WORKING DRAFT

Garfield County
Air Toxics Inhalation: Screening Level Human Health Risk Assessment

Inhalation Of Volatile Organic Compounds Measured In Rural, Urban, and Oil &Gas Areas In Air Monitoring Study
(June 2005 – May 2007)

December 2007

Prepared by the

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Executive Summary

This report discusses results for a screening-level risk assessment of potential human health impacts from inhalation of air toxics (i.e., Volatile Organic Compounds; VOCs) in Garfield County, Colorado. The purpose of the evaluation was to determine if residents at any of the locations are being exposed to airborne concentrations of VOCs via inhalation that may pose unacceptable risks to human health. This evaluation was conducted to address concerns from local citizens about potential health effects from air pollution in the area, primarily as a result of the dramatic increase in oil and gas development activities.

The risk assessment was conducted in accordance with the Tier-1 of EPA's Air Toxic Risk Assessment Library (EPA, 2004). The data for risk assessment was collected from fourteen fixed air monitoring sites for 24-hours on a once per month or once per quarter basis. These fourteen sites are 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 for VOCs at 27 locations based on odor complaints.

This document provides an overview of EPA's Air Toxic Risk Assessment process and methodology, potential exposure scenarios, and the potential health effects with the associated uncertainties. Two types of health effects were evaluated: Cancer risk, which represents the potential for increased risk of cancer in a lifetime associated with exposure to air toxics, and non-cancer hazards (both chronic and short-term) which represent the potential for a non-cancer health effect due to exposure to air toxics.

Overall, the non-cancer hazards on either a chronic or short-term (average) basis do not exceed an acceptable value of one 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). Although the estimated exposures are not likely to result in significant cancer and non-cancer health effects, this screening-level analysis stresses the need for continued air monitoring and source apportionment for the following reasons:

a. The combined findings of the theoretical cancer risks and the short-term non-cancer hazards (high-end) are somewhat indicative of potential for benzene impacts across the oil and gas development area, based on the estimated exposures at the Brock monitoring site.

b. Overall, the estimated cancer risks and the non-cancer hazards across the rural background area appear to be significantly lower than those across the oil and gas development and urban areas.

c. Although total cancer risks are slightly higher in the urban area than those in the oil and gas area, the major contributors of cancer risk are different between the two areas. For example, benzene is the major contributor of risk across the oil and gas development area while TCE and 1,4-dichlorobenzene are the major contributors in the urban area. It should be recognized that TCE, a major

contributor of the cancer risk, occurred only at one urban site at the detection frequency of 12.5% based on a small sample size (8 samples).

d. The cancer risk estimates for benzene across the oil and gas development area, as represented by the Brock monitoring site, are significantly higher than those across the urban and rural background areas. It should be noted that the estimated cancer risks for benzene at the Brock monitoring site are somewhat driven by exposures to a very high concentration over the 24-hour period. These results identify the substantial uncertainty associated with the limited sampling on a once per month or once per quarter basis.

e. The high-end short-term non-cancer hazard estimates across the oil and gas development area, as represented by the Brock monitoring site, exceed an acceptable value of one for benzene (e.g., Hazard Quotients of 2 or 3) showing the potential for adverse health effects. These non-cancer hazard estimates are driven by exposures to the 24-hour maximum detected concentrations for 1-364 days (acute- and intermediate-duration).

f. The high-end acute non-cancer hazard estimates for benzene across the oil and gas development area, as represented by several grab sampling sites, exceed an acceptable value of one (e.g., Hazard Quotients of 2 to 6) showing the potential for adverse health effects. It should be noted that these estimates of maximum acute impact are based on the conservative assumption of exposure to the 15-second maximum detected concentrations for 1-14 days. Although the estimated exposures are based on an extremely conservative assumption and the likelihood of such exposures is uncertain, these findings emphasize the need for further investigation.

g. Benzene is a serious concern from toxicological standpoint because it is a proven human carcinogen (Class A, known human carcinogen) based on occupational studies in adults that demonstrated increased incidence of several types of leukemia in exposed adults. Additionally, the elevated non-cancer hazards indicate increased potential for immunological effects to occur in an individual exposed for the short-term exposure duration (1-364 days) at this location. In general, short-term inhalation of benzene at low exposure levels can alter certain immune system associated processes. For example, lymphopenia, lymphocyte depression, and increased susceptibility to bacterial infection are some of the adverse immunological effects observed in acute-duration inhalation studies in animals.

In general, this risk assessment can be considered a conservative estimate of current exposures on the basis of the exposure assessment. For example, the chronic risk estimates are based on an individual that is exposed to the monitored concentrations over 70 years, for 24 hours per day. Actual risks from current exposures to air toxics evaluated in this investigation are likely to be lower than the upper-bound risks presented in this risk assessment. However, the future exposures may be underestimated because

this evaluation does not take into account increase in air concentrations of VOCs over time, as a result of anticipated increase in oil and gas development activities. The monitoring study only looked at a total of 43 air toxics and some important air toxics are absent which may underestimate potential risks. Most importantly, the study is based on the limited monitoring data collected on a once per month or once per quarter basis which is significantly lower than the EPA National Air Toxic Program recommended data collection frequency on a once per week basis. Additionally, science is currently unable to assess exposures to multiple air toxics simultaneously. Overall, uncertainties and limitations exist in the methods used to assess exposure and toxicity. Due to these limitations, this investigation is best viewed as a "snapshot" of air quality.

This evaluation strongly supports 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 activities.

1 Introduction

This report presents the methodologies and findings of the risk evaluation for ambient air toxics monitoring conducted at fourteen fixed sites in Garfield County, Colorado from June 2005 through May 2007. According to CDPHE (2007), fixed VOC sites were selected based on population exposure, local citizen complaints, or willingness of land owners. Thus, four sites were located in urban areas for population protection, nine sites were located in oil and gas development areas for citizen complaints, and two sites were located in rural area for background concentrations. Detailed site locations and air monitoring are discussed elsewhere (CDPHE, 2007). The assessment represents a "snapshot" in time for characterizing health risks from exposure to only VOCs. It does not take into account potential increase in emissions over time, as a result of anticipated increase in oil and gas development activities. It is also not designed to characterize risks sufficiently from inhalation of all types of air toxics (e.g., all VOCs, semi-VOCs, and metals). Additionally, the risk assessment is limited to inhalation risk from outdoor sources and it does not characterize risks through pathways other than inhalation of contaminated air (i.e., indirect exposure pathways). In air toxic risk assessment, the inhalation pathway is commonly assessed. However, indirect exposure pathways can be significant for chemicals which are relatively persistent in the environment.

1.1 Purpose

The purpose of the evaluation is to determine if residents at any of these locations are being exposed to airborne concentrations of measured volatile organic compounds (VOCs) via inhalation that may pose unacceptable risks to human health. In addition, this risk assessment will help the Garfield County and others to set priorities for the collection of additional information to improve future health assessments.

1.2 Overview Of Risk Assessment Process

A human health risk assessment process attempts to understand public health risks potentially associated with exposures to measured VOCs emitted into the air from sources of interest and any uncertainties associated with the assessment. Specifically, the 1990 National Contingency Plan (NCP) (55 Fed. Reg. 8665-8865 (Mar. 8, 1990) states that the risk assessment should " characterize the current and potential threats to human health and the environment that may be posed by contaminants migrating to ground water or surface water, releasing to air, leaching through soil, remaining in the soil…." (Section 300.430(d) (4) as cited by EPA, 1991). Risk assessment is generally a four-step process consisting of hazard identification, exposure assessment, dose-response assessment, and characterization of risk based on the combination of results of the three previous steps, and the associated uncertainties (USEPA, 1989, RAGs Part A; USEPA, 1992a).

Traditionally, various EPA documents and the Air Program's *Residual Risk Report to Congress* recommend a tiered framework for risk assessment (USEPA, 1999, 2004). Consistent with the *Residual Risk Report to Congress and the EPA Risk Assessment Reference Library*, the three-tiered framework could include: Tier 1-which is represented

as an initial relatively simple, screening-level analysis using conservative exposure assumptions (e.g., receptors are located in the area with the highest estimated concentrations); Tier 2-which is represented as an intermediate-level analysis using more realistic exposure assumptions (e.g., use of actual receptor locations and more site-specific inputs; and Tier 3-which is represented as an advanced analysis using probabilistic techniques and intensive site-specific modeling. Conceptually, these tiers are best thought as points along a spectrum of increasing complexity and detail in the risk assessment. The existing risk assessment results are evaluated to determine whether they are sufficient for the risk management decision, and if not, what refinements are needed including moving up the next tier. The decision regarding which of the three tiers is most appropriate for a given site must balance the need for accuracy with considerations of cost and timeliness (EPA, 2004). It is important to note that risk assessment only provides one of several important tools in the whole risk management process. EPA's regulatory process also calls for consideration of non-scientific factors (e.g., economic, social, political, and legal factors) in decision-making (USEPA, 1992a; 2004).

1.3 Organization of This Report

Section 1 Introduction

This section provides the purpose of risk assessment and the document organization.

Section 2 Selection Of Chemicals Of Potential Concern

This section discusses the chemicals of potential concern to human health, and provides a summary of the available data on the levels of these chemicals.

Section 3 Exposure Assessment

This section discusses how humans may be exposed to air toxics, now or in the future, and provides the approach for quantifying the level of exposure for those chemicals that are considered to be of potential significance

Section 4 Toxicity Assessment

This section summarizes the characteristic cancer and noncancer health effects of the chemicals of potential concern, and provides quantitative toxicity factors that can be used to calculate cancer and noncancer risk levels.

Section 5 Risk Characterization

This section combines data on the level of exposure to chemicals of potential concern (Section 3) with information on the toxicity of each chemical (Section 4) to yield quantitative estimates of the risks of cancer and non-cancer effects in exposed humans.

Section 6 Uncertainties

This section reviews the sources of uncertainty in the risk estimates for humans, and evaluates which sources of uncertainty are likely to underestimate and which are likely to overestimate risk.

Section 7 Summary and Conclusions of the Screening Level Risk Assessment

Section 8 References for Risk Assessment

This section provides full citations for EPA guidance documents and scientific publications referenced in the risk assessment.

2 Selection of Chemicals Of Potential Concern

This Section selects chemicals of potential concern for further analysis in the risk assessment. Chemicals of Potential Concern (COPCs) are chemicals that exist in the environment at concentration levels of potential health concern to humans. For the risk assessment, each monitor location will be evaluated separately, so the data analysis and selection of chemicals of potential concern (COPCs) is presented individually for each monitor.

Chemicals of potential concern (COPCs) are chemicals that a) are present, and b) occur at concentrations that are or might be of health concern to exposed humans. The U.S. Environmental Protection Agency (USEPA) has derived a standard method for selecting COPCs, as detailed in Risk Assessment Guidance for Superfund: Human Health Evaluation Manual (Part A) (USEPA, 1989). Additionally, Regional-specific guidance has been developed by USEPA Region 8 (1994) for use in the selection of COPCs. In brief, USEPA assumes that any chemical detected is a candidate for selection as a COPC, but identifies a number of methods that may be used for determining when a chemical is not of authentic concern and may be eliminated from further consideration. Each risk assessment may choose to apply some or all of the methods identified by USEPA to select COPCs, as appropriate. It is, however, important to note that the USEPA RAGs Part A (USEPA, 1989) superfund method is generally applied to other sites which are not part of the superfund process, because this method provides a selection process to reduce the number of contaminants of potential concern to a reasonable amount using the risk-based scientific approach. Note that this approach is not applied in this evaluation and all

chemicals having detection frequencies >0% are conservatively retained as chemicals of potential concern (COPCs) for further evaluation.

2.1 Summary of COPCs

The data analysis for 43 chemicals for 24-hour samples (June 2005-May 2007) and 15-second grab samples is summarized in Appendix A. Table A1 summarizes the detected chemicals in 24-hour and grab samples across all sampling locations. Table A2 provides a list of 28 chemicals that were analyzed for, but were never detected across all stations. The overall summary of site-specific COPCs is provided in Table 1. As seen, the most commonly detected COPCs across oil and gas, urban, and rural background sites included: acetone, benzene, toluene, vinyl acetate, 2-butanone, and m,p-xylene. Other COPCs detected at several monitoring locations across oil and gas, urban, and rural background sites included: 1,4-dichlorobenzene, ethylbenzene, o-xylene, and 2-hexanone. The COPCs that occurred infrequently only at some sites included: (a) Trichloroethene at one urban site (Parachute); (b) Tetrachloroethene at one urban (Rifle) and one oil and gas development site (Haire); (c) Trichlorofloromethane only at one urban site (Parachute); (d) Styrene at two oil and gas development sites (Haire and Isley); and (e) Methylene chloride at two urban sites and two oil and gas development sites. The site-specific COPCs are discussed in the following sections for each individual monitoring area (e.g., Oil and gas development, urban, and rural background).

COPCs For Oil and Gas Development Sites

Bell Site

Table A3 summarizes the COPC screening process for the Bell monitoring location. As seen, of the 15 chemicals that were initially measured, 6 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 9 chemicals were retained for the risk characterization at this monitoring location.

Brock Site

Table A3 summarizes the COPC screening process for the Brock monitoring location. As seen, of the 15 chemicals that were initially measured, 7 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 8 chemicals were retained for the risk characterization at this monitoring location.

Butterfly Site

Table A3 summarizes the COPC screening process for the Butterfly monitoring location. As seen, of the 15 chemicals that were initially measured, 6 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 9 chemicals were retained for the risk characterization at this monitoring location.

Haire Site

Table A3 summarizes the COPC screening process for the Haire monitoring location. As seen, of the 15 chemicals that were initially measured, 6 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 9 chemicals were retained for the risk characterization at this monitoring location.

Isley Site

Table A4 summarizes the COPC screening process for the Isley monitoring location. As seen, of the 15 chemicals that were initially measured, 6 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 9 chemicals were retained for the risk characterization at this monitoring location.

Sebold Site

Table A4 summarizes the COPC screening process for the Sebold monitoring location. As seen, of the 15 chemicals that were initially measured, 7 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 8 chemicals were retained for the risk characterization at this monitoring location.

Thompson Site

Table A4 summarizes the COPC screening process for the Thompson monitoring location. As seen, of the 15 chemicals that were initially measured, 12 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 3 chemicals were retained for the risk characterization at this monitoring location.

West landfill Site

Table A4 summarizes the COPC screening process for the West Landfill monitoring location. As seen, of the 15 chemicals that were initially measured, 5 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 10 chemicals were retained for the risk characterization at this monitoring location.

COPCs For Urban Sites

Glenwood Springs Site

Table A5 summarizes the COPC screening process for the Glenwood Spring monitoring location. As seen, of the 15 chemicals that were initially measured, 7 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 8 chemicals were retained for the risk characterization at this monitoring location.

New Castle Site

Table A5 summarizes the COPC screening process for the New castle monitoring location. As seen, of the 15 chemicals that were initially measured, 5 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 10 chemicals were retained for the risk characterization at this monitoring location.

Parachute Site

Table A5 summarizes the COPC screening process for the Parachute monitoring location. As seen, of the 15 chemicals that were initially measured, 4 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 11 chemicals were retained for the risk characterization at this monitoring location.

Rifle Site

Table A5 summarizes the COPC screening process for the Rifle monitoring location. As seen, of the 15 chemicals that were initially measured, 5 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 10 chemicals were retained for the risk characterization at this monitoring location.

COPCs For Rural Background

Cox Site

Table A6 summarizes the COPC screening process for the Cox monitoring location. As seen, of the 15 chemicals that were initially measured, 9 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 6 chemicals were retained for the risk characterization at this monitoring location.

Daley Site

Table A6 summarizes the COPC screening process for the Daley monitoring location. As seen, of the 15 chemicals that were initially measured, 9 were eliminated because they were found to have an overall frequency of detection of 0% (i.e., non-detects). A total of 6 chemicals were retained for the risk characterization at this monitoring location.

3 Exposure Assessment

The process that characterizes the route, duration, intensity, and frequency of contact with a chemical by a receptor is known as the exposure assessment. In this evaluation, the receptors of interest are individuals that may reside within a monitoring area, and the

principal exposure route of interest is inhalation. For this evaluation, long-term (chronic) exposure to relatively low levels of VOCs repeatedly over a prolonged period of time is evaluated. Additionally, short-term exposure (acute- and intermediate-duration) to the measured concentrations in 24-hour and grab samples over a period of up to 1-year is evaluated.

The following assumptions were made regarding long-term exposure at the monitoring locations:

- A person lives, works, and otherwise stays near a given monitoring location for a 70-year time period.
- the air that the person breathes, both while indoors and outdoors, contains the same concentrations of pollutants measured in the study (represented by the 24-hour average values).
- Air quality, as reflected by the monitoring results, was assumed to remain relatively constant over the entire 70-year lifetime of a person living in the area.

The following assumptions were made regarding short-term non-cancer exposure at the monitoring locations:

- A person lives, works, and otherwise stays near a given monitoring location for a time period of 1-14 days (Acute-duration) and/or 15 to 364 days (Intermediate-duration as defined by ATSDR).
- The air that the person breathes, both while indoors and outdoors, contains the same concentrations of pollutants measured in the study.
- Typically, short-term exposures are estimated using the 1-hour or 8-hour maximum detected concentration of air toxics. Since these data are not available, a plausible range of short-term non-cancer hazards is estimated (average to high-end) using the following exposure point air concentrations: 24-hour average for the average or Central Tendency Exposures (CTE)[1], 24-hour maximum for near the high-end or Reasonable Maximum Exposures (RME)[2], and 15-second maximum for the high-end or Maximum Exposed Individual (MEI)[3] for acute- duration only.
- Air quality, as reflected by the monitoring results, was assumed to remain relatively constant over the entire period (1-364 days) of a person living in the area.

Analytical data for COPCs were processed to derive exposure concentrations. The first step was to process all chemical results reported as non-detects. A non-detect indicates that the measurement equipment could not positively identify the chemical. This does not mean the chemical is not present; rather, if it is present it is at a concentration lower than the instrument can detect. As is standard practice in conducting risk assessments, all

[1] CTE – Conceptually, it is assumed to describe average or 50th percentile exposures.
[2] RME- Conceptually, it is assumed to describe exposures above the 90th percentile of population.
[3] MEI- Conceptually, it is assumed to describe exposures above the 95th percentile of population

samples reported as non-detects were assigned a value of ½ the lowest concentration that the instrument can detect, known as the sample quantitation limit or SQL.

The concentration term used to assess risk from exposure is the arithmetic mean concentration of a contaminant, averaged over the location where exposure is presumed to occur during a specified time interval (USEPA, 1989). The location and size of the Exposure Point depends in part on human activity patterns and in part on the length of time that is required for a chemical to cause adverse effects.

Because the true mean concentration of a chemical within an Exposure Area cannot be calculated with certainty from a limited set of measurements, the USEPA recommends that the upper 95th confidence limit (UCL) of the arithmetic mean concentration be used as the Exposure Point Concentration (EPC) in calculating exposure and risk (USEPA 1992b). If the calculated UCL is higher than the highest measured value, then the maximum value is used as the EPC instead of the UCL (USEPA, 1992b). The maximum detected concentration was used as the EPC for sample size <10 (EPA Region 8, 1994).

The EPA ProUCL version 4.0 (available at: http://www.epa.gov/nerlesd1/tsc/install.htm) was used to calculate the 95 percent UCL (USEPA, 2007). The EPC values on a monitoring location basis are summarized in Appendix A, Table A7.

4 Toxicity Assessment

4.1 Overview

The basic objective of a toxicity assessment is to identify what adverse health effects a chemical causes, and how the appearance of these adverse effects depends on dose. In addition, the toxic effects of a chemical frequently depend on the route of exposure (oral, inhalation, dermal) and the duration of exposure (acute, intermediate, chronic or lifetime), age, sex, diet, family traits, lifestyle, and state of health. Thus, a full description of the toxic effects of a chemical includes a listing of what adverse health effects the chemical may cause, and how the occurrence of these effects depends upon dose, route, duration of exposure, age, sex, diet, family traits, lifestyle, and state of health.

The toxicity assessment process is usually divided into two parts: the first characterizes and quantifies the cancer effects of the chemical, while the second addresses the non-cancer effects of the chemical. This two-part approach is employed because there are typically major differences in the risk assessment methods used to assess cancer and non-cancer effects. For example, cancer risks are expressed as a probability of suffering an adverse effect (cancer) during a lifetime and noncancer hazards are expressed, semi-quantitatively, in terms of the hazard quotient (HQ), defined as the ratio between an individual's estimated exposure and the RfC. 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. However, both cancer risks and hazard quotients estimate population risks and not an individual's personal risk.

4.2 Cancer Effects

For cancer effects, the toxicity assessment process has two components. The first is a qualitative evaluation of the weight of evidence that the chemical does or does not cause cancer in humans. Typically, this evaluation is performed by the EPA, using the system summarized in the table below:

Category	Meaning	Description
A	Known human carcinogen	Sufficient evidence of cancer in humans.
B1	Probable human carcinogen	Suggestive evidence of cancer incidence in humans.
B2	Probable human carcinogen	Sufficient evidence of cancer in animals, but lack of data or insufficient data from humans.
C	Possible human carcinogen	Suggestive evidence of carcinogenicity in animals.
D	Cannot be evaluated	No evidence or inadequate evidence of cancer in animals or humans.

For chemicals which are classified in Group A, B1, B2, or C, the second part of the toxicity assessment is to describe the carcinogenic potency of the chemical. This is done by quantifying how the number of cancers observed in exposed animals or humans increases as the dose increases. Typically, it is assumed that the dose response curve for cancer has no threshold, arising from the origin and increasing linearly until high doses are reached. Thus, the most convenient descriptor of cancer potency is the slope of the dose-response curve at low dose (where the slope is still linear). This is referred to as the Slope Factor (SF), which has dimensions of risk of cancer per unit dose. Conversely, the inhalation unit risk (IUR) is defined as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 ug/m 3 in air.

Estimating the cancer SF and/or IUR is often complicated by the fact that observable increases in cancer incidence usually occur only at relatively high doses, frequently in the part of the dose-response curve that is no longer linear. Thus, it is necessary to use mathematical models to extrapolate from the observed high dose data to the desired (but unmeasurable) slope at low dose. In order to account for the uncertainty in this extrapolation process, EPA typically chooses to employ the upper 95th confidence limit of the slope as the Slope Factor. That is, there is a 95% probability that the true cancer potency is lower than the value chosen for the Slope Factor. This approach ensures that there is a margin of safety in cancer as well as noncancer risk estimates.

4.3 Non-Cancer Effects

Essentially all chemicals can cause adverse health effects if given at a high enough dose. However, when the dose is sufficiently low, no adverse effect is observed. Thus, in characterizing the non-cancer effects of a chemical, the key parameter is the threshold dose or concentration at which an adverse effect first becomes evident. Exposures below the threshold are considered to be safe, while exposures above the threshold are likely to cause an effect.

The threshold dose is typically estimated from toxicological data (derived from studies of humans and/or animals) by finding the highest dose that does not produce an observable adverse effect, and the lowest dose that does produce an effect. These are referred to as the "No-observed-adverse-effect-level" (NOAEL) and the "Lowest-observed-adverse-effect-level" (LOAEL), respectively. The threshold is presumed to lie in the interval between the NOAEL and the LOAEL. However, in order to be conservative (protective), non-cancer risk evaluations are not based directly on the threshold exposure level, but on a value referred to as the Reference Dose (RfD) or Reference Concentration (RfC). The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure (dose) to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfC has a similar definition, but represents the continuous inhalation concentration that is likely to be without an appreciable risk of deleterious effects during a lifetime. An RfC is reported in milligrams of pollutant per cubic meter of air (mg/m^3).

The RfD or RfC value is derived from the NOAEL (or the LOAEL if a reliable NOAEL is not available) by dividing by an "uncertainty factor". If the data are from studies in humans, and if the observations are considered to be very reliable, the uncertainty factor may be as small as 1.0. However, the uncertainty factor is normally at least 10, and can be much higher if the data are limited. The effect of dividing the NOAEL or the LOAEL by an uncertainty factor is to ensure that the toxicity value is not higher than the threshold level for adverse effects. Thus, there is always a "margin of safety" built into an RfD or RfC, and doses equal to or less than these toxicity values are nearly certain to be without any risk of adverse effect. Exposures higher than the RfD or RfC may carry some risk, but because of the margin of safety, an exposure above the RfD or RfC does not mean that an effect will necessarily occur.

4.4 Toxicity Values

The following hierarchy was used to compile a list of cancer and non-cancer toxicity values for this report. To start, inhalation values established specifically by the State of Colorado (e.g., TCE) were given priority over all other sources of toxicity values. The second source used to identify relevant toxicity values was EPA's Air Toxics Website (http://www.epa.gov/ttn/atw/toxsource/summary.html). This website contains a relatively comprehensive listing of chronic inhalation-based toxicity values for a wide range of chemicals. These values are currently utilized in the National-Scale Air Toxics

Assessment and were selected so that results of this current assessment would be comparable to others conducted across the nation. If values were not available from Colorado or the Air Toxics Website, an effort was made to fill these data gaps using (in order of preference) IRIS (EPA's Integrated Risk Information System), PPTRVs (EPA's Provisional Peer-Reviewed Toxicity Values), and other secondary (e.g., California EPA; ATSDR) sources, as applicable.

For some substances that lack inhalation-specific toxicity values, values were derived from oral toxicity estimates. Although conversion of oral dose-response information to inhalation exposure is not optimal risk assessment practice, the alternative would be to omit these substances altogether from any quantitative inhalation risk estimates. For this screening-level risk assessment it was regarded that the use of route-extrapolated toxicity values were preferable to the assumption of "zero" risk for these analytes. However, it is acknowledged that there is considerable uncertainty surrounding this approach and that results should be evaluated accordingly. For example, one consideration is that in some cases oral exposures may underestimate the toxicity from inhalation exposures since absorption may not be as fast or complete by the oral route

Available toxicity values derived from these sources for the chemicals of potential concern in this investigation are presented in Appendix B (Tables B1 and B2).

Assessment of Cancer Effects

Only those substances that are known or suspected human carcinogens were considered in calculating incremental cancer risks (USEPA WOE (Weight of evidence) groups).

A cancer toxicity criterion is a health assessment value that can be matched with environmental exposure data to estimate health risk. For carcinogens, toxicity measurements are generally expressed as a risk per unit concentration (e.g., an inhalation UR (unit risk) in units of risk per mg/m3) or as a risk per daily intake (e.g., an oral carcinogenic potency slope factor, or CPSo, in units of risk per mg/kg–day).

Inhalation URs were used if available. The inhalation UR represents an estimate of the increased cancer risk from a lifetime (assumed to be 70 years) of continuous exposure to a concentration of one unit of exposure.

If no inhalation UR was available for a known or suspected human carcinogen, the oral slope factor was converted to an inhalation UR by the following equation:

$$IUR = (SFo * IR)/BW$$

where:
IUR = inhalation unit risk estimate (1/mg/m3)
SFo = oral carcinogenic potency slope factor, equal to risk per mg/kg-day
IR = standard inhalation rate for an adult, equal to 20 m3/day; and
BW = standard assumption for average adult body weight, equal to 70 kg.

Appendix B, Table B1 contains the inhalation unit risk values for the COPCs.

Assessment of Non-cancer Effects

For non–cancer effects, toxicity benchmarks are generally expressed as a concentration in air (e.g., an inhalation reference concentration or RfC in units of mg/m3 air) or as a daily intake (e.g., an oral reference dose or RfD in units of mg/kg–day).

RfCs are generally used for evaluating the inhalation route of exposure and were given preference for this study. The reference concentration 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. If no RfC was available, RfDs were converted to RfCs using the following equation:

$$RfC = (RfD * BW)/IR$$

where:
RfC = Inhalation reference concentration (mg/m3);
RfD = Oral reference dose (mg/kg–day);
IR = Standard inhalation rate for an adult, equal to 20 m3/day; and
BW = Standard assumption for average adult body weight, 70 kg.

In Appendix B, Table B1 contains the chronic non-cancer toxicity values and Table B2 contains the acute- and intermediate-duration toxicity values for the COPCs. It should be noted that the ATSDR Minimal Risk Levels (MRLs) were generally used to evaluate short-term non-cancer effects (i.e., acute- and intermediate-duration).

5 Risk Characterization

5.1 Basic Approach

The risk characterization integrates the information from the exposure assessment and the toxicity assessment to provide an estimate of the magnitude of potential risks, and the strength of the conclusions based on the uncertainty in the information used to generate these estimates. For this risk assessment, the risk characterization means combining the exposure concentrations with the toxicity data to provide a quantitative estimate of the potential health impacts. Both cancer and non-cancer health effects are evaluated in this risk characterization.

5.1.1 Cancer Risk Estimates

In this evaluation, risk estimates for COPCs with a cancer endpoint were expressed in terms of the probability of contracting cancer from a lifetime of continuous exposure (70

year lifespan) to a constant air concentration of the COPC. The lifetime cancer risk for each COPC at each monitoring location was derived by multiplying the 95th percent upper confidence limit on the mean of the monitored ambient air concentrations by the respective IUR value, as shown in the following equation. The resulting products 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 risk estimate.

$$Riskx = EPC * IURx$$

Where:
Riskx = the risk of the Xth COPC at a monitor:
EC = the exposure point concentration of the substance (i.e., most stringent of the 95% UCL or maximum air concentration); and
IURx = the inhalation unit risk of the substance.

Estimates of cancer risk were 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 $lx10^{-6}$ or lE-06.

The level of cancer risk that is of concern is a matter of individual, community and regulatory judgment. However, the USEPA typically considers risks below 1E-06 to be so small as to be negligible (USEPA 1991).

5.1.2 Non-Cancer Hazard Estimates

In contrast to cancer risks, non-cancer hazards are not expressed as a probability of an individual suffering an adverse effect. Instead, non-cancer hazard to individuals is expressed in terms of the hazard quotient (HQ), defined as the ratio between an individual's estimated exposure and the Reference Concentration (RfC). 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. For a given air toxic, exposures below the reference level (HQ<1) are not likely to be associated with adverse health effects. With exposures increasingly greater than the reference concentration, the potential for adverse effects increases. HQs were calculated as follows:

$$HQ_x = EPC_x/RfC_x$$

Where:
HQx = the hazard quotient of the Xth COPC at a monitor:
EPC_x = the exposure point concentration of the substance (i.e., most stringent of the 95% UCL or maximum air concentration); and
RfCx = the reference concentration of the substance.

When used in the assessment of non-cancer risks, the hazard quotient is commonly reported to one significant figure (EPA, 1989). For example, a hazard quotient of 0.13 is rounded to 0.1, and a hazard quotient of 1.6 is rounded to 2.

Hazard quotient calculations for an individual chemical estimate the potential for adverse effects if a receptor is exposed to only that chemical. If there are multiple chemicals to which the receptor may be exposed then the consequences of the multiple exposures can be quantified, within some limitations. Because different pollutants may cause similar adverse health effects, it is often appropriate to combine hazard quotients associated with different substances. For non-carcinogenic chemicals, the hazard quotients for each exposure pathway can be summed to develop a hazard index (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 unity as a consequence of summing several hazard quotients of similar value, it would be appropriate to segregate the compounds by effect and by mechanism of action and to derive separate hazard indices for each group.

5.2 Quantification Of Risk

5.2.1 Lifetime Cancer Risk Estimates, Chronic Non-Cancer Hazards, and the Average Short-Term (acute & intermediate) Non-Cancer Hazards Based On the EPC (95% UCL on the mean)

Tables C1 to C4 summarize the cancer and non-cancer risk estimates at the monitoring sites evaluated in this investigation. A description of the findings for each site is presented below.

5.2.1.1 Risks For Oil and Gas Development Sites

Overview

COPCs for cancer risk across the eight oil and gas development monitoring sites include benzene, 1,4-dichlorobenzene, tetrachloroethene, methylene chloride. The combined cancer risk estimates were found to range from 2E-05 (20 excess cancers per 1 million individuals) to 1E-04 (100 excess cancers per 1 million individuals) across the eight monitoring sites. Benzene is one of the major contributors to the total risk at each monitoring site, with risk estimates for this chemical ranging from 1E-05 (at the Haire, Isley, and Sebold monitoring sites) to 1E-04 (at the Brock monitoring site). It should be noted that the cancer risk for benzene at the Brock monitoring site is somewhat influenced by a very high concentration of benzene detected over 24 hours (1 out of 22

samples). 1,4-dichlorobenzene is the second major contributor to the total cancer risk at each monitoring site, with risk estimates for this chemical ranging from 1E-05 to 3.5E-05 (at the Butterfly monitoring site). It is important to note that benzene was selected as a COPC across all monitoring sites, 1,4-dichlorobenzene was a COPC at 4 out of 8 monitoring sites, and tetrachloroethene was a COPC at 1 out of 8 monitoring sites. Methylene chloride was found at 2 out of 8 monitoring sites. It was not a risk contributing COPC, with cancer risk estimates of 5E-07 and 6E-07. Cancer risks for each monitoring site are briefly discussed below and summarized in Table 2 and Figures 1 and 2.

None of the individual chemicals that were assessed at any monitoring location were found to have a Hazard Quotient (HQ) exceeding a value of one for chronic as well as short-term (average) exposure durations. Table 3 shows a comparison of combined Hazard Indices (HIs) across all monitoring sites. None of the HIs exceeded a value of one. The estimates of non-cancer hazards for each monitoring site are briefly discussed below.

Bell Site

Nine chemicals from the Bell monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, two were evaluated for cancer risk and up to nine were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 1.2E-05 to 2.8E-05, with a combined total risk of 4.0E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributor to the total cancer risk estimate is benzene (2.8E-05).

Individual chronic non-cancer hazard quotients for nine chemicals ranged from 0.001 to 0.1, with a combined hazard index of 0.3 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are 2-hexanone (HQ=0.1) and benzene (HQ=0.1).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for six chemicals ranged from 0.000 to 0.2, with a combined hazard index of 0.3 (Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target

specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.1) and benzene (HQ=0.2).

Individual acute non-cancer hazard quotients for seven chemicals ranged from 0.000 to 0.1, with a combined hazard index of 0.1 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.1).

Brock Site

Eight chemicals from the Brock monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, one was evaluated for cancer risk and up to eight were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risk for the individual carcinogen benzene was 1.0E-04. This risk estimate for benzene was determined to have a cancer risk at the upper end of EPA's generally acceptable range of 1E-06 to 1E-04.

Individual chronic non-cancer hazard quotients for eight chemicals ranged from 0.000 to 0.4, with a combined hazard index of 0.6 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.4).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for six chemicals ranged from 0.000 to 0.7, with a combined hazard index of 0.8 (Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.1) and benzene (HQ=0.7).

Individual acute non-cancer hazard quotients for six chemicals ranged from 0.000 to 0.5, with a combined hazard index of 0.5 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.5).

Butterfly Site

Nine chemicals from the Butterfly monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, two were evaluated for cancer risk and up to nine were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 2.9E-05 to 3.5E-05, with a combined total risk of 6.4E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributors to the total cancer risk estimate are benzene (2.9E-05) and 1,4-dichlorobenzene (3.5E-05).

Individual chronic non-cancer hazard quotients for nine chemicals ranged from 0.000 to 0.15, with a combined hazard index of 0.3 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are m,p-xylene (HQ=0.15) and benzene (HQ=0.1) .

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual hazard quotients for intermediate non-cancer risks, based on six chemicals, ranged from 0.000 to 0.2, with a combined hazard index of 0.3 (Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.1) and benzene (HQ=0.2).

Individual acute non-cancer hazard quotients for eight chemicals ranged from 0.000 to 0.1, with a combined hazard index of 0.1 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.1).

Haire Site

Nine chemicals from the Haire monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, two were evaluated for cancer risk and up to nine were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 6.7E-06 to 8.9E-06, with a combined total risk of 1.6E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributors to the total cancer risk estimate are benzene (8.9E-06) and tetrachloroethene (6.7E-06).

Individual chronic non-cancer hazard quotients for nine chemicals ranged from 0.001 to 0.04, with a combined hazard index of 0.1 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ=0.04).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for five chemicals ranged from 0.000 to 0.1, with a combined hazard index of 0.2 (Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.1) and benzene (HQ=0.1).

Individual acute non-cancer hazard quotients for seven chemicals ranged from 0.000 to 0.04, with a combined hazard index of 0.04 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.04).

Isley Site

Nine chemicals from the Isley monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, three were evaluated for cancer risk and up to nine were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 4.9E-07 to 1.8E-05, with a combined total risk of 3.5E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributors to the total cancer risk estimate are benzene (1.1E-05) and 1,4-dichlorobenzene (1.8E-05).

Individual chronic non-cancer hazard quotients for nine chemicals ranged from 0.001 to 0.05, with a combined hazard index of 0.1 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ=0.05)

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for six chemicals ranged from 0.001 to 0.14, with a combined hazard index of 0.2(Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.14) and benzene (HQ=0.07).

Individual acute non-cancer hazard quotients for eight chemicals ranged from 0.000 to 0.05, with a combined hazard index of 0.05 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.05).

Sebold Site

Eight chemicals from the Sebold monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, two were evaluated for cancer risk and up to eight were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals were about 1.0E-05, with a combined total risk of 2.4E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributors to the total cancer risk estimate are benzene (1.0E-05) and 1,4-dichlorobenzene (1.35E-05).

Individual chronic non-cancer hazard quotients for eight chemicals ranged from 0.001 to 0.1, with a combined hazard index of 0.2 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are 2-hexanone (HQ=0.1) and benzene (HQ=0.04).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for five chemicals ranged from 0.001 to 0.1, with a combined hazard index of 0.2(Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.1) and benzene (HQ=0.1).

Individual acute non-cancer hazard quotients for six chemicals ranged from 0.000 to 0.04, with a combined hazard index of 0.05 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.04).

Thompson Site

Three chemicals from the Thompson monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, none was evaluated for cancer risk and three were evaluated for non-cancer hazards. Noncancer hazards (chronic, intermediate, and acute) ranged from 0.000 to 0.006 (Tables C2 to C4). Since all non-cancer hazards were zero, this site is not discussed further.

West Landfill Site

Ten chemicals from the West Landfill monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, two were evaluated for cancer risk and up to ten were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 5.8E-07 to 3.9E-05, with a combined total risk of 3.9E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributor to the total cancer risk estimate is benzene (3.9E-05).

Individual chronic non-cancer hazard quotients for ten chemicals ranged from 0.001 to 0.2, with a combined hazard index of 0.5 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are 2-hexanone (HQ=0.1), m, p-xylene (HQ=0.1), and benzene (HQ=0.2).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for seven chemicals ranged from 0.000 to 0.2, with a combined hazard index of 0.4(Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.1) and benzene (HQ=0.2).

Individual acute non-cancer hazard quotients for seven chemicals, ranged from 0.000 to 0.2, with a combined hazard index of 0.2 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.2).

5.2.1.2 Risks For Urban Sites

Overview

COPCs for cancer risk across the four urban monitoring sites include trichloroethene, benzene, 1,4-dichlorobenzene, tetrachloroethene, and methylene chloride. The combined cancer risk estimates were found to range from 3.5E-05 (35 excess cancers per 1 million individuals) to 3.6E-04 (360 excess cancers per 1 million individuals) across the four monitoring sites. Trichloroethene is the major contributors to the highest risk at the Parachute monitoring site, with risk estimate of 3.6E-04 for this chemical. 1,4-dichlorobenzene is the major contributor at the Glenwood Springs, with risk estimate of 1.3E-04 for this chemical. Other major contributor to the combined cancer risks is benzene with risk estimates ranging from 3E-05 to 4E-05. It is important to note that trichloroethene was a COPC only at 1 out of 4 monitoring sites (detection frequency of 12.5%), benzene was a COPC at all four monitoring sites, 1,4-dichlorobenzene was a COPC at 3 out of 4 monitoring sites, and tetrachloethene (7E-06) was a COPC at 1 out of 4 monitoring sites. Methylene chloride was found at 2 out of 4 monitoring sites. It was not a major risk contributing COPC, with cancer risk estimates of 1E06 and 1.3E-06.

None of the individual chemicals that were assessed at any monitoring location were found to have a Hazard Quotient (HQ) exceeding a value of one for chronic as well as short-term (average) exposure durations. Table 3 shows a comparison of combined Hazard Indices (HIs) across all monitoring sites. None of the HIs exceeded a value of one. The estimates of non-cancer hazards for each monitoring site are briefly discussed below.

Glenwood Springs Site

Eight chemicals from the Glenwood Spring monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, three were evaluated for cancer risk and up to eight were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 1.1E-06 to 1.3E-04, with a combined total risk of 1.6E-04. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributor to the total cancer risk estimate is 1,4-dichlorobenzene (1.3E-04).

Individual chronic non-cancer hazard quotients for eight chemicals ranged from 0.001 to 0.12, with a combined hazard index of 0.2 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.12).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for six chemicals ranged from 0.001 to 0.2, with a combined hazard index of 0.4 (Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.2) and benzene (HQ=0.2).

Individual acute non-cancer hazard quotients for seven chemicals ranged from 0.000 to 0.1, with a combined hazard index of 0.1 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ=0.1).

New Castle Site

Ten chemicals from the New Castle monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, three were evaluated for cancer risk and up to ten were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 1.3E-06 to 3.9E-05, with a combined total risk of 7.2E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributors to the total cancer risk estimate are benzene (3.9E-05) and 1,4-dichlorobenzene (3.2E-05).

Individual chronic non-cancer hazard quotients for ten chemicals ranged from 0.000 to 0.2, with a combined hazard index of 0.25 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.2).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for eight chemicals ranged from 0.000 to 0.2, with a combined hazard index of 0.4(Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.1) and benzene (HQ=0.2).

Individual acute non-cancer hazard quotients for eight chemicals ranged from 0.000 to 0.16, with a combined hazard index of 0.2 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.16).

Parachute Site

Eleven chemicals from the Parachute monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, three were evaluated for cancer risk and up to eight were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 2.4E-05 to 3.0E-04, with a combined total risk of 3.6E-04. One individual chemical, and the cumulative total cancer risk somewhat exceed the upper end of EPA's generally acceptable level range of 1E-06 to 1E-04. The largest individual contributors to the total cancer risk estimate are trichloroethene (3.0E-04), benzene (4.0E-05), and 1,4-dichlorobenzene (2.4E-05).

Individual chronic non-cancer hazard quotients for eleven chemicals ranged from 0.001 to 0.2, with a combined hazard index of 0.6 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are benzene (HQ= 0.2), 2-hexanone (HQ=0.2), and m,p-xylene (HQ=0.1).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for seven chemicals ranged from 0.000 to 0.3, with a combined hazard index of 0.6(Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.3) and benzene (HQ=0.3).

Individual acute non-cancer hazard quotients for eight chemicals ranged from 0.000 to 0.2, with a combined hazard index of 0.2 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ=0.2).

Rifle Site

Ten chemicals from the Rifle monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, two were evaluated for cancer risk and up to ten were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risks for the individual chemicals ranged from 6.7E-06 to 2.9E-05, with a combined total risk of 3.5E-05. Each individual chemical was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04, and the cumulative total cancer risk was not found to exceed the upper end of this range. The largest individual contributors to the total cancer risk estimate are benzene (2.6E-05) and tetrachloroethene (6.2E-06).

Individual chronic non-cancer hazard quotients for ten chemicals ranged from 0.001 to 0.1, with a combined hazard index of 0.4 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are 2-hexanone (HQ=0.1) and benzene (HQ=0.1).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for six chemicals ranged from 0.000 to 0.4, with a combined hazard index of 0.6(Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemicals that contribute to this hazard index are vinyl acetate (HQ=0.4) and benzene (HQ=0.2).

Individual acute non-cancer hazard quotients for seven chemicals ranged from 0.000 to 0.1, with a combined hazard index of 0.1 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.1).

5.2.1.3 Risks For Rural Background Site

Overview

COPCs for cancer risk across the two rural background monitoring sites include benzene (at Daley) and 1,4-dichlorobenzene (at Cox). The combined cancer risk estimates were found to range from 2E-05 for benzene (20 excess cancers per 1 million individuals) to 5E-05 for 1,4-dichlorobenzene (50 excess cancers per 1 million individuals) across the two monitoring sites.

None of the individual chemicals that were assessed at any monitoring location were found to have a Hazard Quotient (HQ) exceeding a value of one for chronic as well as short-term (average) exposure durations. Table 3 shows a comparison of combined Hazard Indices (HIs) across all monitoring sites. None of the HIs exceeded a value of one. The estimates of non-cancer hazards for each monitoring site are briefly discussed below.

Cox Site

Six chemicals from the Cox monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, one was evaluated for cancer risk and up to six were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risk for the individual carcinogen benzene was 1.5E-05. This risk estimate for benzene was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04.

Individual chronic non-cancer hazard quotients for six chemicals ranged from 0.001 to 0.06, with a combined hazard index of 0.16 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ= 0.06).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for four chemicals ranged from 0.001 to 0.2, with a combined hazard index of 0.3 (Table C3). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is vinyl acetate (HQ=0.2).

Individual acute non-cancer hazard quotients for five chemicals ranged from 0.000 to 0.06, with a combined hazard index of 0.07 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is benzene (HQ=0.06).

Daley Site

Six chemicals from the Daley monitoring station were carried through for evaluation in the risk characterization. Of these chemicals, one was evaluated for cancer risk and about six were evaluated for non-cancer hazards.

Chronic Risks (Cancer and Non-Cancer)

As shown in Table C1, cancer risk for the individual carcinogen 1,4-dichlorobenzene was 5.1E-05. This risk estimate for 1,4-dichlorobenzene was determined to have a cancer risk below the upper end of EPA's generally acceptable range of 1E-06 to 1E-04.

Individual chronic non-cancer hazard quotients for six chemicals ranged from 0.001 to 0.05, with a combined hazard index of 0.08 (Table C2). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is m, p-xylene (HQ= 0.05).

Average Short-Term Non-Cancer Hazards (Intermediate and Acute)

Individual intermediate non-cancer hazard quotients for four chemicals ranged from 0.001 to 0.1, with a combined hazard index of 0.1 (Table C3). None of the individual

hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is vinyl acetate (HQ=0.1).

Individual acute non-cancer hazard quotients for five chemicals ranged from 0.000 to 0.01, with a combined hazard index of 0.01 (Table C4). None of the individual hazard quotients or combined hazard index exceeded a value of one. Therefore, it was not necessary to group hazard quotients according to critical effect and recalculate target specific hazard indices. The major chemical that contributes to this hazard index is toluene (HQ=0.01).

5.3.1 High-End Short-Term Non-Cancer Hazards Based On the Maximum Detected Concentration

Since inadequate air monitoring data are available to represent short-term exposures, a plausible range of short-term non-cancer hazards (i.e., intermediate- and acute-duration) was estimated. The high-end hazards were calculated by using the maximum detected concentrations of: (1) the 24-hour location-specific samples for HQs of acute and intermediate exposure durations; and (2) the 15-second grab samples for HQs of acute duration only. The average or Central Tendency Exposures (CTE) based on the 95% UCL on the mean of the 24-hour samples are already discussed above in Section 5.2.1.

5.3.1.1 Near the High-End (or RME) Non-cancer Hazards (Acute and Intermediate) Based on the 24-Hour Maximum Detected Air Concentrations In Fixed Samples

Tables D1 and D2 summarize near the high-end (RME) acute and intermediate non-cancer hazard quotients at the monitoring sites evaluated in this investigation. A brief summary of the findings for each monitoring area (oil and gas development, urban, and rural background) is presented below.

Non-cancer hazards were assessed at all fixed monitoring sites by comparing the location specific maximum concentration to a concentration that is considered to be without an appreciable risk of deleterious effects during the exposure durations of 1-14 days (acute) and 15-364 days (intermediate), for even the most sensitive individual. Benzene exceeded a level of one only at the Brock monitoring site (Intermediate HQ= 2.5, Acute HQ= 1.6). None of the individual chemicals that were assessed at any monitoring location were found to have a HQ exceeding a value of one. HIs for each monitoring site were calculated by summing HQs of individual chemicals. HIs exceeded a level of one at the Brock monitoring site in the oil and gas area (Intermediate HI= 2.8; Acute HI= 1.7) and the New Castle monitoring site in the urban area (Intermediate HI=1.2). HIs did not exceed a level of one at any other monitoring site.

Acute HIs were found to range from 0.01 to 0.1, 0.1 to 0.5, and 0.001 to 1.7 across rural background, urban, and oil and gas development sites, respectively. Intermediate HIs were found to range from 0.3 to 0.4, 0.4 to 1.2, and 0.0 to 2.8 across rural background, urban, and oil and gas development sites, respectively. The largest contributor to the cumulative acute and intermediate hazard indices is benzene. Overall, acute and intermediate non-cancer hazard estimates across the rural background sites appeared to be significantly lower than those across the oil and gas development and urban sites.

5.3.1.2 High-End (or MEI) Non-cancer Hazards (Acute) based on the15-Second Maximum Detected Air Concentrations In Grab Samples

Tables 5 and 6 summarize the acute non-cancer hazard quotients at the grab sampling sites evaluated conservatively in this investigation. The individual HQs and the cumulative HIs based on the maximum concentration detected across grab sampling sites is presented in Table 5. As seen, only benzene exceeds a level of one (HQ = 6). Since the major contributor to the cumulative HI is benzene, none of the HQs for individual chemicals are discussed further in this assessment. Therefore, benzene was further evaluated by calculating HQs for <14 days as well as for 6-hour exposure durations at all grab-sampling sites (Table 6). As seen, none of the sites were found to have a HQ for benzene exceeding a value of one for the 6-hr exposure duration. However, 6 out of 27 sites were found to have a HQ for benzene exceeding a value of one for the exposure duration of 14 days or less. Hazard quotients ranging from 2 to 6 were seen for potential immunological effects of benzene at the following grab sampling locations: CR 326, Trulove, Hooker Pad, Truelove @ Kitchen door, and Hoffmeister (Table 6).

6 Uncertainties

Quantitative evaluation of the risks to humans from environmental contamination is frequently limited by uncertainty (lack of knowledge) regarding a number of important exposure and toxicity factors. This lack of knowledge is usually circumvented by making estimates based on whatever limited data that are available, or by making assumptions based on professional judgment when no reliable data are available. Because of these assumptions and estimates, the results of risk calculations are themselves uncertain, and it is important for risk managers and the public to keep this in mind when interpreting the results of a risk assessment. The following sections review the main sources of uncertainty in the risk calculations summarized in this report.

Uncertainties in Monitoring

One uncertainty in this study was the use of monitoring data to estimate the potential human health exposures and risks. The uncertainty stems from the inability to realistically monitor continuously at all places of interest. Thus a decision is made to

monitor a portion of the time and in specific locations and apply the results to a broader situation.

The monitoring data at each station reflects two years or less of chemical concentrations in air. Most importantly, the monitoring data was collected on a once per month or once per quarter basis in contrast to the EPA National Air Toxic Program recommended monitoring data collection frequency of a once per week basis. It is uncertain how well this dataset reflects the lifetime exposure assumed in this risk assessment as changes in meteorology and chemical emissions could lead to lower or higher concentrations in air from year-to-year. To reduce this uncertainty would require monitoring over several years, or modeling based on changes in meteorology and chemical emissions.

Monitoring locations may or may not be representative of air concentrations to which an individual could be exposed 24 hours a day for a lifetime. As discussed previously, several of these monitoring locations were placed in areas with mixed industrial use or heavier traffic patterns. Potential health impacts associated with contaminant concentrations at these locations could over estimate the true risk since they may not reflect the actual long-term residential exposure concentration. Additionally, they could underestimate true risk to people living near sources of high concentrations of contaminant emissions.

A large number of chemicals were selected for monitoring, but still, limiting the number of VOCs and other classes of chemicals analyzed in the monitoring program can result in an underestimation of risk, which could in some cases be reduced by monitoring for a larger group of chemicals. For example, no metals and semi-VOCs (e.g., Polycyclic aromatic hydrocarbons; PAHs) were analyzed.

Uncertainties in COPC Selection

The frequency at which positively identified chemicals in the dataset were detected at a monitor was calculated and used as a means to focus the risk assessment on the most frequently detected chemicals. Any chemical that was not detected in any of the samples reported for a location (i.e., non-detect) was removed from further analysis in the risk assessment. Application of this non-detect rule for each monitor location led to the selection of the chemicals of potential concern (COPCs) for evaluation in the risk assessment. Eliminating chemicals that were undetected could lead to an underestimate of the health impacts.

Uncertainties in Concentration Estimates

Evaluation of human health risk at any particular location requires accurate information on the average concentration level of a COPC at that location. However, concentration values may vary from sample to sample, so the USEPA recommends that the 95% upper confidence limit (95% UCL) of the mean be used in evaluation of exposure and risk. This approach typically ensures that the risk estimates are likely higher than if means were used.

In deriving the exposure point concentration (i.e., 95% UCL) for this investigation, all non-detects were assigned a value of ½ the detection limit. When a chemical is reported as non-detectable, it does not mean the chemical is not present; rather, it may be present at a concentration lower than the instrument can detect. The true value of a non-detected chemical may range from not being present (i.e., zero concentration) to being present at a concentration just under the detection limit. The use of ½ the detection limit may over- or under-estimate the true concentration.

Uncertainties in Human Exposure

There is usually wide variation between different individuals with respect to the level of contact they may have to chemicals in the environment. This introduces uncertainty as to the most appropriate values to use for exposure parameters.

Once released to the atmosphere, some air toxics can transfer to other media such as water, soil and vegetation. Air toxics with low vapor pressure are typically present in atmospheric particles which may deposit to the terrestrial environment by dry deposition processes. Besides being deposited, some of these can also accumulate, to a significant degree, in soil and vegetation, as well as bioaccumulate in living organisms and biomagnify in food chains. As a result, exposure to these air toxics can occur through multiple exposure pathways, including inhalation (breathing), dermal contact (touching), and ingestion (eating and drinking). The majority of risk for this evaluation is assumed to be a consequence of inhalation exposure, with other pathways contributing to a much lesser extent. However, by focusing on inhalation only, total risks are underestimated.

Another source of uncertainty is the risk for children, because children generally are expected to have some exposures that differ (higher or lower) from those of adults due to 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. In addition, children are more at risk because of the availability of a longer latency period for the development of cancer.

Uncertainty in Risk Estimates due to Multiple Contaminants

Both carcinogenic and noncarcinogenic risks for multiple contaminants are assumed to be additive, in accordance with the EPA guidance for health risk assessment of chemical

mixtures. This assumption, however, is associated with several limitations and, therefore, there is potential for under- or over-estimation of risk. For example, the assumption of additivity of risk does not account for synergistic or antagonistic chemical interactions.

Uncertainties in Toxicity Values

One of the most important sources of uncertainty in a risk assessment is in the RfC values used to evaluate non-cancer risk and in the inhalation unit risk values used to quantify cancer risk. In many cases, these values are derived from a limited toxicity database, and this can result in substantial uncertainty, both quantitatively and qualitatively. In order to account for these and other uncertainties associated with the evaluation of toxicity data, both RfCs and IURs are derived by the USEPA in a way that is intentionally conservative; that is, risk estimates based on these RfCs and IURs are more likely to overestimate risk.

For some substances that lack inhalation-specific toxicity values, values were derived from oral toxicity estimates. Although conversion of oral dose-response information to inhalation exposure is not optimal risk assessment practice, the alternative would be to omit these substances altogether from any quantitative inhalation risk estimates. For this screening-level risk assessment, the use of route-extrapolated toxicity values was preferred. It should be noted that the chemicals for which route-to-route extrapolation was used were not major risk contributors.

Uncertainties in the EPA cancer toxicity values (i.e., IURs) for risk driving chemicals (e.g., benzene and TCE) are notable. EPA has calculated a range of IURs for benzene and the upper-bound value is used in this evaluation in accordance with the EPA Air Toxic guidance. For example, EPA estimates that, if an individual were to continuously breath air containing benzene at an average of 0.13 to 0.45 µg/m^3 over the entire lifetime, that person would theoretically have no more than one in a million increased chance of developing cancer. EPA's 2001 draft risk assessment has also estimated a range of cancer slope factors (cancer toxicity value) for TCE and the upper-bound value is used in this evaluation in accordance with the CDPHE policy. The cancer toxicity value for TCE is currently under evaluation by the EPA.

7 Summary and Conclusions

A screening-level risk assessment of the potential human health impacts from inhalation of air toxics has been conducted, in accordance with the Tier-1 of EPA's Air Toxic Risk Assessment Library (EPA, 2004), using data collected from fourteen air monitoring sites in Garfield County, Colorado. These fourteen sites are 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 for VOCs at 27 locations based on odor complaints. The potential human health implications of these exposures were characterized for both cancer and non-cancer health effects. It is important to note that non-cancer hazards were characterized over long-term (chronic; 7 years to lifetime) and

short-term (intermediate; 15-364 days, and acute; 1-14 days) exposure durations. Additionally, the potential short-term non-cancer hazards were evaluated for a plausible range of average and high-end exposures using the following variations in air concentrations as the point of contact: (a) the 24-hour EPC (95 %UCL on the mean) across fourteen fixed monitoring sites for the average or Central Tendency Exposures (CTE) of intermediate- and acute-duration; (b) the 24-hour maximum detected concentration across fourteen fixed monitoring sites for near the high-end or the Reasonable Maximum Exposures (RME) of intermediate and acute-duration; and (c) the 15-Second maximum detected concentration of grab samples across 27 sites for the high-end or the Maximally Exposed Individual (MEI) exposures of acute-duration. The overall findings and conclusions are briefly summarized below:

(a) As summarized in Table 1, the most commonly detected COPCs across three categories of sites (oil and gas development, urban, and rural background) included: acetone, benzene, toluene, vinyl acetate, 2-butanone, and m,p-xylene. Benzene did not occur only at one rural background site (Daley). Other COPCs detected at several monitoring locations across oil and gas, urban, and rural background sites included: 1,4-dichlorobenzene, ethylbenzene, o-xylene, and 2-hexanone. The COPCs that occurred only at one or two locations in the oil and gas development and urban areas included trichloroethene, tetrachloroethene, styrene, trichlorofloromethane, and methylene chloride.

(b) As summarized in Table 2 and Figure 1, the cancer risks are not similar across monitoring sites. The risks across the oil and gas development and urban areas are somewhat higher than the rural background area. For example, total cancer risks across oil and gas development and urban sites slightly exceed, or are equal to, the upper end of EPA's acceptable risk range, and total cancer risks for rural background sites are well below the upper end of EPA's acceptable risk range. A range of "acceptable" health risk values for carcinogens has been historically proposed by U.S. EPA that ranges from one in one million (1×10^{-06}) to one hundred per million (1×10^{-04}).

(c) As summarized in Figure 2, the largest individual contributors to the total cancer risks are different across oil and gas development, urban, and rural background sites. For example, benzene is the largest contributor across oil and gas development sites, trichloroethene and 1,4-dichlorobenzene across urban sites, and 1,4-dichlorobenzene across rural background sites. Additionally, benzene risks at oil and gas sites are somewhat higher than those at urban and rural background sites. It is important to note that total cancer risks across urban sites and rural background sites are based on the maximum detected concentration of 8 samples. In contrast, total cancer risks across oil and gas development monitoring sites are estimated using the 95 UCL on the mean (of >20 samples). Additionally, risks due to trichloroethene are likely to be conservative and uncertain because the cancer toxicity value for this chemical is currently under evaluation by the USEPA. Overall, these findings are somewhat indicative of potential for benzene impacts in the oil and gas development area.

(d) As summarized in Table 3, chronic non-cancer hazard quotients (HQs) and Hazard Indices (HIs) did not exceed a value of one. HIs for the combined hazard of multiple chemicals at each monitoring site were calculated by summing HQs of individual chemicals. Chronic HIs were found to range from 0.08 to 0.16, 0.24 to 0.61, and 0.006 to 0.55 across rural background, urban, and oil and gas development sites, respectively. The largest chemical contributor to the HIs at each of these sites was benzene (HQ=0.6). Overall, the non-cancer hazard estimates were generally lower across the rural background sites than those across the oil and gas development and urban sites. These HQs and HIs of less than one indicate that continuous chronic exposures of 7 years to lifetime are not likely to result in significant non-cancer adverse health effects across all monitoring sites in the rural, urban, and oil and gas development areas.

(e) Since inadequate air monitoring data are available to represent short-term exposures, a plausible range of short-term non-cancer hazards is estimated (average to high-end) using the following exposure point air concentrations: the 24-hour average, the 24-hour maximum, and the 15-second maximum. These results are summarized below:

- As summarized in Table 3, the average (CTE) short-term HQs or HIs, based on the average exposure point concentration (the 95 % UCL on the mean), did not exceed an acceptable level of one. Acute HIs were found to range from 0.01 to 0.07, 0.1 to 0.2, and 0.001 to 0.5 across rural background, urban, and oil and gas development sites, respectively. Intermediate HIs were found to range from 0.1 to 0.3, 0.4 to 0.6, and 0.0 to 0.8 across rural background, urban, and oil and gas development sites, respectively. Intermediate and acute HIs for the combined hazard of multiple chemicals were the lowest across rural background sites. The largest chemical contributor to the HIs at each of these sites was benzene for both acute and intermediate exposure durations. These HIs of less than one indicate that the average short-term exposures of acute and intermediate duration (1- 364 days) are not likely to result in significant non-cancer adverse health effects across all monitoring sites in the rural, urban, and oil and gas development areas.

- As summarized in Table 4 and Figures 3 and 4, near the high-end (RME) short-term HQs or HIs, based on the maximum detected exposure point concentration, exceeded a level of one for benzene only at the Brock monitoring site in the oil and gas development area. HIs for the combined hazard of multiple chemicals exceeded a level of one at the Brock (oil and gas site) and New Castle (urban site) monitoring sites, with benzene as the largest contributor. Intermediate and acute HIs were the lowest across rural background sites. Since the largest chemical contributor to the HIs at each of these sites was benzene for acute and intermediate exposure durations, the cumulative intermediate and acute hazard indices of 3 and 2

at the Brock monitoring site indicate increased potential for adverse health effects based on the exposure duration (of up to 1-year) at this location. These non-cancer hazard estimates are driven by exposures to the maximum detected concentration of benzene over 24-hours at the Brock monitoring station.

- As summarized in Tables 5 and 6, the high-end (MEI) acute non-cancer hazard quotients at the grab sampling sites were also evaluated conservatively in this investigation. Only benzene exceeds a level of one (HQ = 6) based on the maximum detected concentration among 27 sites. Therefore, benzene was further evaluated by calculating HQs for <14 days as well as for 6-hour exposure durations at all grab-sampling sites. None of the sites were found to have a HQ for benzene exceeding a value of one for the 6-hr exposure duration. However, 6 out of 27 sites were found to have a HQ for benzene exceeding a value of one (HQs ranging from 2 to 6) for the exposure duration of 1-14 days.

In conclusion, the combined findings of the theoretical lifetime cancer risk and short-term non-cancer hazard (high-end) estimates are somewhat indicative of potential for benzene impacts at the Brock monitoring site in the oil and gas development area and need for air monitoring and source apportionment. Specifically, the pattern of cancer risk estimates for benzene in relation to the monitoring areas (i.e., oil and gas development, urban, and rural background) indicates greatest potential cancer risks for benzene across the oil and gas development area. Additionally, the chronic and short-term non-cancer hazard estimates were the highest across the oil and gas development sites and the lowest across the rural background sites. The high-end short-term hazard quotients (intermediate and/or acute) for the potential adverse health effects of benzene ranged from 2 to 6 for the exposure durations of 1 to 364 days. Benzene is a serious concern from toxicological standpoint because it is a proven human carcinogen (Class A, known human carcinogen) based on occupational studies in adults that demonstrated increased incidence of several types of leukemia in exposed adults (USEPA, 2000). The elevated non-cancer HQs for benzene indicate increased potential for immunological effects to occur in an individual exposed for the short-term exposure duration (1-364 days) at the Brock monitoring site or other grab sampling locations. In general, short-term inhalation of benzene at low exposure levels can alter certain immune system associated processes. For example, lymphopenia, lymphocyte depression, and increased susceptibility to bacterial infection are some of the adverse immunological effects observed in several acute-duration inhalation studies in animals (ATSDR, 2005).

It should be noted that the results of this screening level risk assessment are subject to some significant uncertainties. In general, this risk assessment can be considered a conservative estimate of current exposures on the basis of the exposure assessment. For example, the chronic risk estimates are based on an individual that is exposed to the monitored concentrations over 70 years, for 24 hours per day. However, the future exposures may be underestimated because the assessment does not take into account increase in air concentrations of VOCs over time, as a result of increase oil and gas

development. All air toxics of potential concern were not monitored and only 43 VOCs were monitored. Since diesel vehicles/engines and oil and gas industry are known to emit metals, PAHs, and other VOCs, some important chemicals are absent from this analysis. This investigation is based on two years data collected at 14 fixed stations and 15-second grab samples collected at 27 locations. These fixed monitoring stations or grab-samples may not appropriately characterize exposures of a mobile population. For example, the 15-second grab samples are not likely to represent the high-end acute exposures over a period of 1-14 days, thereby overestimating acute risks for the maximally exposed individual (MEI). Furthermore, the study is based on the monitoring data collected on a once per month or once per quarter basis which is significantly lower than the EPA National Air Toxic Program recommended data collection frequency of a once per week basis. Additionally, science is currently unable to assess exposures to multiple air toxics simultaneously. Risk calculations in this report use CDPHE, EPA, and ATSDR most recent toxicity values for each chemical compound which may change in the future. Most importantly, concentrations of chemicals in the air are likely to change over time. Therefore, this investigation is best viewed as a “snapshot” of air quality.

8 References

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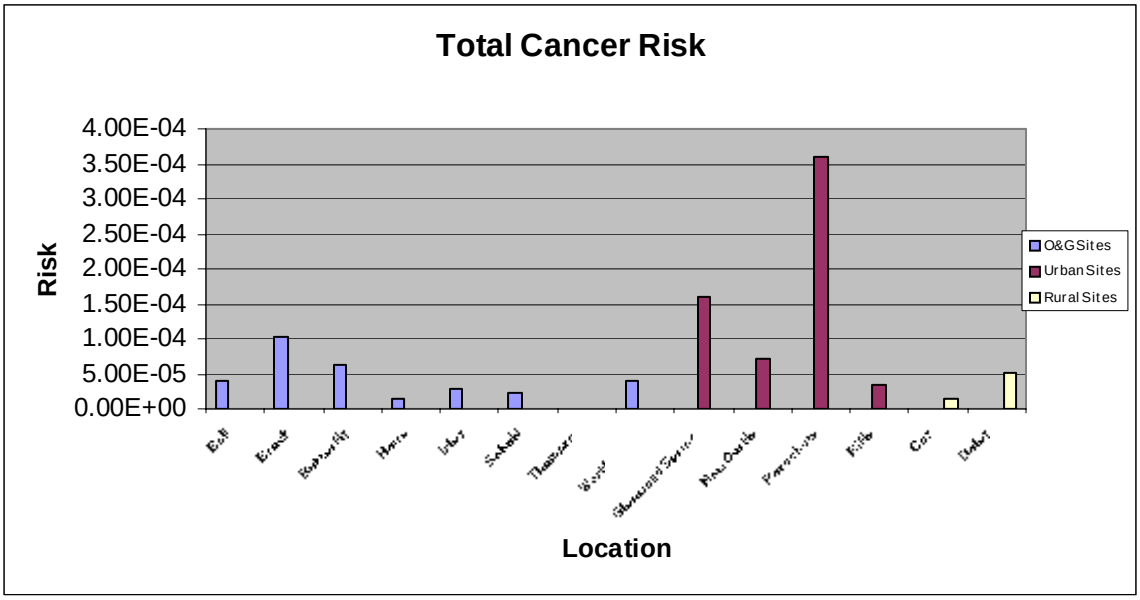

Figure 1. Total Cancer Risk Estimates Across 14 Sites in Oil &Gas, Urban, and Rural Background Areas

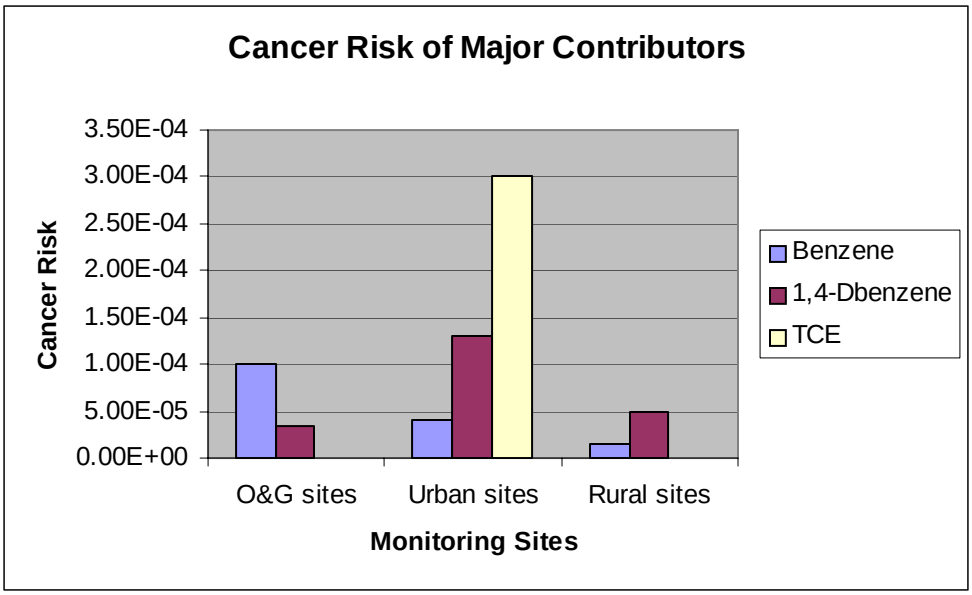

Figure 2. Pattern of Major Contributors of Cancer Risk Across Oil & Gas Sites, Urban Sites, and Rural Background Site.

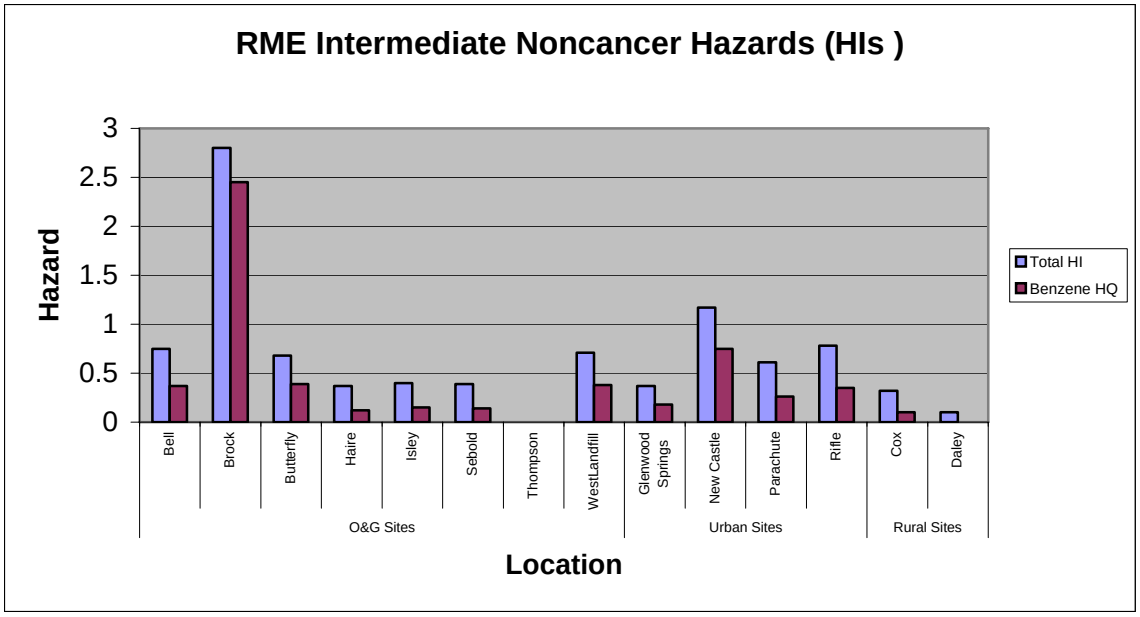

Figure 3. RME (near the high-end) Intermediate Non-Cancer Combined Hazard Estimates (Hazard Index; HIs) Of Total Chemicals For Exposure Duration of 15-365 days, With Benzene Hazard Quotients (HQs) As The Major Contributor Across14 Sites in Oil &Gas, Urban, and Rural Background Areas.

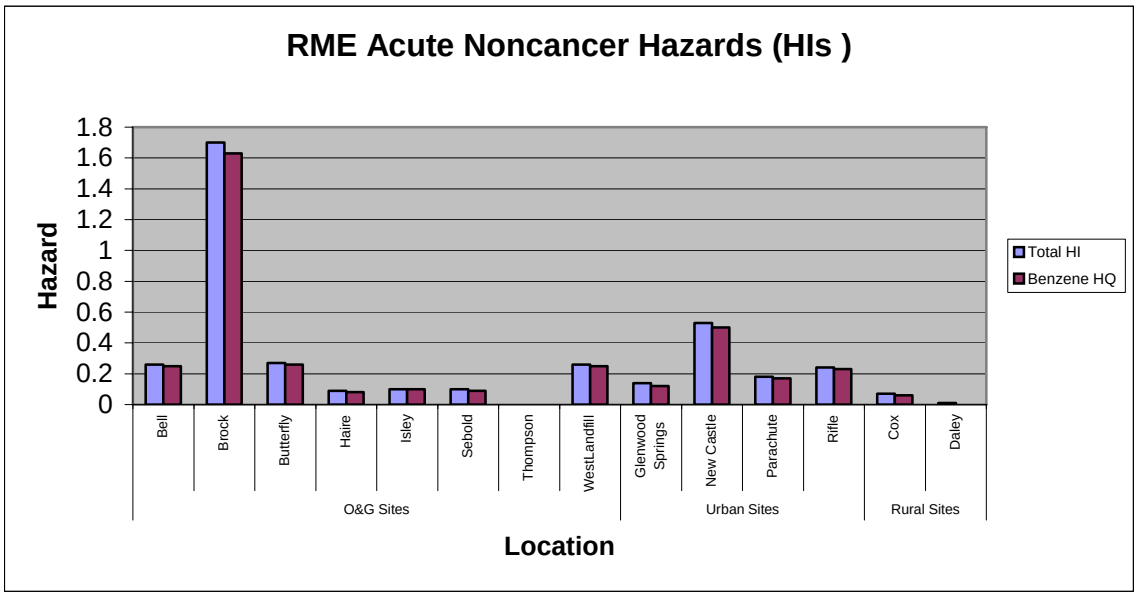

Figure 4. RME (near the high-end) Acute Non-Cancer Combined Hazard Estimates (Hazard Index; HIs) Of Total Chemicals For Exposure Duration of 14 Days or Less, With Benzene Hazard Quotients (HQs) As The Major Contributor Across14 Sites in Oil &Gas, Urban, and Rural Background Areas

Table 1. Summary of Selected Chemicals of Potential Concern (COPCs) For All Sites

Monitoring Sites	Number of samples	Number of COPCs	COPCs
O&G Development			
Bell	24	9	Acetone, Vinyl acetate, 2-Butanone, Benzene, Toluene, 2-Hexanone, m,p-Xylene, o-Xylene, 1,4-dichlorobenzene
Brock	22	8	Acetone, Vinyl acetate, 2-Butanone, Benzene, Toluene, Ethylbenzene, m,p-Xylene, o-Xylene
Butterfly	21	9	Acetone, Vinyl acetate, 2-Butanone, Benzene, Toluene, Ethylbenzene, m,p-Xylene, o-Xylene , 1,4-dichlorobenzene
Haire	22	9	Acetone, Vinyl acetate, 2-Butanone, Benzene, Toluene, tetrachloroethene, Ethylbenzene, m,p-Xylene, Styrene,
Isley	20	9	Acetone, Methylene chloride, Vinyl acetate, 2-Butanone, Benzene, Toluene, m,p-Xylene, Styrene, 1,4-dichlorobenzene
Sebold	21	8	Acetone, Vinyl acetate, 2-Butanone, Benzene, Toluene, 2-Hexanone, m,p-Xylene, 1,4-dichlorobenzene
Thompson	3	3	Acetone, 2-Butanone, Toluene
West Landfill	23	10	Acetone, Methylene chloride, Vinyl acetate, 2-Butanone, Benzene, Toluene, 2-Hexanone, Ethylbenzene, m,p-Xylene, o-Xylene
Urban			
Glenwood Springs	8	8	Acetone, Methylene chloride, Vinyl acetate, 2-Butanone, Benzene, Toluene, m,p-Xylene, 1,4-dichlorobenzene,
New Castle	21	10	Acetone, Methylene chloride, Vinyl acetate, 2-Butanone, Benzene, Toluene, Ethylbenzene, m,p-Xylene, o-Xylene, 1,4-dichlorobenzene,
Parachute	8	11	Acetone, Trichlorofluoromethane, Vinyl acetate, 2-Butanone, Benzene, Toluene, 2-Hexanone, Trichloroethene, m,p-Xylene, o-Xylene, 1,4-dichlorobenzene
Rifle	23	10	Acetone, Vinyl acetate, 2-Butanone, Benzene, Toluene, 2-Hexanone, tetrachloroethene, Ethylbenzene, m,p-Xylene, o-Xylene
Rural Background			
Cox	8	6	Acetone, Vinyl acetate, 2-Butanone, Benzene, Toluene, m,p-Xylene,
Daley	8	6	Acetone, Vinyl acetate, 2-Butanone, Toluene, 1,4-dichlorobenzene

Table 2. Site Summary of Cumulative Lifetime Cancer Risk For All COPCs Based On The 24-Hour Average Exposure Point Concentration (EPC; 95 UCL on the Mean)

Monitoring Sites	Number of Samples	Lifetime Cumulative Cancer Risk	Number of carcinogenic COPCs	Risk Contributing Carcinogens
O&G Development				
Bell	24	3.95E-05	2	Benzene (2.8E-05), 1,4-dichlorobenzene (1.2E-05)
Brock	22	1.04E-04	1	Benzene (1.04E-04)
Butterfly	21	6.41E-05	2	Benzene (2.9E-05), 1,4-dichlorobenzene (3.5E-05)
Haire	22	1.56E-05	2	Benzene (8.9E-06), tetrachloroethene (6.7E-06)
Isley	20	2.93E-05	3	Benzene (1.1E-05), 1,4-dichlorobenzene (1.8E-05), methylene chloride (5E-07)
Sebold	21	2.36E-05	2	Benzene (1.0E-05), 1,4-dichlorobenzene (1.35E-05)
Thompson	3	NA	0	NA
West Landfill	23	3.94E-05	2	Benzene (3.9E-05), methylene chloride (5.8E-07)
Urban				
Glenwood Springs	8	1.60E-04	3	Benzene (2.7E-05), 1,4-dichlorobenzene (1.3E-04),methylene chloride (1.1E-06)
New Castle	21	7.15E-05	3	Benzene (3.85E-05), 1,4-dichlorobenzene (3.2E-05), methylene chloride (1.3E-06)
Parachute	8	3.61E-04	3	Benzene (4E-05), Trichloroethene (3E-04), 1,4-dichlorobenzene (2.4E-05)
Rifle	23	3.52E-05	2	Benzene (8.9E-06), tetrachloroethene (6.7E-06)
Rural Background				
Cox	8	1.48E-05	1	Benzene (1.48E-05)
Daley	8	5.06E-05	1	1,4-dichlorobenzene (5.06E-05)

Table 3. Summary Of Non-Cancer Hazard Indices (HI) For Total Combined Chemicals For Exposures Of Chronic (7 year to lifetime); Intermediate (15-364 days); and Acute (1-14 days) Durations, Based On The 24-hour Average EPC (95 UCL on the mean)

Monitoring Sites	Chronic HI	Intermediate HI	Acute HI	Number of samples	Noncancer Hazard driving COPCs
O&G Development					
Bell	0.33	0.32	0.12	24	Benzene, 2-Hexanone [c], Vinyl Acetate [a]
Brock	0.55	0.80	0.46	22	Benzene, Vinyl Acetate [a]
Butterfly	0.33	0.32	0.13	21	Benzene, m, p-Xylene [b], Vinyl Acetate [a]
Haire	0.09	0.16	0.04	22	Benzene, m, p-Xylene [b], Vinyl Acetate [a]
Isley	0.11	0.21	0.05	20	Benzene, Vinyl Acetate [a]
Sebold	0.21	0.19	0.05	21	2-Hexanone [c], Benzene, Vinyl Acetate [a]
Thompson	0.006	0.000	0.001	3	Acetone
West Landfill	0.48	0.38	0.17	23	Benzene, 2-Hexanone [c], m, p-Xylene [b], Vinyl Acetate [a]
Urban					
Glenwood Springs	0.24	0.37	0.14	8	Benzene, Vinyl Acetate [a]
New Castle	0.25	0.38	0.18	21	Benzene, Vinyl Acetate [a]
Parachute	0.61	0.61	0.18	8	m, p-Xylene, 2-Hexanone, Benzene, Vinyl Acetate [a]
Rifle	0.40	0.55	0.13	23	Benzene, 2-Hexanone [c], Vinyl Acetate [a]
Rural Background					
Cox	0.16	0.32	0.07	8	Benzene, Vinyl Acetate [a]
Daley	0.08	0.10	0.01	8	m, p-Xylene [b], Vinyl Acetate [a]

[a] Vinyl acetate is a contributor for intermediate exposure duration only
[b] m,p-Xylene is a contributor for chronic exposure duration only
[c] 2-Hexanon is a contributor for chronic exposure duration only

Table 4. Summary Of RME Non-Cancer Hazard Indices (HI) For Total Combined Chemicals For Exposures Of Intermediate (15-364 days); and Acute (1-14 days) Durations, Based On The 24-hour Maximum Detected Concentration Across Monitoring Sites.

Monitoring Sites	RME Intermediate HI	RME Acute HI	Number of Samples	Noncancer Hazard driving COPCs
O&G Development				
Bell	0.75	0.26	24	Benzene, Vinyl Acetate [a]
Brock	**2.8**	**1.7**	22	Benzene, Vinyl Acetate [a]
Butterfly	0.68	0.27	21	Benzene, Vinyl Acetate [a]
Haire	0.37	0.09	22	Benzene, Vinyl Acetate [a]
Isley	0.40	0.10	20	Benzene, Vinyl Acetate [a]
Sebold	0.39	0.10	21	Benzene, Vinyl Acetate [a]
Thompson	0.000	0.001	3	Acetone
West Landfill	0.71	0.26	23	Benzene, Vinyl Acetate [a]
Urban				
Glenwood Springs	0.37	0.14	8	Benzene, Vinyl Acetate [a]
New Castle	1.17	0.53	21	Benzene, Vinyl Acetate [a]
Parachute	0.61	0.18	8	Benzene, Vinyl Acetate [a]
Rifle	0.78	0.24	23	Benzene, Vinyl Acetate [a]
Rural Background				
Cox	0.32	0.07	8	Benzene, Vinyl Acetate [a]
Daley	0.10	0.01	8	Vinyl Acetate [a]

[a] Vinyl acetate is a hazard driver for intermediate exposure duration only

Table 5. The High-End Acute Non-Cancer Hazard Quotients (HQs) and Hazard Index (HI) for Maximally Exposed Individuals (MEI), Based on the 15-Second Maximum Detected Values In Grab Samples Collected Across Grab Sampling Location In Response to Citizens Complaints.

Compound	**% Detect**	**Air Concentration µg/m³**	**ATSDR MRL for Acute Duration of 14 days or less µg/m³**	**Acute HQ for 14 days or less**
Chloromethane	3.7%	15.0	1031.0	0.02
Acetone	77.8%	81.0	61724.0	0.001
Trichlorofluoromethane	7.4%	15.0	NA	NA
Vinyl Acetate	14.8%	15.0	NA	NA
2-Butanone (MEK)	70.4%	15.0	13000.0	0.001
Chloroform	3.7%	15.0	488.0	0.03
Benzene	92.6%	180.0	30.0	**6.0**
Toluene	92.6%	540.0	3766.0	0.14
2-Hexanone	14.8%	15.0	NA	NA
Ethylbenzene	63.0%	96.0	NA	NA
m,p-Xylenes	92.6%	1500.0	9000.0	0.20
o-Xylene	81.5%	260.0	9000.0	0.03
Total Chemicals HI				**HI=6.42**

Table 6. High-End Acute Non-Cancer Hazard Quotients (HQs) of Benzene For The Maximally Exposed Individuals (MEI), Based On The 15-Second Maximum Detected Values In Grab Samples Collected Across Grab Sampling Location In Response To Citizens Complaints.

Grab Sample Location	**Benzene Level** µg/m³	**Acute HQ for 1-14 days** [a] µg/m³	**Acute HQ for 6-hr** [b] µg/m³
W-27-3	NA	NA	NA
Ferguson	4.5	0.15	0.003
Bell	21.0	0.70	0.020
West Landfill	4.0	0.13	0.003
Bell (2)	10.0	0.33	0.008
CR 326	67.0	**2.23**	0.050
CR 326 (2)	180.0	**6.00**	0.140
Trulove	29.0	**1.00**	0.022
1921 CR 322	5.1	0.20	0.004
Hooker Pad	68.0	**2.30**	0.050
Trulove (2)	56.0	**1.90**	0.043
Smith	11.0	0.40	0.008
Bell (3)	3.6	0.10	0.003
Trulove (3)	15.0	0.50	0.011
Kelly	4.5	0.15	0.003
Trulove (4)	5.0	0.17	0.004
Trulove @ Kitchen Door	73.0	**2.43**	0.060
Trulove (5)	3.6	0.12	0.003
Dardynski	22.0	0.73	0.020
Grass Mesa Smoke Plume	1.5	0.05	0.001
Hoffmeister	130.0	**4.33**	0.100
Hughes	2.9	0.10	0.002
Bell (4)	9.6	0.32	0.007
Hughes (2)	11.0	0.37	0.008
Kochevar	6.9	0.23	0.005
Bell (5)	16.0	0.53	0.012
Bell/Curry	NA	NA	NA

NA-Not available

[a] HQs for 14 days or less are calculated using ATSDR Minimal Risk Level (MRL) of 30 µg/m³, based on immunological effects (e.g., depressed peripheral lymphocytes)

[b] HQs for 6-hr exposure durations are calculated using California EPA Reference Exposure Levels (RELs) of 1300 µg/m³ based on the reproductive/developmental toxicologic endpoint
(OEHHA, 2007 at http://www.oehha.ca..gov/air/acute_rels/allAcRELs.html

Appendix A: Summary Data And Selection of Chemicals of Potential Concern (COPC)

Table A1. Summary Statistics For The 24-Hour and Grab Sample Data Across All Sampling Locations (2005-2007)

Detected Compounds		**Overall 24-Hr Samples (231 samples, 14 sites)**				**Overall Grab Samples (27 samples, 27 sites)**			
CAS #	**Chemical**	**Avg µg/m³**	**Max µg/m³**	**Min µg/m³**	**% Detects**	**Avg µg/m³**	**Max µg/m³**	**Min µg/m³**	**% Detects**
74-87-3	Chloromethane	ND	ND	ND	0.0%	1.5	15.0	0.7	3.7%
67-64-1	Acetone	18.5	80.0	3.6	81.9%	26.0	81.0	3.7	77.8%
75-69-4	Trichlorofluoromethane	1.0	26.0	0.7	0.4%	1.5	15.0	0.7	7.4%
75-09-2	Methylene chloride	1.0	8.4	0.7	1.7%	ND	ND	ND	0.0%
108-05-4	Vinyl Acetate	2.1	15.0	0.7	23.3%	2.5	15.0	0.7	14.8%
78-93-3	2-Butanone (MEK)	2.2	12.0	0.7	55.2%	3.0	15.0	0.8	70.4%
67-66-3	Chloroform	ND	ND	ND	0.0%	1.5	15.0	0.7	3.7%
71-43-2	Benzene	2.2	49.0	0.8	39.2%	28.2	180.0	0.8	92.6%
79-01-6	Trichloroethene	0.9	2.7	0.7	0.4%	ND	ND	ND	0.0%
108-88-3	Toluene	7.4	130.0	0.8	89.7%	91.4	540.0	0.8	92.6%
591-78-6	2-Hexanone	1.0	4.4	0.7	3.0%	1.7	15.0	0.7	14.8%
127-18-4	Tetrachloroethene	0.9	2.3	0.7	0.9%	ND	ND	ND	0.0%
100-41-4	Ethylbenzene	1.0	3.4	0.7	3.4%	8.3	96.0	0.8	63.0%
136777-61-2	*m,p*-Xylenes	3.9	24.0	0.8	64.2%	106.6	1500.0	0.8	92.6%
100-42-5	Styrene	0.9	6.0	0.7	0.9%	ND	ND	ND	0.0%
95-47-6	o-Xylene	1.1	4.3	0.7	10.3%	18.1	260.0	0.8	81.5%
106-46-7	1,4-Dichlorobenzene	1.1	12.0	0.7	3.4%	ND	ND	ND	0.0%

NOTE: 1/2 of Minimum Reporting Level used for non-detect values.

Table A2- List Of Chemicals That Were Analyzed For, But Never Detected In 24-hour Samples (26 of 43 compounds were never detected) And Grab Samples (31 of 43 compounds were never detected), Across All Monitoring Sites (2005-2007).

Cas No.	Compounds Never Detected in 24-Hrour Samples	Compounds Never Detected in Grab Samples
74-87-3	Chloromethane	*Detected*
75-01-4	Vinyl Chloride	Vinyl Chloride
74-83-9	Bromomethane	Bromomethane
75-00-3	Chloroethane	Chloroethane
75-35-4	1,1-Dichloroethene	1,1-Dichloroethene
76-13-1	Trichlorotrifluoroethane	Trichlorotrifluoroethane
75-15-0	Carbon Disulfide	Carbon Disulfide
156-60-5	trans-1,2-Dichloroethene	trans-1,2-Dichloroethene
75-34-3	1,1-Dichloroethane	1,1-Dichloroethane
1634-04-4	Methyl tert-Butyl Ether	Methyl tert-Butyl Ether
156-59-2	cis-1,2-Dichloroethene	cis-1,2-Dichloroethene
67-66-3	Chloroform	*Detected*
107-06-2	1,2-Dichloroethane	1,2-Dichloroethane
71-55-6	1,1,1-Trichloroethane	1,1,1-Trichloroethane
56-23-5	Carbon Tetrachloride	Carbon Tetrachloride
78-87-5	1,2-Dichloropropane	1,2-Dichloropropane
75-27-4	Bromodichloromethane	Bromodichloromethane
10061-01-5	cis-1,3-Dichloropropene	cis-1,3-Dichloropropene
108-10-1	4-Methyl-2-pentanone	4-Methyl-2-pentanone
10061-02-6	trans-1,3-Dichloropropene	trans-1,3-Dichloropropene
79-00-5	1,1,2-Trichloroethane	1,1,2-Trichloroethane
124-48-1	Dibromochloromethane	Dibromochloromethane
106-93-4	1,2-Dibromoethane	1,2-Dibromoethane
108-90-7	Chlorobenzene	Chlorobenzene
75-25-2	Bromoform	Bromoform
79-34-5	1,1,2,2-Tetrachloroethane	1,1,2,2-Tetrachloroethane
541-73-1	1,3-Dichlorobenzene	1,3-Dichlorobenzene
95-50-1	1,2-Dichlorobenzene	1,2-Dichlorobenzene
106-46-7	*Detected*	1,4-Dichlorobenzene
75-09-2	*Detected*	Methylene chloride
79-01-6	*Detected*	Trichloroethene
127-18-4	*Detected*	Tetrachloroethene
100-42-5	*Detected*	Styrene

Table A3. Selection Of Chemicals Of Potential Concern (COPCs) Based On The Detection Frequency (DF) For Oil and Gas Sites

Oil & Gas Sites	**Bell (24 Samples)**			**Brock (22 Samples)**			**Butterfly (21 Samples)**			**Haire (22 Samples)**		
Compound	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**
Acetone	57.0	87.5%		56.0	86.4%		61.0	85.7%		56.0	77.3%	
Trichlorofluoromethane	1.1	0.0%	No	1.2	0.0%	No	1.1	0.0%	No	1.1	0.0%	No
Methylene chloride	1.1	0.0%	No	1.2	0.0%	No	1.1	0.0%	No	1.1	0.0%	No
Vinyl Acetate	13.0	16.7%		13.0	22.7%		9.7	23.8%		8.6	13.6%	
2-Butanone (MEK)	9.8	58.3%		6.7	63.6%		4.1	42.9%		4.1	50.0%	
Benzene	7.4	41.7%		49.0	45.5%		7.7	38.1%		2.3	9.1%	
Trichloroethene	1.1	0.0%	No	1.2	0.0%	No	1.1	0.0%	No	1.1	0.0%	No
Toluene	27.0	95.8%		130.0	90.9%		43.0	85.7%		27.0	77.3%	
2-Hexanone	4.4	4.2%		1.2	0.0%	No	1.1	0.0%	No	1.1	0.0%	No
Tetrachloroethene	1.1	0.0%	No	1.2	0.0%	No	1.1	0.0%	No	1.7	4.5%	
Ethylbenzene	1.1	0.0%	No	3.4	9.1%		1.7	4.8%		1.7	4.5%	
m,p-Xylenes	14.0	66.7%		12.0	63.6%		19.0	47.6%		5.0	31.8%	
Styrene	1.1	0.0%	No	1.2	0.0%	No	1.1	0.0%	No	1.8	4.5%	
o-Xylene	2.3	4.2%		2.7	9.1%		3.1	19.0%		1.1	0.0%	No
1,4-Dichlorobenzene	2.3	4.2%		1.2	0.0%	No	9.9	4.8%		1.1	0.0%	No

Table A4. Selection of Chemicals Of Potential Concern (COPCs) Based On the Detection Frequency (DF) for Oil and Gas Sites

Oil & Gas Sites	**Isley (20 Samples)**			**Sebold (21 Samples)**			**Thompson (3 Samples)**			**West Landfill (23 Samples)**		
Compound	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**
Acetone	51.0	65.0%		58.0	76.2%		15.0	66.7%		80.0	87.0%	
Trichlorofluoromethane	1.4	0.0%	No	1.4	0.0%	No	1.0	0.0%	No	1.0	0.0%	No
Methylene chloride	1.8	5.0%		1.4	0.0%	No	1.0	0.0%	No	3.5	4.3%	
Vinyl Acetate	8.5	35.0%		8.8	33.3%		1.0	0.0%	No	11.0	30.4%	
2-Butanone (MEK)	6.0	55.0%		8.1	66.7%		2.1	33.3%		6.6	52.2%	
Benzene	3.0	20.0%		2.7	14.3%		1.0	0.0%	No	7.5	95.7%	
Trichloroethene	1.4	0.0%	No	1.4	0.0%	No	1.0	0.0%	No	1.0	0.0%	No
Toluene	10.0	100.0%		10.0	90.5%		3.8	100.0%		26.0	100.0%	
2-Hexanone	1.4	0.0%	No	2.1	4.8%		1.0	0.0%	No	2.7	13.0%	
Tetrachloroethene	1.4	0.0%	No	1.4	0.0%	No	1.0	0.0%	No	1.0	0.0%	No
Ethylbenzene	1.4	0.0%	No	1.4	0.0%	No	1.0	0.0%	No	2.9	4.3%	
m,p-Xylenes	4.8	55.0%		5.1	81.0%		1.0	0.0%	No	24.0	100.0%	
Styrene	6.0	5.0%		1.4	0.0%	No	1.0	0.0%	No	1.0	0.0%	No
o-Xylene	1.4	0.0%	No	1.4	0.0%	No	1.0	0.0%	No	4.3	30.4%	
1,4-Dichlorobenzene	6.0	5.0%		3.0	4.8%		1.0	0.0%	No	1.0	0.0%	No

Table A5. Selection of Chemicals Of Potential Concern (COPCs) Based On The Detection Frequency (DF) For Urban Sites

Urban Sites	**Glenwood (8 Samples)**			**New Castle (21 Samples)**			**Parachute (8 Samples)**			**Rifle (23 Samples)**		
Compound	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**
Acetone	37.0	75.0%		73.0	71.4%		46.0	87.5%		55.0	95.7%	
Trichlorofluoromethane	1.1	0.0%	No	1.3	0.0%	No	26.0	12.5%		2.2	0.0%	No
Methylene chloride	2.3	12.5%		8.4	4.8%		1.3	0.0%	No	2.2	0.0%	No
Vinyl Acetate	6.2	25.0%		14.0	14.3%		12.0	25.0%		15.0	26.1%	
2-Butanone (MEK)	3.9	62.5%		4.5	42.9%		7.2	62.5%		12.0	65.2%	
Benzene	3.5	12.5%		15.0	33.3%		5.1	62.5%		6.9	78.3%	
Trichloroethene	1.1	0.0%	No	1.3	0.0%	No	2.7	12.5%		2.2	0.0%	No
Toluene	57.0	100.0%		100.0	90.5%		13.0	100.0%		19.0	100.0%	
2-Hexanone	1.1	0.0%	No	1.3	0.0%	No	2.1	12.5%		3.0	4.3%	
Tetrachloroethene	1.1	0.0%	No	1.3	0.0%	No	1.3	0.0%	No	2.3	4.3%	
Ethylbenzene	1.1	0.0%	No	3.1	4.8%		1.3	0.0%	No	2.2	8.7%	
m,p-Xylenes	5.4	50.0%		6.6	66.7%		11.0	87.5%		12.0	100.0%	
Styrene	1.1	0.0%	No	1.3	0.0%	No	1.3	0.0%	No	2.2	0.0%	No
o-Xylene	1.1	0.0%	No	3.0	4.8%		1.9	12.5%		3.0	34.8%	
1,4-Dichlorobenzene	12.0	12.5%		8.8	4.8%		2.2	12.5%		2.2	0.0%	No

Table A6. Selection of Chemicals of Potential Concern (COPCs) Based on the Detection Frequency (DF) For Rural Background Sites

Rural Background	**Cox (8 Samples)**			**Daley (8 Samples)**		
Compound	**Max µg/m³**	**% time detected**	**COPC If DF>0%**	**Max µg/m³**	**% time detected**	**COPC If DF>0%**
Acetone	32.0	87.5%		21.0	87.5%	
Trichlorofluoromethane	1.1	0.0%	No	1.2	0.0%	No
Methylene chloride	1.1	0.0%	No	1.2	0.0%	No
Vinyl Acetate	7.9	25.0%		3.2	12.5%	
2-Butanone (MEK)	2.9	62.5%		3.7	37.5%	
Benzene	1.9	12.5%		1.2	0.0%	No
Trichloroethene	1.1	0.0%	No	1.2	0.0%	No
Toluene	10.0	50.0%		27.0	37.5%	
2-Hexanone	1.1	0.0%	No	1.2	0.0%	No
Tetrachloroethene	1.1	0.0%	No	1.2	0.0%	No
Ethylbenzene	1.1	0.0%	No	1.2	0.0%	No
m,p-Xylenes	4.2	25.0%		4.9	12.5%	
Styrene	1.1	0.0%	No	1.2	0.0%	No
o-Xylene	1.1	0.0%	No	1.2	0.0%	No
1,4-Dichlorobenzene	1.1	0.0%	No	4.6	12.5%	

Table A7. Exposure Point Concentrations (EPCs) Represented As The 95% Upper Confidence Limit (UCL) On The Mean

EPCs	Oil &Gas Sites EPCs								Urban Sites EPCs				Rural Sites EPCs	
Compound	**Bell N=24**	**Brock N=22**	**Butterfly N=21**	**Haire N=22**	**Isley N=20**	**Sebold N=21**	**Thompson N=3**	**West Landfill N=23**	**Glenwood N=8**	**New Castle N=21**	**Parachute N=8**	**Rifle N=23**	**Cox N=8**	**Daley N=8**
Acetone	26.850	24.700	21.950	20.560	21.200	24.260	15.0	32.360	37.0	23.330	46.0	27.790	32.0	21.0
Trichlorofluoromethane	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.0	0.000	26.0	0.000	0.0	0.0
Methylene chloride	0.000	0.000	0.000	0.000	1.043	0.000	0.0	1.232	2.3	2.767	0.0	0.000	0.0	0.0
Vinyl Acetate	4.953	4.759	4.210	3.482	4.962	4.154	0.0	4.384	6.2	4.443	12.0	12.630	7.9	3.2
2-Butanone (MEK)	4.515	3.098	2.523	2.723	3.254	3.853	2.1	4.011	3.9	2.719	7.2	4.081	2.9	3.7
Benzene	3.555	13.270	3.739	1.143	1.385	1.286	0.0	4.981	3.5	4.931	5.1	3.658	1.9	0.0
Trichloroethene	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.000	0.0	0.000	2.7	0.000	0.0	0.0
Toluene	8.669	69.940	10.360	8.334	4.939	5.246	3.8	16.090	57.0	54.550	13.0	10.200	10.0	27.0
2-Hexanone	1.314	0.000	0.000	0.000	0.000	1.104	0.0	1.330	0.0	0.000	2.1	1.204	0.0	0.0
Tetrachloroethene	0.000	0.000	0.000	1.135	0.000	0.000	0.0	0.000	0.0	0.000	0.0	1.135	0.0	0.0
Ethylbenzene	0.000	1.432	0.992	1.005	0.000	0.000	0.0	1.151	0.0	1.173	0.0	1.188	0.0	0.0
m,p-Xylenes	4.329	4.425	15.340	2.451	2.517	3.037	0.0	13.420	5.4	2.993	11.0	6.916	4.2	4.9
Styrene	0.000	0.000	0.000	1.018	1.639	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.0
o-Xylene	1.069	1.309	1.430	0.000	0.000	0.000	0.0	2.303	0.0	1.159	1.9	2.146	0.0	0.0
1,4-Dichlorobenzene	1.071	0.000	3.180	20.560	1.639	1.230	0.0	0.000	12.0	2.888	2.2	0.000	0.0	4.6

Note:

- EPCs Calculated Using the EPA ProUCL 4.0 Software
- For Glenwood Springs, Parachute, Cox, Daley, and Thompson with <10 sample, the maximum detected concentration is used as the EPC.
- EPC of 0.000 represents chemicals eliminated as COPCs due to the detection frequency of 0%.
- N= Number of Samples

Appendix B: Toxicity Values Used to Calculate Risks

Table B1. Toxicity Values For Cancer Effects And Chronic Non-Cancer Effects

Compound	Cancer Risk Factor		Chronic Non-cancer Reference Factor	
	1/µg/m³	Source	µg/m³	Source
Acetone	NC		3,150.0	Region 9
Trichlorofluoromethane	NC		700.0	Region 9
Methylene chloride	4.7E-07	ATW-IRIS	1,000.0	ATW-IRIS
Vinyl Acetate	NC		200.0	ATW-IRIS
2-Butanone (MEK)	NC		5,000.0	IRIS
Benzene	7.8E-06	ATW-IRIS	30.0	ATW-IRIS
Trichloroethene	1.1E-04	CDPHE	600.0	ATW-Cal
Toluene	NC		5,000.0	ATW-IRIS
2-Hexanone	NC		9.88	Mass-AAL
Tetrachloroethene	5.9E-06	CDPHE/OSWER	270.0	ATW-MRL
Ethylbenzene	NC		1,000.0	ATW-IRIS
m,p-Xylene	NC		100.0	ATW-IRIS
Styrene	NC		1,000.0	ATW-IRIS
0-Xylene	NC		100.0	ATW-IRIS
1,4-Dichlorobenzene	1.1E-05	ATW-Cal	800.0	ATW-IRIS

NC= Non-carcinogen
IRIS=EPA's Integrated Risk Information System
ATW= EPA's Air Toxic Website at: http://www.epa.gov/ttn/atw/toxsource/table1.pdf
CDPHE/OSWER-CDPHE adopted EPA's Oswer Directive for the use of Cal EPA inhalation cancer unit risk as the provisional value until the withdrawn EPA IRIS value is re-evaluated.
Cal = California EPA; OEHHA
Mass-AAL=Massachusetts Ambient Air Limits at: http://www.mass.gov/dep/air/aallist.pdf
Region 9=EPA Region 9 PRG Table
CDPHE=Colorado Department of Public Health and Environment
MRL= Minimal Risk Level of Agency for Toxic Substances and Disease Registry (ATSDR) adopted by ATW

Table B2. Short-Term (Intermediate and Acute) Toxicity Values

Compound	Intermediate Toxicity Reference Value (15-364 days)		Acute Toxicity Reference Value (1-14 days)	
	µg/m³	Source	µg/m³	Source
Acetone	30862.0	ATSDR-MRL	61724.0	ATSDR-MRL
Trichlorofluoromethane	na		na	
Methylene chloride	1041.0	ATSDR-MRL	2082.0	ATSDR-MRL
Vinyl Acetate	35.0	ATSDR-MRL	na	
2-Butanone (MEK)	na		13000.0	ATSDR-MRL
Benzene	20.0	ATSDR-MRL	30.0	ATSDR-MRL
Trichloroethene	537.0	ATSDR-MRL	10741.0	ATSDR-MRL
Toluene	na		3766.0	ATSDR-MRL
2-Hexanone	na		na	
Tetrachloroethene	na		1080.0	ATSDR-MRL
Ethylbenzene	4339.0	ATSDR-MRL	na	ATSDR-MRL
m,p-Xylene	3037.0	ATSDR-MRL	9000.0	ATSDR-MRL
Styrene	na		21000.0	ATSDR-MRL
o-Xylene	3037.0	ATSDR-MRL	9000.0	ATSDR-MRL
1,4-Dichlorobenzene	1201.0	ATSDR-MRL	12017.0	ATSDR-MRL

na = Not available
ATSDR-MRL= ATSDR Minimal Risk Level

Appendix C: Cancer Risk Estimates, Chronic Non-Cancer Hazards, and Average Short-Term Non-Cancer Hazards (Intermediate and Acute), based on the EPC (95% UCL on the Mean)

Table C1. Theoretical Lifetime Cancer Risks For Individual Chemicals and Total Combined Chemicals

Lifetime Cancer Risk Estimates	**Oil &Gas Sites**								**Urban Sites**				**Rural Sites**	
Compound	**Bell**	**Brock**	**Butterfly**	**Haire**	**Isley**	**Sebold**	**Thompson**	**West Landfill**	**Glenwood**	**New Castle**	**Parachute**	**Rifle**	**Cox**	**Daley**
Acetone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichlorofluoromethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	NA	*4.90E-07*	NA	NA	*5.79E-07*	*1.08E-06*	*1.30E-06*	NA	NA	NA	NA
Vinyl Acetate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone (MEK)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	*2.77E-05*	*1.04E-04*	*2.92E-05*	*8.92E-06*	*1.08E-05*	*1.00E-05*	*NA*	*3.89E-05*	*2.73E-05*	*3.85E-05*	*3.98E-05*	*2.85E-05*	*1.48E-05*	NA
Trichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	*2.97E-04*	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	NA	NA	NA	*6.70E-06*	NA	NA	NA	NA	NA	NA	NA	*6.70E-06*	NA	NA
Ethylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
m,p-Xylenes	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Styrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	*1.18E-05*	NA	*3.50E-05*	NA	*1.80E-05*	*1.35E-05*	NA	NA	*1.32E-04*	*3.18E-05*	*2.42E-05*	NA	NA	*5.06E-05*
Total Chemicals Cancer Risk	**3.95E-05**	**1.04E-04**	**6.41E-05**	**1.56E-05**	**2.93E-05**	**2.36E-05**	**NA**	**3.94E-05**	**1.6E-04**	**7.15E-05**	**3.61E-04**	**3.52E-05**	**1.48E-05**	**5.06E-05**

NA= Not a COPC or a non-carcinogen

Table C2. Chronic (7 years to lifetime exposure duration) Non-Cancer Hazard Estimates Represented As Hazard Quotients (HQs) For Individual Chemicals And As Hazard Indices (HIs) For Total Combined Chemicals

Chronic Hazard Estimates	**Oil &Gas Sites HQs**								**Urban Sites HQs**				**Rural Sites HQs**	
Compound	**Bell**	**Brock**	**Butterfly**	**Haire**	**Isley**	**Sebold**	**Thompson**	**West Landfill**	**Glenwood**	**New Castle**	**Parachute**	**Rifle**	**Cox**	**Daley**
Acetone	0.008	0.008	0.007	0.006	0.007	0.008	0.005	0.010	0.012	0.007	0.015	0.009	0.010	0.007
Trichlorofluoromethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.037	NA	NA	NA
Methylene chloride	NA	NA	NA	NA	0.001	NA	NA	0.001	0.002	0.003	NA	NA	NA	NA
Vinyl Acetate	0.025	0.024	0.021	0.017	0.025	0.021	NA	0.022	0.031	0.022	0.060	0.063	0.039	0.016
2-Butanone (MEK)	0.001	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001
Benzene	0.118	0.442	0.125	0.038	0.046	0.043	NA	0.166	0.117	0.164	0.170	0.122	0.063	NA
Trichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.004	NA	NA	NA
Toluene	0.002	0.014	0.002	0.002	0.001	0.001	0.001	0.003	0.011	0.011	0.003	0.002	0.002	0.005
2-Hexanone	0.121	NA	NA	NA	NA	0.101	NA	0.122	NA	NA	0.193	0.111	NA	NA
Tetrachloroethene	NA	NA	NA	0.004	NA	NA	NA	NA	NA	NA	NA	0.004	NA	NA
Ethylbenzene	NA	0.001	0.001	0.001	NA	NA	NA	0.001	NA	0.001	NA	0.001	NA	NA
m,p-Xylenes	0.043	0.044	0.153	0.024	0.025	0.030	NA	0.134	0.054	0.030	0.110	0.069	0.042	0.049
Styrene	NA	NA	NA	0.001	0.002	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	0.011	0.013	0.014	NA	NA	NA	NA	0.023	NA	0.012	0.019	0.021	NA	NA
1,4-Dichlorobenzene	0.008	NA	0.004	NA	0.002	0.001	NA	NA	0.015	0.004	0.015	NA	NA	0.006
Total Chemical HIs	**0.33**	**0.55**	**0.33**	**0.09**	**0.11**	**0.21**	**0.006**	**0.48**	**0.24**	**0.25**	**0.61**	**0.40**	**0.16**	**0.08**

NA= Not a COPC

Table C3. Average (CTE) Intermediate (15-364 days exposure duration) Non-Cancer Hazard Estimates Represented As Hazard Quotients (HQs) For Individual Chemicals And As Hazard Indices (HIs) For Total Combined Chemicals

CTE Intermediate Hazard Estimates	**Oil &Gas Sites HQs**								**Urban Sites HQs**				**Rural Sites HQs**	
Compound	**Bell**	**Brock**	**Butterfly**	**Haire**	**Isley**	**Sebold**	**Thompson**	**West Landfill**	**Glenwood**	**New Castle**	**Parachute**	**Rifle**	**Cox**	**Daley**
Acetone	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Trichlorofluoromethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	NA	0.001	NA	NA	0.001	0.002	0.003	NA	NA	NA	NA
Vinyl Acetate	0.141	0.136	0.120	0.10	0.142	0.119	NA	0.125	0.177	0.127	0.343	0.361	0.226	0.092
2-Butanone (MEK)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	0.178	0.663	0.187	0.057	0.069	0.064	NA	0.249	0.175	0.246	0.255	0.183	0.095	NA
Trichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.005	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	NA	0.000	0.000	0.000	NA	NA	NA	0.000	NA	0.000	NA	0.000	NA	NA
m,p-Xylenes	0.001	0.001	0.005	0.001	0.001	0.001	NA	0.004	0.002	0.001	0.003	0.002	0.001	0.001
Styrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	0.000	0.000	0.000	NA	NA	NA	NA	0.001	NA	0.000	0.000	0.001	NA	NA
1,4-Dichlorobenzene	0.001	NA	0.003	NA	0.001	0.001	NA	NA	0.010	0.002	0.002	NA	NA	0.004
Total Chemical HIs	**0.32**	**0.80**	**0.32**	**0.16**	**0.21**	**0.19**	**0.000**	**0.38**	**0.37**	**0.38**	**0.61**	**0.55**	**0.32**	**0.10**

NA= Not a COPC or toxicity value is not available

Table C4 Average (CTE) Acute (1-14 days exposure duration) Non-Cancer Hazard Estimates Represented As Hazard Quotients (HQs) For Individual Chemicals And As Hazard Indices (HIs) For Total Combined Chemicals

CTE Acute Hazard Estimates	**Oil &Gas Sites HQs**								**Urban Sites HQs**				**Rural Sites HQs**	
Compound	**Bell**	**Brock**	**Butterfly**	**Haire**	**Isley**	**Sebold**	**Thompson**	**West Landfill**	**Glenwood**	**New Castle**	**Parachute**	**Rifle**	**Cox**	**Daley**
Acetone	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
Trichlorofluoromethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	NA	0.001	NA	NA	0.001	0.001	0.001	NA	NA	NA	NA
Vinyl Acetate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone (MEK)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Benzene	0.118	0.442	0.124	0.038	0.046	0.043	NA	0.166	0.117	0.164	0.17	0.122	0.063	NA
Trichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.000	NA	NA	NA
Toluene	0.002	0.018	0.003	0.002	0.001	0.001	0.001	0.004	0.015	0.014	0.003	0.002	0.002	0.007
2-Hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	NA	NA	NA	0.001	NA	NA	NA	NA	NA	NA	NA	0.001	NA	NA
Ethylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
m,p-Xylenes	0.000	0.001	0.001	0.000	0.000	0.000	NA	0.001	0.000	0.000	0.001	0.001	0.000	0.000
Styrene	NA	NA	NA	0.000	0.000	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	0.000	0.000	0.000	NA	NA	NA	NA	0.000	NA	0.000	0.000	0.000	NA	NA
1,4-Dichlorobenzene	0.000	NA	0.000	NA	0.000	0.000	NA	NA	0.001	0.000	0.0003	NA	NA	0.000
Total Chemical HIs	**0.12**	**0.46**	**0.13**	**0.04**	**0.05**	**0.05**	**0.001**	**0.17**	**0.14**	**0.18**	**0.18**	**0.13**	**0.07**	**0.009**

NA= Not a COPC or toxicity value is not available

Appendix D: High-End Short-Term Non-Cancer Hazards Based On the Maximum Detected Air Concentrations of the 24-Hour Long-Term Samples and 15-Second Grab Samples

Table D1. Near The High-End (RME) Intermediate (15-364 days exposure duration) Non-Cancer Hazard Estimates Represented As Hazard Quotients (HQs) For Individual Chemicals And As Hazard Indices (HIs) For Total Combined Chemicals

RME Intermediate Hazard Estimates	**Oil &Gas Sites HQs**								**Urban Sites HQs**				**Rural Sites HQs**	
Compound	**Bell**	**Brock**	**Butterfly**	**Haire**	**Isley**	**Sebold**	**Thompson**	**West Landfill**	**Glenwood**	**New Castle**	**Parachute**	**Rifle**	**Cox**	**Daley**
Acetone	0.002	0.002	0.002	0.002	0.002	0.002	0.000	0.003	0.001	0.002	0.001	0.002	0.001	0.001
Trichlorofluoromethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	NA	0.002	NA	NA	0.003	0.002	0.008	NA	NA	NA	NA
Vinyl Acetate	0.371	0.371	0.277	0.246	0.243	0.251	NA	0.314	0.177	0.400	0.343	0.429	0.226	0.091
2-Butanone (MEK)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Benzene	**0.370**	**2.450**	**0.385**	**0.115**	**0.150**	**0.135**	**0.000**	**0.375**	**0.175**	**0.750**	**0.255**	**0.345**	**0.095**	**0.000**
Trichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.005	NA	NA	NA
Toluene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Ethylbenzene	NA	0.001	0.000	0.000	NA	NA	NA	0.001	NA	0.001	NA	0.000	NA	NA
m,p-Xylenes	0.005	0.004	0.006	0.002	0.002	0.002	0.000	0.008	0.002	0.002	0.004	0.004	0.001	0.002
Styrene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	0.001	0.001	0.001	NA	NA	NA	NA	0.001	NA	0.001	0.001	0.001	NA	NA
1,4-Dichlorobenzene	0.002	NA	0.008	NA	0.002	0.002	NA	NA	0.010	0.007	0.002	0.002	NA	0.004
Total Chemicals HIs	**0.75**	**2.83**	**0.68**	**0.37**	**0.40**	**0.39**	**0.000**	**0.71**	**0.37**	**1.17**	**0.61**	**0.78**	**0.32**	**0.100**

NA= Not a COPC or toxicity value is not available

Table D2. Near High-End (RME) Acute (1-14 days exposure duration) Non-Cancer Hazard Estimates Represented As Hazard Quotients (HQs) For Individual Chemicals And As Hazard Indices (HIs) For Total Combined Chemicals

RME Acute Hazard Estimates	**Oil &Gas Sites**								**Urban Sites**				**Rural Sites**	
Compound	**Bell**	**Brock**	**Butterfly**	**Haire**	**Isley**	**Sebold**	**Thompson**	**West Landfill**	**Glenwood**	**New Castle**	**Parachute**	**Rifle**	**Cox**	**Daley**
Acetone	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Trichlorofluoromethane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	NA	0.001	NA	NA	0.002	0.001	0.004	NA	NA	NA	NA
Vinyl Acetate	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone (MEK)	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.001	0.001	0.000	0.000
Benzene	**0.247**	**1.633**	**0.257**	**0.077**	**0.100**	**0.090**	**0.000**	**0.250**	**0.117**	**0.500**	**0.170**	**0.230**	**0.063**	**0.000**
Trichloroethene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.000	NA	NA	NA
Toluene	0.007	0.035	0.011	0.007	0.003	0.003	0.001	0.007	0.015	0.027	0.003	0.005	0.003	0.007
2-Hexanone	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	NA	NA	NA	0.002	NA	NA	NA	NA	NA	NA	NA	0.002	NA	NA
Ethylbenzene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
m,p-Xylenes	0.002	0.001	0.002	0.001	0.001	0.001	0.000	0.003	0.001	0.001	0.001	0.001	0.000	0.001
Styrene	NA	NA	NA	0.000	0.000	NA	NA	NA	NA	NA	NA	NA	NA	NA
o-Xylene	0.000	0.000	0.000	NA	NA	NA	NA	0.000	NA	0.000	0.000	0.000	NA	NA
1,4-Dichlorobenzene	0.000	NA	0.001	NA	0.000	0.000	NA	NA	0.001	0.001	0.000	NA	NA	0.000
Total Chemicals HIs	**0.26**	**1.67**	**0.26**	**0.09**	**0.10**	**0.10**	**0.001**	**0.26**	**0.14**	**0.53**	**0.18**	**0.24**	**0.07**	**0.009**

NA= Not a COPC or toxicity value is not available