation will also include removal of coarse fragments (rock material) that exceed 35% to 40% of the soil surface as well as rocks 8" in diameter that occupy more than 10% of the soil surface.

SEEDING METHODS AND TIMES

If interim seeding is performed in the spring, it will be accomplished by May 15; if fall seeding is performed, it will be completed after August 30 and before the soil freezes. Both temporary and interim vegetation efforts will consist of drill seeding with a rangeland drill to a planting depth of ¼" to ½" on slopes 3:1 or flatter. Broadcast seeding, followed by harrowing or hand raking to lightly cover the seed with soil, will be used on slopes steeper than 3:1 or areas inaccessible for drill seeding equipment. All well sites, access roads, and flow line and gathering line right-of-ways will be mulched immediately after seeding and no later than 24 hours after seeding with a weed-free straw or grass hay material. Grass hay mulch will be applied at 1 ½ tons per acre, or straw mulch will be applied at 2 tons per acre. Mulch material will be crimped into the soil surface with a commercial mulch crimper, a straight disc, or bulldozer tracks if too steep to otherwise crimp mulch in place.

SEED MIXTURES

The seed mixtures will be those as recommended by the BLM for the appropriate habitat or affected community and or as requested by the landowner.

EROSION CONTROL BLANKETS AND OTHER SPECIAL PROVISIONS FOR EROSION CONTROL

Erosion control procedures will be specified by the site specific Storm Water Management Plan (SWMP) as required by the Colorado Department of Public Health and Environment, Water Quality Control Division. The SWMP will include, among other things, detailed descriptions of erosion control best management practices (BMPs). The location of each site specific BMP will be identified on a plat.

NOXIOUS WEED CONTROL PLAN

The location will be inspected three times per year by a qualified person. Based on this inspection, methods, materials, and timing of weed control measures will be specified. Weed control inspections and response measures will be documented. A table of the noxious weeds of concern to Garfield County is presented below.

Table 1: Garfield County Noxious Weed List

Scientific Name/Common Name
Cirsium arvense Canada thistle
Cichorium intybus Chicory
Arctium minus Common burdock
Linaria dalmatica Dalmatian toadflax
Centaurea diffusa Diffuse knapweed
Cardaria draba Hoary cress
Cynoglossum officinale Houndstongue
Aegilops cylindrica Jointed goatgrass
Euphorbia esula Leafy spurge
Carduus spp. Musk thistle
Crysanthemum leucanthemum Oxeye daisy
Carduus acanthoides Plumeless thistle
Lythrum salicaria Purple loosestrife
Centaurea repens Russian knapweed
Elaeagnus angustifolia Russian olive
Tamarix parviflora, Salt Cedar
Tamarix ramosissima, Salt Cedar
Onopordum acanthium Scotch thistle
Centaurea maculosa Spotted knapweed
Centaurea solstitialis Yellow starthistle
Linaria vulgaris Yellow toadflax
Source: Garfield County - Noxious Weed List, 2007.

FINAL RECLAMATION

Successful final reclamation of the Property shall consist of compliance with the provisions of this Exhibit D and full compliance with the then-applicable provisions of COGCC Rule 1004.e or such comparable provision as is in effect at the time of such final reclamation.

Prior to final reclamation of Wellsites L and M, Operator and Owner agree to confer and determine between themselves what form the final reclamation of these Wellsites shall take. The agreement reached between these parties shall be reduced to writing and executed by both for submission to the COGCC, In the event no agreement can be reached, Operator shall reclaim these Wellsites as set forth above.

CURRICULUM VITAE

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(303) 355-2625

POSITION:

Medical Toxicologist
President
Daniel Thau Teitelbaum, M.D., P.C.
Medical Toxicology & Occupational Medicine

ADDRESS:

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(303) 355-2625

SCOPE OF PRACTICE:

Medical Toxicology
Occupational Medicine
Occupational and Environmental Toxicology
Acute and Chronic Poisoning
Analytical Toxicology
Clinical Pharmacology

BORN:

May 26, 1935
New York, New York
Citizenship: U.S.A.

PROFESSIONAL EXPERIENCE:

Qualified Expert Witness in Clinical Toxicology since 1967.

Consultant to the Industrial Commission and State Compensation Fund of Colorado, The United States Food and Drug Administration and the Occupational Safety and Health Administration.

Consultant to industry, agriculture, and labor in occupational and environmental toxicology, including: IBM, CFI Steel, Dresser Industries, W.R. Grace, Coors, Monfort of Colorado, Dynalectron Corporation, Amoco, Xerox, Northern Telecom, Motorola, NCR, TRW, Intel Corporation, Heat and Frost and Asbestos Workers Union, Colorado Construction Trades Council, etc.

Lecturer and seminar leader in all aspects of toxicology practice. Fields of interest: solvents, asbestos, lead, carcinogenesis and biomedical and environmental monitoring.

Extensive experience in the practice of analytical, biomedical and occupational/environmental toxicology. Founder and former director of Poisonlab and Enbionics, independent toxicology laboratories licensed by CDC accredited by AIHA (#60.) Consultant in analytical and clinical toxicology to Bioscience Laboratories and other independent laboratories.

ACADEMIC AFFILIATIONS:

Adjunct Professor Occupational and Environmental Health, Colorado School of Public Health, University of Colorado at Denver, Denver, Colorado.

Adjunct Professor of Environmental Sciences, Colorado School of Mines.

Visiting Professor, Medicine and Toxicology, Israel Institute of Technology, The Technion, Haifa Israel.

Scope of teaching: Medical, occupational and environmental toxicology, and occupational medicine.

Former Member of Physicians' Poison Consultation Service	University of Colorado Medical Center, Denver, Colorado
Consultant in Medical Toxicology	Denver General Hospital and Rocky Mountain Poison Center 1967-1993

CDC licensed Clinical Laboratory Director

7/2008- Present	Private Practice, Limited 355 Ogden Street Denver, Colorado 80218
2006 – 2008	Private Practice Medical Toxicology 50 S. Steele Street, Suite 588 Denver, Colorado 80209
1988-2006	Private Practice Medical Toxicology 155 N. Madison Denver, CO 80206
1983 - 1988	Director / Occupational Medicine and Toxicology Denver Clinic (Accord Medical Center) 701 East Colfax Avenue Denver, Colorado 80203
1982 - 1983	Staff Physician / Occupational Medicine Denver Clinic 701 East Colfax Avenue

Denver, Colorado 80203

1982 - 1989 Medical Director, Analytitox Inc.
Denver, Colorado

1979 - 1982 President
Worksafe, Inc.
6825 East Tennessee
Denver, Colorado 80224

1973 - 1979 President, Poisonlab / Enbionics
Division of Chemed Corporation
1469 South Holly Street
Denver, Colorado 80222

Offices in Denver, San Diego, Cleveland
CLIA #05-1014   AIHA #60

1970 - 1973 Founder, President, and Toxicology Consultant
Poisonlab, Inc.
1469 South Holly Street
Denver, Colorado 80222

Private Practice - Clinical Toxicology
2045 Franklin Street
Denver, Colorado 80222

1970 - 1971 Director of Licensed Methadone Treatment Program
IND 6867
2045 Franklin Street
Denver, Colorado 80205

1968 - 1970 Director of Emergency Services
University of Colorado Medical Center
Denver, Colorado

Assistant Professor of Medicine and Preventive Medicine
University of Colorado Medical Center
Denver, Colorado

1967 - 1968 Clinical Instructor, Preventive Medicine
University of Colorado Medical Center
Denver, Colorado

EDUCATION:

1956 Bachelor of Arts   Hamilton College
Clinton, New York

1960	Master of Hebrew Letters and Rabbi	Jewish Theological Seminary of America
1964	Doctor of Medicine	Albert Einstein College of Medicine
1964 - 5	Intern, Mixed Medicine	Montefiore Hospital New York City, New York
1965 - 7	Resident, Internal Medicine	University of Colorado Medical Center Denver, Colorado
1967 - 8	Fellow in Medicine and Toxicology	University of Colorado Medical Center Denver, Colorado
1991 - 2	Occupational and Environmental Medicine Program	University of California San Francisco, California

BOARD CERTIFICATION:

Board Certified American Board of Medical Toxicology, 1975
Recertified by examination, August 1976
Board Certified American Board of Preventive Medicine in Occupational Medicine, January, 1994

COMMITTEES:

Physician Panel Member, U. S. Department of Energy, Office of Worker Advocacy

Member, Metalworking Fluids Standards Advisory Committee, Occupational Safety and Health Administration (OSHA)

Former Member, Toxicology Resource Committee, College of American Pathologists

Former Member, Education Committee, American Academy of Clinical Toxicology

Chairman, United States Food and Drug Administration Advisory Committee on toxicology diagnostic products. (Executive Appointment) 1976 - 1978

Special Consultant to OSHA, U.S. Department of Labor on Lead, 1977. Participant on behalf of OSHA in lead standards setting hearings

Member, Committee on Operation of Centers, American Association of Poison Control Centers

Chairman, Drug Abuse Committee, American Occupational Medical Association, 1977 -1978

Former Member, ASTM Committee E-34 on Safety in the Workplace

Former Member, Board of Trustees, American Academy of Clinical Toxicology

Former Member, Environmental Affairs Committee, W.R. Grace and Company

Former Member, Chemical Regulations Advisory Committee, Manufacturing Chemists Association

Member, Forensic Sciences Committee of the American Society for Testing and Materials

Member, Occupational Medicine Committee of the American Industrial Hygiene Association

Special Consultant to OSHA, USDOL on Access to Medical Records Standard, 1981

Former Member, State Poison Control Committee, Colorado Department of Health

Former Member, Joint Pesticide Advisory Committee, State of Colorado

Former Secretary - Treasurer to the American Academy of Clinical Toxicology

Former Chairman, Therapeutics Committee, American Academy of Clinical Toxicology

Special Consultant to OSHA, USDOL on Hazard Communication Standard, 1982

Special Consultant to OSHA, USDOL on Ethylene Dibromide Standard, 1984

Member, Editorial Board, Journal of Toxicology, Clinical Toxicology, 1968 - 1982

Peer Reviewer, Annals of Internal Medicine, 1970 - 1985

Peer Reviewer, Journal of the American Medical Association, 1975 - 1985

Member, Special Blue Ribbon Panel of the Executive Office of the President, National Science Foundation / Council on Environmental Quality on Future Health Implications of Emerging Technologies, 1984

Secretary of the Medical Executive Committee, Saint Joseph Hospital, Denver, Colorado, 1985 - 1986

Special Consultant to OSHA, USDOL on Benzene Standard, 1986

Witness before The Committee on Oversight and Government Reform on the public health implications of oil and gas development, Oct 2007

SOCIETIES:

American Academy of Clinical Toxicology
American Academy of Forensic Sciences
American Association for the Advancement of Science
American Association of Poison Control Centers
American College of Medical Toxicology
American College of Clinical Pharmacology
American College of Preventive Medicine
American Industrial Hygiene Association
American Medical Association
American Society of Clinical Pathologists
American Society for Testing and Materials
American Society of Veterinary Toxicologists
Colorado Medical Society
Denver Medical Society
Forensic Science Society
Occupational Medical Association
Rocky Mountain Academy of Industrial Medicine
Society for Risk Analysis
Society of Sigma Xi, The Scientific Research Society

HONORS:

Elected fellow of Collegium Ramazzini, November 1994
World Health Organization Traveling Fellowship in Clinical Toxicology
Founders Award, American Academy of Clinical Toxicology
Student Fellowship, Jackson Memorial Laboratory, 1952 - 3
Numerous Academic Prizes in College

FELLOWSHIPS:

Fellow, American College of Clinical Pharmacology, 1973
Fellow, American Academy of Clinical Toxicology, 1976

PUBLICATIONS:

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01/09