Environmental and Health Monitoring Study Final Design Battlement Mesa, Garfield County Colorado

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Acronyms

Acronym	Definition
ATSDR	Agency of Toxic Substances and Disease Registry
BOCC	Garfield County Board of County Commissioners
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CBI	Colorado Bureau of Investigation
CDE	Colorado Department of Education
CDPHE	Colorado Department of Public Health and Environment
COGCC	Colorado Oil and Gas Conservation Commission
CoHID	Colorado Health Information Dataset
CSP	Colorado State Patrol
CSPH	Colorado School of Public Health
E&P	Exploration and Production
EHMS	Environmental and Health Monitoring Study
EPA	United States Environmental Protection Agency
GSA	Garfield County Assessor
GCSO	Garfield County Sheriff's Office
GCPH	Garfield County Department of Public Health
HAP	Hazardous air pollutant
HHRA	Human health risk assessment
HIA	Health impact assessment
HIPAA	Health Insurance Portability and Accountability Act
IRB	Institutional Review Board
MSDS	Material Safety Data Sheet
NAAQS	National Ambient Air Quality Standards
NGD	Natural gas development
NO_2	Nitrogen dioxide
PAHs	Polycyclic aromatic hydrocarbons
PARCCS	Precision, Accuracy, Representativeness, Comparability, Completeness, and Sensitivity
PID	Photoionization detector
$PM_{2.5}$	Particulate matter 2.5 microns or less
PM_{10}	Particulate matter 10 microns or less
PO	Post Office
Ppb	Parts per billion
PPD	Parachute Police Department
QAPP	Quality assurance project plan
PUD	Planned unit development
SF-Tool	Short form survey tool
SNMOCs	Speciated non-methane organic compounds
SO_2	Sulfur dioxide
STI	Sexually transmitted infection
TEOM	Tapered element oscillating microbalance
TPH	Total petroleum hydrocarbons
U.S.	United States

Acronym	Definition
UTLs	Upper tolerance limits
VOCs	Volatile Organic Compounds

1.0 Introduction

In order to scientifically evaluate if and how natural gas development (NGD) impacts public health, extensive information about environmental exposures and access to health information is needed. The Garfield Board of County Commissioners (BOCC) contracted the Colorado School of Public Health (CSPH) at the University of Colorado Anschutz Medical Campus to design an Environmental and Health Monitoring Study (EHMS) to begin to gather this information. (EHMS Scope of Work: Appendix A). This EHMS Design presents five study designs with the purpose of (1) filling information gaps identified in the Battlement Mesa Health Impact Assessment (HIA)[1]; (2) monitoring the environment in Battlement Mesa throughout Antero Resource's NGD project; and (3) monitoring the health of Battlement Mesa residents and the Battlement Mesa community throughout Antero Resource's NGD project. While these designs were motivated by proposed activities in Battlement Mesa, they also may be applied to other NGD areas in Garfield County.

1.1 Information Gaps

Garfield County's significant efforts to monitor ambient air in NGD areas and to measure air pollutants associated with drilling and completion are important first steps in understanding environmental and health impacts of NGD. While these efforts are important, the following information gaps remain, as identified in the HIA:[1]

- We don't know all chemicals emitted during NGD or used by the industry.
    - We need to know about the chemicals being used and emitted in order to predict health effects and know how to respond in an emergency.
- We don't know all the know sources of emissions to air, water, and soil in NGD.
    - We need to know the sources of emissions in order to engineer better pollution prevention methods and to understand short- and long-term exposures. We need to know when water is contaminated.
- We don't know the levels of chemicals people are exposed to.
    - We need to know exposure levels in order to know what kinds of health effects to expect and if there would be short term or long term health effects. We need to know exposure levels to know if mitigation is needed. We need to determine safe setbacks.
- We don't have physical or mental health tracking data.
    - We need to have health tracking data to follow health trends over time.
- We don't have community health measures.

  - We need community health measures to monitor community well-being.

- We don't know the full health impact of cumulative air pollution from the sum of natural gas development and production activities in the region.

  - We need to know if declining ambient air quality is having adverse effects on Garfield County residents.

1.2 Study Designs

To fill these information gaps, the HIA[1] recommended further investigation to document environmental exposures and subsequent health effects of the NGD project through implementation of an EHMS. Here we present the following five study designs, each of which is a component of the larger EHMS Design:

1. Air, Water, and Soil Monitoring Study designed to monitor the levels of pollutants released to air, water, and soil throughout the well development and production process.
2. Characterization of Air Emissions Study designed to assess the hazardous air pollutants (HAPs) emitted from NGD activities and their impact on human health
3. Dispersion of Air Emissions Study designed to assess the degree and extent of HAPs emitted from NGD activities and their impact on human health.
4. Medical Monitoring Study designed to track physical and mental health trends over time and to identify health effects of NGD in Battlement Mesa.
5. Community Monitoring Study designed to track ongoing community health status and identify community effects of NGD.

The "Air, Water, and Soil Monitoring Study" (number 1) is designed to be conducted independently. The "Characterization of Air Emission Study" and the "Dispersion of Air Emissions Study" (numbers 2 and 3) are designed to be conducted together because the Dispersion of Emissions Study" relies on information from the "Characterization of Air Emission Study". In addition, conducting these studies together will allow for significant cost savings in sampling and field efforts. The "Medical Monitoring Study" and "Community Monitoring Study" (numbers 4 and 5) are designed to be conducted together because the survey presented in the "Medical Monitoring Study is designed to collect information for both. Conducting one survey for both studies will realize significant cost savings.

Many of the components for the "Characterization of Air Emissions Study" and the "Dispersion of Air Emissions Study" were in included in a proposal that the CSPH prepared with the Garfield County Department of Public Health (GCPH) and the Colorado Department of Public Health and Environment (CDPHE) and submitted to the United States Environmental Protection Agency (EPA) in May of 2011. Appendix B contains the proposal as submitted.

1.3 References

[1] Witter, R., L. McKenzie, et al. *Draft health impact assessment for battlement mesa, Garfield County, Colorado*. 2011.

2.0 Air, Water, and Soil Monitoring: Study Design 1

The purpose of the "Air, Water, and Soil Monitoring Study " is to monitor the levels of pollutants released to air, water, and soil throughout the well development and production process.

Systematic and sufficient monitoring of air emissions in NGD areas is needed to fill gaps in knowledge regarding cumulative emissions throughout the lifetime of NGD activities. Cumulative emissions from individual wells have health implications for residents living near wells, while cumulative emissions from thousands of wells have implications for the health of the general population in a NGD area. In addition, this monitoring is necessary to ensure that Garfield County is in compliance with National Ambient Air Quality Standards (NAAQS) and that there is not an immediate threat to the health of residents. It is important to note that the NAAQS are for six criteria pollutants (nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone, carbon monoxide, particulate pollution (PM_{10}, $PM_{2.5}$), and lead)[1] and the EPA lists 187 additional chemicals as HAPs, with potential to harm public health[2]. Therefore, protection of public health involves active endeavors to reduce emissions of HAPs to the lowest possible levels as well as compliance with NAAQS.

Systematic and sufficient monitoring of potential drinking water sources, both groundwater and surface water, for pollutants associated with NGD is needed to determine if water is contaminated by NGD activities, which include but are not limited to drilling, hydraulic fracturing, tanks on the well pads, pipelines, and storage pits or tanks at centralized exploration and production (E&P) waste management facilities. Systematic sampling of water sources prior to any well development activities is necessary for establishment of baseline water quality and pollutant levels.[3,4] Sampling throughout the development activities is needed to monitor water quality and to determine if and when contamination occurs. Sampling must include industrial chemicals known to be used at the sites (well pads and centralized E&P waste management facility) and chemicals associated with the resource as well as standard water quality parameters.

In addition, it is necessary to determine whether or not soil has been contaminated before a well pad or centralized E&P waste management facility can be closed and reclaimed for residential, recreational, or agricultural use. Baseline sampling would be needed to determine if NGD activities were responsible for any contamination discovered or if the contamination was historical.

An on-going air, water, and soil monitoring study will provide the information necessary to determine if NGD pollution control measures are effective and if NGD activities have or have not contaminated air, water, and/or soil quality at levels that may affect health. The number of sites (i.e., 9 well pads and 1 centralized E&P waste management facility) presented in this study design are specific to Antero Resource's proposed NGD in Battlement Mesa. If this design were to be applied to another NGD project elsewhere in the county, sites would need to selected based on the specific project and the numbers revised accordingly.

2.1 Specific Aims and Objectives

This study aims to build on data from on-going ambient air monitoring studies in Garfield County; collect new data to address gaps in the ambient air monitoring studies; and address water and soil monitoring at NGD well sites. The specific objective of this study are to (1)

establish baseline levels of ambient air, water, and soil quality for which to compare the effect of pollution reduction measures and long-term monitoring; (2) monitor ambient air quality throughout the NGD project to determine if air pollution reduction measures are effective in maintaining pollution levels below baseline levels and NAAQS; (3) monitor localized air quality at the perimeter of individual well sites during well completion activities and high emission production and maintenance activities (such as re-stimulation of wells, maintenance of gathering lines, and venting/emptying condensate tanks) to determine if localized air emissions pose an immediate health threat to nearby residents; (4) monitor groundwater quality throughout the NGD project to determine if pollution prevention measures are effective and for early detection of groundwater contamination; (5) monitor surface water quality throughout the NGD project to determine if pollution prevention measures are effective and for early detection of surface water contamination; and (6) confirm soil quality at well sites and water treatment facility prior to closing of sites to determine if pollution prevention measures are effective and to ensure remediation, if necessary, of sites prior to closing.

2.2 Technical Approach

The specific objectives presented in Section 2.1 will be met as described in the following sections.

2.2.1 Ambient Air Quality Monitoring

Currently, GCPH collects 24-hour integrated ambient air samples every 6-days for analyses of speciated non-methane organic compounds (SNMOCs) by EPA's compendium method TO-12 and every 12-days for carbonyls by EPA's compendium method TO-11a from a the roof of the centrally located fire station in Battlement Mesa[5]. In addition, GCPH also collects meteorological data (wind direction and speed, temperature, relative humidity, and precipitation) at this location. To meet the objectives listed in Section 2.1, this design adds the collection of the following samples for comprehensive monitoring that addresses the range of air pollutants that could be associated with NGD:

- 24-hour integrated samples for analysis of polycyclic aromatic hydrocarbons (PAHs) by EPA compendium method TO-13[6] every 12 days
- Real-time monitoring of aromatic volatile organic compounds (VOCs), PM_{10}, $PM_{2.5}$, nitrogen oxides (NOx,) and ozone
- Sampling for any additional air pollutants identified to be of concern in the characterization study (see Section 3)
- A log of activities occurring at the fire house (e.g., idling trucks) to the current monitoring.

This monitoring should be conducted beginning one year prior to the NGD project to establish baseline conditions for ambient air and continue throughout the NGD project (i.e. 30 years). Expanded ambient air monitoring also will address some of the information gaps regarding cumulative impacts to ambient air quality caused by the sum of NGD in the region. Table 2-1 summarizes the ambient air quality monitoring design.

2.2.2 Localized Air Quality

To meet the objectives listed in Section 2.1, this design includes the following:

- Real-time hourly monitoring for aromatic VOCs and odors, at four locations along the perimeter of the well pad ((1) the predominant downwind direction, (2) the truck access direction, and (3) the next two dominant downwind directions)
- Odor monitoring and collection of samples during drilling and well completions
- Collection of meteorological data (wind direction and speed, temperature, relative humidity, and precipitation) at each well pad

The monitoring will begin with baseline sampling to be done before any development activity takes place and then when drilling begins and continue until all hydraulic fracturing and flow back operations have been completed, the wells are installed and tanks associated with these activities are removed from the well pad site. Odor monitoring will be conducted per CDPHE's Air Control Emission's Regulation 2[7] by an individual selected using a "detectability rating test" as outlined in "Selection and Training of Judges for Sensory Evaluation of the Intensity and Character of Diesel Exhaust Odors.".[8] In addition, this monitoring will also be conducted during high emission production and maintenance activities (such as re-stimulation of wells, maintenance of gathering lines, and venting/emptying condensate tanks).

Grab samples will be collected for expedited analysis of VOCs by EPA method TO-15[9] and carbonyls by EPA method TO-11a[10] if odors are detected in odorous air diluted by seven volumes of odor free air or if real-time aromatic VOC measurements exceed ambient air upper tolerance limits (UTLs) established in the baseline sampling. Table 2-2 summarizes the localized air quality design.

2.2.3 Groundwater Quality

To meet the objectives listed in Section 2.1, this design includes the following:

- Installation of one up-gradient and two down-gradient groundwater monitoring wells at each of the nine well pads as well as at the centralized E&P waste management facility, based on hydrology information obtained prior to installation of the centralized E&P waste management facility
- Baseline sampling
- Monthly sampling during drilling and well completions (approximately one year for each well pad)
- Annual monitoring for the duration of operations at each pad and at the centralized E&P waste management facility (30 years)

All the samples listed above will be analyzed for major cations, metals, major anions, alkalinity total dissolved solids, BTEX, methane, pH, specific conductance, and any chemical identified from the full disclosure of chemicals to be of potential concern to groundwater. Table 2-3 summarizes the groundwater quality monitoring design.

2.2.4 Surface Water Quality

To meet the objectives listed in Section 2.1, this design includes the following:

- Baseline sampling of any surface water bodies (including intermittent streams and irrigation ditches) that are located within ½ mile of a well pad or the centralized E&P waste management site.
- Monthly sampling at a location closest to the well pad during drilling and well completions (approximately one year)
- Annual sampling for the duration of operations at each pad and at the centralized E&P waste management facility (30 years).

All of the samples listed above will be analyzed for major cations, metals, major anions, alkalinity total dissolved solids, BTEX, methane, pH, specific conductance, and any chemical identified from the full disclosure of chemicals to be of potential concern to surface water . If no surface water is located within ½ mile, surface water sampling will not be conducted. Intermittent streams and irrigation ditches will be regularly monitored for the presence of surface water and sampling will only be conducted when surface water is present. Table 2-4 summarizes the surface water quality monitoring design.

2.2.5 Soil Quality

To meet the objectives listed in Section 2.1, this design includes the following:

- Baseline collection of 20 samples of surface soil at 0-2 feet below ground surface and 20 samples of subsurface soil at 2 to 10 feet below ground surface from each well pad site and the centralized E&P waste management facility
- Site-closure collection of 20 samples of surface soil at 0-2 feet below ground surface and 20 samples of subsurface soil at 2 to 10 feet below ground surface from each well pad site and the centralized E&P waste management facility

All of the samples listed above will be analyzed for major cations, metals, major anions, total petroleum hydrocarbons (TPH) BTEX, PAHs, pH, and any chemical identified from the full disclosure of chemicals to be of potential concern to soil . Sample locations will be determined using a randomized sampling scheme. Samples also will be collected from any visibly stained areas. Table 2-5 summarizes the soil quality monitoring design.

2.2.6 Quality Assurance/Quality Control

Prior to sample collection, a quality assurance project plan (QAPP) will be prepared per EPA QA/R5.[11] The QAPP will ensure sample collection and analyses methods provide data that is appropriate to support the project objectives. All team members and the subcontracted analytical laboratory(s) will be provided with a copy of the QAPP. For evaluation of precision and accuracy, field duplicates, equipment blanks, and trip blanks samples will be collected at a rate of 5%.

2.3 Data Analysis

Data analysis will begin with data validation for precision, accuracy, representativeness, comparability, completeness, and sensitivity (PARCCS) through evaluation of field duplicates,

blanks, chain-of-custody records, sample receipt records, and sample quantification limits. This will be followed by a statistical evaluation of the data using EPA's ProUCL software and SAS. EPA's ProUCL software will be used to calculate 95% upper tolerance limits (UTLs) from the baseline data.[12] Air UTLs will be calculated from one year of samples collected prior to the beginning of the project. Groundwater UTLs will be calculated from all the baseline samples (all up gradient and all down gradient wells for the nine pads and the centralized E&P waste management facility – 30 samples). Soil UTLs will be calculated for each well pad, as well as the centralized fluids and waste management site using data from the baseline samples. UTLs for surface water will be approximated for each surface water body by multiplying the results from the one baseline sample by 1.25.

Monitoring results will be compared to the UTLs. If any pollutant level is greater than the UTL, further evaluations will be performed to determine if contamination has occurred and if there may be threat to the public health or the groundwater resource. Further evaluations may include additional sampling, additional statistical comparisons, source delineation, trend analysis, transport modeling, comparison to federal and state standards comparison to EPA risk screening levels, and risk assessments. Pollutant levels less than the UTL will indicate contamination has not occurred. This type of monitoring is the best way to ensure pollution control measures are effective in preventing contamination of the air, groundwater, surface water, and soil resources.

2.4 Data Management

The analytical laboratories will provide data in Excel files. After completion of the data validation, all air, groundwater, surface water, and soil monitoring results in the Excel files will be loaded into a database on the Garfield County web site. The database will have an interface that will allow the public to find results by both matrix and location. The database will contain baseline UTLs, current federal and state standards, and current EPA risk screening levels. Real-time aromatic VOC and ozone sampling results will be broadcast on the Garfield County web site, as is done at the Rifle ambient air monitoring station.

2.5 Expected Outputs

This design will produce the following outputs that will be published on the Garfield County web site:

- QAPP
- Annual PARCC summary reports
- Baseline UTLs for air, groundwater, surface water, and soil
- Monthly progress reports during well drilling and completion phase of project summarizing localized air quality for residents near wells and providing comparisons to UTLs
- Annual reports that summarize air, groundwater, surface water, and soil quality, provide comparisons to UTLs, and provide further evaluation as necessary

2.6 References

[1]United States House of Representatives. *Clean Air Act*. United States Code, Title 42, Chapter 85. 2009.
[2]US Environmental Protection Agency. *National Emissions Inventory Emissions Inventory Implementation Plan*. 2008.
[3]US DOE. Secretary of Energy Advisory Board. Shale Gas Production Subcommittee. *Ninety Day Report.* August 11, 2011.
[4]US DOE. Secretary of Energy Advisory Board. Shale Gas Production Subcommittee. *Second Ninety Day Report.* November 18, 2011.
[5]Air Resources Specialists Inc. *Quality Assurance Project Plan for Garfield County Volatile Organic Compounds Monitoring Program*. Prepared for Garfield County Commissioners and the Colorado Department of Public Health and Environment. 2011.
[6]US EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Air Second Edition. *Compendium Method TO-13A – Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)*. Center for Environmental Research Information. Office of Research and Development. 1999.
[7]Coloroado Department of Public Health and Environment Air Quality Control Commission *Regulation Number 2 Odor Emission*. 5CCR 1001-4.
[8] USPHS Pub. #999-AP-32.
[9]US EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Air Second Edition. *Compendium Method TO-15 – Determination Volatile Organic Compounds (VOCs) in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)*. Center for Environmental Research Information. Office of Research and Development. 1999.
[10]US EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Air Second Edition. *Compendium Method TO-11A – Determination of Formaldehyde in Ambient Air Using Absorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC)*. Center for Environmental Research Information. Office of Research and Development. 1999.
[11]US EPA. *EPA Requirements for Quality Assurance Project Plans. EPA QA/R5*. Office of Environmental Information. EPA/240/B-01/003. 2001.
[12]US EPA. *ProUCL Version 4.00.05 Technical Guide (Draft).* EPA/600/R-07/041. 2010.

Table 2-1. Ambient Air Monitoring Design Sampling and Analyses

Air Pollutant	**Method**	**Type of Sample**	**Frequency of sampling**	**Number of Samples[1]**
SNMOCs (includes BTEX)	TO-12	24-hour integrated	Every 6 days	1984 (64/year)
Carbonyls (includes aldehydes)	TO-11a	24-hour integrated	Every 12 days	1024 (32/year)
PAHs	TO-13A	24-hour integrated	Every 12 days	1024 (32/year)
Aromatic VOCs	PID	Real-time	Hourly	NA
PM10	TEOM	Real-time	Hourly	NA
PM2.5	TEOM	Real-time	Hourly	NA
NOx	EPA 7E	Real-time	Hourly	NA
O3	EPA 42C	Real-time	Hourly	NA
Meteorological data (wind direction and speed, temperature, relative humidity, and precipitation)	Various	Real-time	Hourly	NA
Air pollutant identified in Characterization study	TBD	TBD	TBD	TBD

NA = not applicable; PID = photo ionization detector; TBD = To be determined based on results of characterization study; TEOM = Tapered element oscillating microbalance
Italics indicate parameters that are currently collected at the Battlement Mesa fire station.
[1]Includes field duplicates at a rate of 5%, based on 31 years (one year of baseline and 30 years for NGD project).

Table 2-2. Localized Air Monitoring Design Sampling and Analysis

Air Pollutant	**Method**	**Type of Sample**	**Frequency of sampling**	**Number of Samples/Locations**
Aromatic VOCs	PID	Real-time	Hourly	NA
Odors	5 CCR 1001-4[2]	Real-time	Hourly	NA
VOCs (includes BTEX)	TO-15	grab	When real-time VOC > UTL	90 (10 per pad)[1]
Carbonyls	TO-11a	Grab	When real-time VOC > UTL	90 (10 per pad)[1]
Meteorological data (wind direction and speed, temperature, relative humidity, and precipitation)	Various	Real-time	Hourly	NA

BTEX = benzene, toluene, ethylbenzene, and xylenes; NA = not applicable; PID = photoionization detector; UTL = upper tolerance limit; VOC = volatile organic compound;
[1]Assumes 10 grab samples will be collected at each well pad. Actual numbers may be more or less.
[2]Coloroado Department of Public Health and Environment Air Quality Control Commission Regulation Number 2 Odor Emission. 5CCR 1001-4

Table 2-3. Groundwater Monitoring Design Sampling and Analyses

Water Pollutant	**Method**	**Type of Sample**	**Total Number of Samples[3]**
Baseline – Once-[4---]			
BTEX	SW8260B	Grab	37 (3 per site)[4]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Grab	34 (3 per site)[4]
Anions[2]	SW9056A	Grab	34 (3 per site)[4]
Alkalinity	SM 2320	Grab	34 (3 per site)[4]
Total dissolved solids	EPA 160.1	Grab	34 (3 per site)[4]
Methane	RSK 175	Grab	34 (3 per site)[4]
pH	SW9041	Real-time	34 (3 per site)[4]
Specific Conductance	SW9050A	Real-time	34 (3 per site)[4]
Chemicals identified from chemical disclosure	TBD	Grab	34 (3 per site)[4]
Drilling and Completion – Monthly[5]			
BTEX	SW8260B	Grab	426 (36 per site)[5]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Grab	396 (36 per site)[5]
Anions[2]	SW9056A	Grab	396 (36 per site)[5]
Alkalinity	SM 2320	Grab	396 (36 per site)[5]
Total dissolved solids	EPA 160.1	Grab	396 (36 per site)[5]
Methane	RSK 175	Grab	396 (36 per site)[5]
pH	SW9041	Real-time	396 (36 per site)[5]
Specific Conductance	SW9050A	Real-time	396 (36 per site)[5]
Chemicals identified from chemical disclosure	TBD	Grab	396 (36 per site)[5]
Production – Annually[6]			
BTEX	SW8260B	Grab	1110 (90 per site)[6]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Grab	1020 (90 per site)[6]
Anions[2]	SW9056A	Grab	1020 (90 per site)[6]
Alkalinity	SM 2320	Grab	1020 (90 per site)[6]
Total dissolved solids	EPA 160.1	Grab	1020 (90 per site)[6]
Methane	RSK 175	Grab	1020 (90 per site)[6]
pH	SW9041	Real-time	1020 (90 per site)[6]
Specific Conductance	SW9050A	Real-time	1020 ((90 per site)[6]
Chemicals identified from chemical disclosure	TBD	Grab	1020 ((90 per site)[6]

BTEX = benzene, toluene, ethylbenzene, and xylenes; QC = Quality Control; TBD: To be determined

[1] calcium, magnesium, potassium, sodium, aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, zinc

[2] chloride, sulfate, nitrate plus nitrite

[3] includes collection of field duplicates and equipment blanks at the rate of 5% and trip blanks for BTEX of one per shipment.

[4] 3 samples per site * 10 sites (9 pads + 1centralized management facility) + QC samples

[5] 3 samples per site * 9 sites * 12 months) + QC samples

[6] 3 samples * 10 sites (9 pads and 1 centralized management facility) * 30 years) + QC samples

Table 2-4. Surface Water Monitoring Design Sampling and Analyses

Water Pollutant	**Method**	**Type of Sample**	**Total Number of Samples[3]**
Baseline – Once[4]			
BTEX	SW8260B	Grab	12 (one per site)[4]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Grab	11 (one per site)[4]
Anions[2]	SW9056A	Grab	11 (one per site)[4]
Alkalinity	SM 2320	Grab	11 (one per site)[4]
Total dissolved solids	EPA 160.1	Grab	11 (one per site)[4]
Methane	RSK 175	Grab	11 (one per site)[4]
pH	SW9041	Real-time	11 (one per site)[4]
Specific Conductance	SW9050A	Real-time	11 (one per site)[4]
Chemicals identified from chemical disclosure	TBD	Grab	11 (one per site)[4]
Drilling and Completion – Monthly[5]			
BTEX	SW8260B	Grab	144 (12 per site)[5]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Grab	132 (12 per site)[5]
Anions[2]	SW9056A	Grab	132 (12 per site)[5]
Alkalinity	SM 2320	Grab	132 (12 per site)[5]
Total dissolved solids	EPA 160.1	Grab	132 (12 per site)[5]
Methane	RSK 175	Grab	132 (12 per site)[5]
pH	SW9041	Real-time	132 (12 per site)[5]
Specific Conductance	SW9050A	Real-time	132 (12 per site)[5]
Chemicals identified from chemical disclosure	TBD	Grab	132 (12 per site)[5]
Production – Annually[6]			
BTEX	SW8260B	Grab	360 (30 per site)[6]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Grab	330 (30 per site)[6]
Anions[2]	SW9056A	Grab	330 (30 per site)[6]
Alkalinity	SM 2320	Grab	330 (30 per site)[6]
Total dissolved solids	EPA 160.1	Grab	330 (30 per site)[6]
Methane	RSK 175	Grab	330 (30 per site)[6]
pH	SW9041	Real-time	330 (30 per site)[6]
Specific Conductance	SW9050A	Real-time	330 (30 per site)[6]
Chemicals identified from chemical disclosure	TBD	Grab	330 (30 per site)[6]

BTEX = benzene, toluene, ethylbenzene, and xylenes; QC = quality control; TBD: To be determined

[1] calcium, magnesium, potassium, sodium, aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, zinc

[2] chloride, sulfate, nitrate plus nitrite

[3] includes collection of field duplicates and equipment blanks at the rate of 5% and trip blanks for BTEX of one per shipment. Assumes one surface water body per well pad and one surface water body at centralized water treatment facility

[4] 1 sample per site * 10 sites (9 pads + 1 centralized management facility) + QC samples

[5] 1sample per site * 9 sites (9 pads) * 12 months) + QC samples

[6] 1 samples per site * 10 sites (9 pads and 1 centralized management facility) * 30 years) + QC samples

Table 2-5. Soil Monitoring Design Sampling and Analyses

Soil Pollutant	Method	Type of Sample	Total Number of Samples[4]
Baseline –0-2 feet and 2-10 feet below ground surface – Once[5]			
BTEX	SW8260B	Composite	480 (40 per site)[5]
TPH	SW8015	Composite	440 (40 per site)[5]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Composite	440 (40 per site)[5]
Anions[2]	SW9056A	Composite	440 (40 per site)[5]
Total petroleum hydrocarbons	SW8015B	Composite	440 (40 per site)[5]
PAHs	SW8270D	Composite	440 (40 per site)[5]
pH	SW9045	Composite	440 (40 per site)[5]
Chemicals identified from chemical disclosure	TBD	Composite	440 (40 per site)[5]
Site Closure – 0-2 feet and 2-10 feet below ground surface – Once[5]			
BTEX	SW8260B	Composite	480 (40 per site)[5]
TPH	SW8015	Composite	440 (40 per site)[5]
Major cations and metals[1]	SW6010C/ 6020A/ 7000 series	Composite	440 (40 per site)[5]
Anions[2]	SW9056A	Composite	440 (40 per site)[5]
Total petroleum hydrocarbons	SW8015B	Composite	440 (40 per site)[5]
PAHs[3]	SW8270D	Composite	440 (40 per site)[5]
pH	SW9045	Composite	440 (40 per site)[5]
Chemicals identified from chemical disclosure	TBD	Composite	440 (40 per site)[5]

BTEX = benzene, toluene, ethylbenzene, and xylenes; PAH = polycyclic aromatic hydrocarbon; TBD: To be determined; TPH = total petroleum hydrocarbons

[1] calcium, magnesium, potassium, sodium, aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, zinc

[2] chloride, sulfate, nitrate plus nitrite

[3] Acenaphthene, anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluroanthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorine, indeno(1,2,3-cd)pyrene, naphthalene, pyrene

[4] includes collection of field duplicates and equipment blanks at the rate of 5% and trip blanks for BTEX of one per shipment.

TBD: To be determined based on review of chemical disclosure

[5] 20 surface and 20 subsurface samples/ pad * 9 well pads and 1 centralized management facility

3.0 Characterization of Air Emissions: Study Design 2

The purpose of the "Characterization of Air Emissions Study" is to better assess the HAPs emitted from NGD activities and their impact on human health. The characterization of air emissions study design addresses two of the information gaps identified in the HIA[1]: (1) we don't know all chemicals emitted during NGD or used by the industry; and (2) we don't know all the know sources of emissions to air in the NGD area. Many components of this study design were submitted as a proposal to EPA in May 2011 (Appendix B).

As evidenced by ambient air studies in Garfield County, NGD activities emit several HAPs, including benzene, toluene, ethylbenzene, and xylenes (BTEX). BTEX measurements from Garfield County's 2009 ambient air study were compared to regional measurements from 37 sites across the US. Levels of benzene, toluene, and xylenes at three out of four sites in Garfield County were higher than levels measured at most of the other sites.[2] The CDPHE's 2007 emissions inventory for Garfield County indicates that the oil and gas industry is the primary contributor to benzene.[3]

The 2008 Garfield County Air Toxics Study, which monitored four sites each undergoing drilling activities and well completion activities, concluded that the well completion activities emit larger volumes of volatile organic compounds (VOCs) than drilling activities. The report indicated that the high concentrations of VOCs could be of great concern, as many of the well pads are located close to populated areas in Garfield County. In addition, the report indicated local wind speeds, directions and surrounding topography were important factors in influencing levels of pollutants at any one sampling site and that these factors varied greatly from site to site.[4]

Ozone levels in Garfield County appear to be related to ozone precursor pollutant emissions from NGD activities. CPDHE's 2007 emission inventory for Garfield County indicates that the NGD industry is the primary contributor to NO_x emissions as well as the primary non-biogenic contributor of VOC, as noted above.[3] Garfield County's 2009 Air Quality Monitoring Summary Report attributes NGD activities as the largest contributing source of ozone precursors, such as light alkanes.[2] In 2008, the 8-hr average ozone concentrations measured at Garfield County's monitoring station in Rifle, CO surpassed the 75 parts per billion (ppb) NAAQS on one day and the proposed 60 -70 ppb NAAQS on five days in March and April 2009.[2]

The Agency for Toxic Substances and Disease Registry's (ATSDR) 2008 Health Consultation for Garfield County concluded that that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing cancer, chronic non-cancer health effects, and acute non-cancer health effects.[5]

While there are data on some HAPs in Garfield County's ambient air, there is little data suitable for characterizing the NGD sources. This type of data is needed to determine pollutants and levels emitted during NGD. The screening level HHRAs, HIA, and ATSDR Health Assessment for Garfield County all identified lack of data on emissions during specific stages of well development activities and lack of emission factors from NGD as key gaps to better understanding of health effects from HAP exposures. The 2008 Air Toxics Study concluded that additional research is needed to understand the local effects that drilling and completion activities can have on the public at large.

3.1 Specific Aims and Objectives

This study aims to build on data from previous and on-going ambient air monitoring studies in Garfield County and collect new data to address gaps identified in previous studies. The specific objectives of this study are to: (1) characterize near-source pollutant concentrations from NGD activities, including drilling, well completions, and production; (2) provide data to investigate the relationship between HAPs and health impacts; and (3) provide a baseline for which to compare the effect of pollution reduction measures at various stages of well development.

3.2 Technical Approach

To meet the objectives listed in Section 3.1, this design will:

- Characterize sources specific to each emission stage of NGD development activities (i.e., drilling, well completion transitions, hydraulic fracturing, flowback, and production)
- Develop emission factors specific to each emission stage of NGD development activities (i.e., drilling, well completion transitions, hydraulic fracturing, flowback, production)

Concentrations of HAPs adjacent to three well pads will be directly measured to capture operator, terrain, and seasonal variability in emissions. At each pad, emission data for HAPs from four directions: (1) the predominant downwind direction, (2) the truck access direction, and (3) the next two dominant downwind directions will be collected, as well as meteorological data (wind direction and speed, temperature, relative humidity, and precipitation). To characterize each well source profile, emissions in these four directions at 150 feet from the well head will be directly measured for 3 days each during drilling, hydraulic fracturing and flowback; and 2 days during well completion transitions (11 days each pad). When the well is turned to production, emissions in the four directions will be directly measured quarterly over 1 year of production per pad (4 days). Sample collection will include integrated 24-hour samples for determination of HAPs by EPA's compendium methods TO-15 for volatile organic compounds (VOCs)[6], TO-11a for carbonyls[7], and TO-13a for PAHs[8], as well as real-time monitoring of PM_{10}, $PM_{2.5}$, and NO_x,. In addition, samples will be collected for analysis of any other pollutants, such as gluteraldehyde, that are identified to be of concern in the chemical disclosure.

Currently, GCPH collects ambient air samples every 6-days for SNMOCs by EPA's compendium method TO-12 and every 12-days for carbonyls EPA's compendium method TO-11A from the roof of the fire station in Battlement Mesa[9]. The SNMOCs, which include HAPs most likely to be associated with the natural gas resource, are on the method TO-15 target analyte list. Therefore, study results would be comparable to results from GCPH ambient air monitoring program. A fixed location from a similar rural residential area located outside the NGD area will be selected as a background location. Background samples will be collected with the well completion samples (24 days) and analyzed for the same parameters as for the source characterization. Table 3-1 summarizes the characterization of air emissions study design.

3.2.1 Quality Assurance/Quality Control

Prior to sample collection, a QAPP will be prepared per EPA QA/R5.[10] The QAPP will ensure sample collection and analyses methods provide data that is appropriate to support our project objectives. All team members and the subcontracted analytical laboratory(s) will be

provided with a copy of the QAPP. For evaluation of precision and accuracy, field duplicates, equipment blanks, and trip blanks samples will be collected at a rate of 5%.

3.3 Data Analysis

Data analysis will begin with data validation for PARCCS through evaluation of field duplicates, blanks, chain-of-custody records, sample receipt records, and sample quantification limits. This will be followed by a statistical evaluation of the data using EPA's ProUCL[11] software and SAS.

Results from the samples collected at 150 feet will be compared to results from the ambient air samples collected at the fixed monitoring station and background location using ProUCL to identify emissions of HAPs associated with drilling, each of the three stages of well completions, and production. Emission factors will be calculated in mass of pollutant per day of activity for these HAPs for drilling, completion transitions, hydraulic fracturing, flowback, and production. Emissions of HAPs also will be compared to available data on gas and condensate composition and diesel emissions, as well as chemical compositions of materials used in the well completions, such as hydraulic fracturing fluids.

3.4 Data Management

The analytical laboratories will provide data in Excel files. After completion of the data validation, all air emission results in the Excel files will be loaded into a database on the Garfield County web site. The database will have an interface that will allow the public to find results by both matrix and location. The database will contain current federal and state standards, and current EPA risk screening levels.

3.5 Expected Outputs

This design will produce the following outputs that will be published on the Garfield County web site:

- QAPP
- Annual PARCC summary reports
- Reports addressing HAP emissions associated with NGD, emission factors, and background comparisons

3.6 References

[1]Witter, R., L. McKenzie, et al. *Draft health impact assessment for battlement mesa, Garfield County, Colorado*. 2011.
[2]Garfield County Public Health Department (GCPH). *Garfield County 2009 Air Quality Monitoring Summary Report*. 2010.
[3]CDPHE Air Pollution Control Division. *Garfield County 2007 Emissions Inventory.* 2009.
[4] CDPHE Air Pollution Control Division. *Analysis of Data Obtained for the Garfield County Air Toxics Study Summer 2008*, 2009.
[5]ATSDR *Health Consultation: Public Health Implications of Ambient Air Exposures to Volatile Organic Compounds as Measured in Rural, Urban, and Oil & Gas Development Areas, an Analysis of 2008 Air Sampling Data Garfield County*, Colorado. 2010.
[6]US EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Air Second Edition. *Compendium Method TO-15 – Determination Volatile Organic Compounds (VOCs) in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)*. Center for Environmental Research Information. Office of Research and Development. 1999.
[7]US EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Air Second Edition. *Compendium Method TO-11A – Determination of Formaldehyde in Ambient Air Using Absorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC)*. Center for Environmental Research Information. Office of Research and Development. 1999.
[8]US EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Air Second Edition. *Compendium Method TO-13A – Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Ambient Air Using Gas Chromatography/Mass Spectrometry (GC/MS)*. Center for Environmental Research Information. Office of Research and Development. 1999.
[9]Air Resources Specialists Inc. *Quality Assurance Project Plan for Garfield County Volatile Organic Compounds Monitoring Program*. Prepared for Garfield County Commissioners and the Colorado Department of Public Health and Environment. 2011.
[10]US EPA. *EPA Requirements for Quality Assurance Project Plans. EPA QA/R5*. Office of Environmental Information. EPA/240/B-01/003. 2001.
[11]US EPA. *ProUCL Version 4.00.05 Technical Guide (Draft).* EPA/600/R-07/041. 2010.

Table 3-1 Characterization of Air Emissions Study Design Sampling and Analyses

Air Pollutant	**Method**	**Type of Sample**	**Frequency of sampling**	**Number of Samples[1]**
Drilling[2]				
VOCs (includes BTEX)	TO-15	24-hour integrated	3 days	44 (12 per site)[2]
Carbonyls (includes aldehydes)	TO-11a	24-hour integrated	3 days	40 (12 per site)[2]
PAHs	TO-13A	24-hour integrated	3 days	40 (12 per site)[2]
PM_{10}	TEOM	Real-time	Hourly	NA
$PM_{2.5}$	TEOM	Real-time	Hourly	NA
NO_x	EPA 7E	Real-time	Hourly	NA
Meteorological data (wind direction and speed, temperature, relative humidity, and precipitation)	Various	Real-time	Hourly	NA
Air pollutant identified in Characterization study	TBD	TBD	TBD	TBD
Well Completions (*hydraulic fracturing, flowback, and transitions)*[3]				
VOCs (includes BTEX)	TO-15	24-hour integrated	8 days	106 (32 per site)
Carbonyls (includes aldehydes)	TO-11a	24-hour integrated	8 days	106 (32 per site)
PAHs	TO-13A	24-hour integrated	8 days	106 (32 per site)
PM_{10}	TEOM	Real-time	Hourly	NA
$PM_{2.5}$	TEOM	Real-time	Hourly	NA
NO_x	EPA 7E	Real-time	Hourly	NA
Meteorological data (wind direction and speed, temperature, relative humidity, and precipitation)	Various	Real-time	Hourly	NA
Air pollutant identified in chemical disclosure	TBD	TBD	TBD	TBD

Table 3-1 continued

Air Pollutant	**Method**	**Type of Sample**	**Frequency of sampling**	**Number of Samples[1]**
Production[4]				
VOCs (includes BTEX)	TO-15	24-hour integrated	4 days	53 (16 per site)[4]
Carbonyls (includes aldehydes)	TO-11a	24-hour integrated	4 days	53 (16 per site)[4]
PAHs	TO-13A	24-hour integrated	4 days	53 (16 per site)[4]
PM_{10}	TEOM	Real-time	Hourly	NA
$PM_{2.5}$	TEOM	Real-time	Hourly	NA
NO_x	EPA 7E	Real-time	Hourly	NA
Meteorological data (wind direction and speed, temperature, relative humidity, and precipitation)	Various	Real-time	Hourly	NA
Air pollutant identified in chemical disclosure	TBD	TBD	TBD	TBD
Background[5]				
VOCs (includes BTEX)	TO-15	24-hour integrated	24 days	28 (9 per site)[5]
Carbonyls (includes aldehydes)	TO-11a	24-hour integrated	24 days	28(9 per site)[5]
PAHs	TO-13A	24-hour integrated	24 days	28(9 per site)[5]
PM_{10}	TEOM	Real-time	Hourly	NA
$PM_{2.5}$	TEOM	Real-time	Hourly	NA
NO_x	EPA 7E	Real-time	Hourly	NA
Meteorological data (wind direction and speed, temperature, relative humidity, and precipitation)	Various	Real-time	Hourly	NA
Air pollutant identified in chemical disclosure	TBD	TBD	TBD	TBD

BTEX = benzene, toluene, ethylbenzene, and xylenes; NA = not applicable; NOx = nitrogen oxides; PAH = polycyclic aromatic hydrocarbon; PM_{10} = particulate matter ≤ 10 microns; $PM_{2.5}$ = particulate matter ≤ 5 microns; QC = Quality Control; TBD = to be determined based on chemical disclosure; TEOM = Tapered element oscillating microbalance; VOCs = volatile organic compounds

Italics indicate components of source characterization included in EPA Proposal (Appendix B).

[1]Includes field duplicates and blanks at a rate of 5%

[2]3 well pads, * 3 days, *4 directions + QC samples

[3]3 well pads * 8 days (3 days hydraulic fracturing, 3 days flowback, and 2 days transitions) * 4 directions each day + QC samples

[4]3 well pads * 4 days *4 directions

[5]3 sites * 9 days

4.0 Dispersion of Air Emissions: Study Design 3

The purpose of the "Dispersion of Air Emissions Study" is to better assess the degree and extent of HAPs emitted from NGD activities and their impact on human health. This study addresses one of the information gaps identified in the HIA[1]: We don't know the levels of pollutants people are exposed to. Most of the components of this study design were submitted as a proposal to EPA in May 2011 (Appendix B).

As evidenced by ambient air studies in Garfield County, NGD activities emit several HAPs, including BTEX. BTEX measurements from Garfield County's 2009 ambient air study were compared to regional measurements from 37 sites across the US.[2] Levels of benzene, toluene, and xylenes at three out of four sites in Garfield County were higher than levels measured at most of the other sites (GCPH 2010). The CDPHE 2007 emissions inventory for Garfield County indicates that the oil and gas industry is the primary contributor to benzene.[3]

The 2008 Garfield County Air Toxics Study indicated that the high concentrations of VOCs could be of great concern, as many of the well pads are located close to populated areas in Garfield County. In addition, the report indicated local wind speeds, directions and surrounding topography were important factors in influencing levels of pollutants at any one sampling site.[4]

CDPHE and CSPH scientists conducted a series of screening level HHRAs using ambient air data collected in the studies described above. Collectively, these risk assessments have identified several HAPs, including BTEX, hexane, 1,3-butadiene, crotonaldehyde, acetaldehyde, and formaldehyde, as chemicals of potential concern in ambient air within Garfield County's NGD area. These HHRAs found cancer risks to typically fall within the 1 and 100 in a million range and chronic non-cancer hazard indices to be less than one (CDPHE 2007, CDPHE 2010, CSPH 2011).[1, 5, 6,] However, the HHRAs indicated that acute and sub-chronic hazard indices exceeding one; therefore, acute and sub-chronic risks may be a concern.

The ATSDR 2008 Health Consultation for Garfield County also concluded that that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing cancer, chronic non-cancer health effects, and acute non-cancer health effects.[7]

While there is data on HAPs in Garfield County's ambient air, there is little data suitable for modeling dispersion of HAPs from NGD sources. This type of data is needed to determine risk of health impacts for residents living in close proximity to NGD activities. The 2008 Air Toxics Study concluded that additional research is needed to understand the local effects that drilling and completion activities can have on the public at large[7].

The health risks from emission sources during many NGD activities are not fully addressed by existing state or federal air rules. The applicable Colorado Oil and Gas Conservation Commission (COGCC) rules specify distances ("set backs") between wells and residences. However, these set backs are primarily based on concerns about safety (e.g., accidents, explosions) during NGD and it is not known if the set back distances protect public health from HAP exposure.[8]

4.1 Specific Aims and Objectives

This study aims to build on data from previous and on-going ambient air monitoring studies in Garfield County, the air emission characterization study, and collect new data to address gaps identified in previous studies. The specific objectives are to: (1) delineate local scale pollutant

concentration gradients in proximity to natural gas well completions; (2) provide data to investigate the relationship between HAPs and health impacts; (3) provide data for estimating health protective set back distances; and (4) evaluate the effectiveness of air quality models in describing dispersion of HAPs from natural gas wells.

4.2 Technical Approach

To meet the objectives listed in Section 4.1 this design will:

- Develop local scale dispersion profiles by measuring concentration gradients of HAPs from well sites to determine concentrations of HAPs at COGCC set-back distances and nearby residential structures.
- Model HAPs dispersion and compare to measurements to evaluate the performance of existing regulatory air models.

4.2.1 Dispersion Profiles

Dispersion profiles for HAPs will be determined with the data from the samples collected at 150 feet in the air emission characterization study and additional integrated 24-hour samples collected in the four directions at 350, 1000, and 2500 feet set backs from the well head during 3-days of flowback operations. These additional 108 samples (3 pads * 3 set backs * 4 directions * 3 days) will be analyzed for VOCs by EPA method TO-15[9]. To augment this data, 27 (3 residences * 3 days * 3 well pads) integrated 24-hour ambient air samples at the nearest three residences downwind of the well pad during flowback operations also will be collected. The meteorological data collected for the air emission characterization study will be applied for the dispersion profiles.

4.2.2 Modeling

Information on emission characteristics (e.g., types and numbers of diesel engines on the well pads and dimensions of flowback and fracturing tanks), chemical composition of condensate and gas (collected by oil and gas operators for permitting), and data from available land use and topographical maps and aerial photographs will be collected. This information, along with the emission factors from the "Air Emission Characterization Study", will be used to build a dispersion-transport model using the EPA recommended steady-state plume AERMOD modeling system (http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod) for describing dispersion of pollutants from surface sources over complex terrain. The dispersion profiles will be used to calibrate the model. The model performance will be tested by comparing modeled results to data collected at residences.

4.2.3 Quality Assurance/Quality Control

Prior to sample collection, a QAPP will be prepared per EPA QA/R5 2001.[10] The QAPP will ensure sample collection and analyses methods provide data that is appropriate to support the project objectives. All team members and the subcontracted analytical laboratory(s) will be provided with a copy of the QAPP. For evaluation of precision and accuracy, field duplicates, equipment blanks, and trip blanks samples will be collected at a rate of 5%.

4.3 Data Analysis Dispersion of Air Emissions Study Design

Data analysis will begin with data validation for PARCCS through evaluation of field duplicates, blanks, chain-of-custody records, sample receipt records, and sample quantification limits. This will be followed by a statistical evaluation of the data using EPA's ProUCL[11] software and SAS.

Dispersion and transport from the well pad will be evaluated using the dispersion profiles from samples collected at 150, 350, 1000, and 2500 feet and meteorological results, as well as data from available land use and topographical maps and aerial photographs. This information, along with the emission factors from the "Air Emissions Characterization Study" will be used to build a dispersion-transport model using AERMOD. The emission profiles will be used to calibrate the model. The model performance will be tested by comparing modeled results to data collected at the residences.

4.4 Data Management

The analytical laboratories will provide data in Excel files. After completion of the data validation, all air emission results in the Excel files will be loaded into a database on the Garfield County web site. The database will have an interface that will allow the public to find results by both matrix and location. The database will contain current federal and state standards, and current EPA risk screening levels.

4.5 Expected Outputs

This design will produce the following outputs that will be published on the Garfield County web site:

- QAPP
- Annual PARCC summary reports
- Model for estimating dispersion of air pollutants from well pads
- Report that summarizes dispersion profiles, model, and potential health risks to residents during well completions

4.6 References

[1]Witter, R., L. McKenzie, et al. *Draft health impact assessment for battlement mesa, Garfield County, Colorado*. 2011.
[2]Garfield County Public Health Department (GCPH). *Garfield County 2009 Air Quality Monitoring Summary Report*. 2010.
[3]CDPHE Air Pollution Control Division. *Garfield County 2007 Emissions Inventory.* 2009.
[4]CDPHE Air Pollution Control Division. *Analysis of Data Obtained for the Garfield County Air Toxics Study Summer 2008*, 2009.
[5]Colorado Department of Public Health and Environment (CDPHE). Environmental Epidemiology Division. *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.
[6]CDPHE Environmental Epidemiology Division *Garfield county air toxics inhalation: screening level human health risk assessment: Inhalation of Volatile Organic Compounds Measured In 2008 Air Quality Monitoring Study*. 2010
[7]ATSDR *Health Consultation: Public Health Implications of Ambient Air Exposures to Volatile Organic Compounds as Measured in Rural, Urban, and Oil & Gas Development Areas, an Analysis of 2008 Air Sampling Data Garfield County*, Colorado. 2010.
[8]Colorado Oil and Gas Conservation Commission (COGCC). *Statement of Basis, Specific Statutory Authority, and Purpose: New Rules and Amendments to Current Rules of the Colorado Oil and Gas Conservation Commission*, 2 CCR 404-1, May 2009.
[9]US EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Air Second Edition. *Compendium Method TO-15 – Determination Volatile Organic Compounds (VOCs) in Air Collected in Specially Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)*. Center for Environmental Research Information. Office of Research and Development. 1999.
[10]US EPA. *EPA Requirements for Quality Assurance Project Plans. EPA QA/R5*. Office of Environmental Information. EPA/240/B-01/003. 2001.
[11]US EPA. *ProUCL Version 4.00.05 Technical Guide (Draft).* EPA/600/R-07/041. 2010.

5.0 Medical Monitoring: Study Design 4

The purpose of the "Medical Monitoring Study" is to track health trends over time and to identify health effects of NGD in residential areas. Citizens living near NGD have reported a variety of health symptoms, yet no systematic collection and analysis of health effects and outcomes data has been conducted.

The medical monitoring study design addresses two of the information gaps identified in the HIA[1]: (1) We don't have physical or mental health tracking data; and (2) We don't know the full health impact of air pollution from gas production facilities.

Ongoing surveillance of populations exposed to NGD using existing health outcomes databases will allow public health officials to understand associated health effects. Using this information, public health agencies and health care providers can strengthen existing interventions and design and implement new interventions as needed. In addition, such information will provide regulators, policy makers and industry professionals the basis for further efforts in exposure mitigation.

Systematic application of questionnaires to general and at risk populations have been used to evaluate environmental exposures[2,3], health status[4], health symptoms[5], and some medical and psychological diagnoses[6,7,8]. Utilization of a questionnaire in an NGD exposed population will supply public health officials information regarding these outcomes and provide basis for public health interventions, exposure mitigations, policy changes and directions for future research.

The zip codes presented in this study design are specific to Battlement Mesa. If this design were to be applied to another NGD project elsewhere in the county, zip codes would need to be revised.

5.1 Specific Aims and Objectives

There are two aims in the medical monitoring study design. The first aim is to use information available in databases maintained by CDPHE to track specific health effects that may be associated with NGD. The second aim is to conduct surveys to prospectively collect and track specific health and exposure information.

The specific objectives of the first aim are to: (1) provide a baseline incidence rate of specific health effects within the Battlement Mesa Community; (2) identify changes in the incidence rate of specific health effects over time; and (3) compare the incidence rate of specific health effects in the Battlement Mesa Community to other communities in Colorado. Population counts by gender, age, and race will be obtained from the U.S. Census Bureau for zip codes 81635 and 81636, as well as Battlement Mesa census tracts. Zip code 81635 denotes physical addresses in both the Battlement Mesa and the town of Parachute, while 81636 is used solely for Post Office (PO) boxes. Because the town of Parachute shares a zip code with Battlement Mesa, it will not be possible to distinguish between the two for some indicators in the Medical Monitoring Study (e.g., mortality, cancer).

The specific objectives of the second aim are to: (1) identify health symptoms that residents associate with NGD exposures; (2) identify medical conditions that residents are diagnosed with during the time when NGD activities are happening nearby; (3) identify exposures that residents associate with health symptoms; and (4) identify NGD activities that residents associate with health symptoms.

5.2 Technical Approach

5.2.1 Medical Monitoring Study Design Aim 1

The following indicators will be monitored to meet the objectives listed in Section 5.1.

5.2.1.1 Mortality

Annually, the CDPHE's Colorado Health Information Dataset (CoHID)- Death Statistics[9] will be used to obtain the following for Battlement Mesa (in zip codes 81635 and 81636), Garfield County, and Colorado:

- Total Deaths
- Suicide
- Homicide
- Substance related
- Firearm related
- Work related
- Nervous system diseases
- Major cardiovascular diseases
- Chronic lower respiratory diseases
- SIDS
- Cancers
- Leukemias

In addition, the following co-variables will be obtained from the death statistics: gender, age, and race. International Classification of Disease, tenth revision or ICD-10 codes will be applied for determining diagnoses.

5.2.1.2 Cancer

Annually, the CDPHE's Colorado Central Cancer Registry[10] will be used to obtain the following for Battlement Mesa (in zip codes 81635 and 81636), Garfield County, and Colorado:

- Total Cancers
- Hodgkin Lymphoma
- Non-Hodgkin Lymphomas
- Multiple Myeloma
- Leukemias (acute lymphoblastic leukemia, acute myeloid leukemia, chronic lymphocytic leukemia, and chronic myelogenous leukemia)
- Melanoma
- Breast cancer
- Prostate cancer

- Bladder cancer
- Colorectal cancer
- Cancer of the adrenal gland

In addition, the following co-variables will be obtained from the cancer registry: gender, age, and race.

5.2.1.3 Birth Outcomes

Annually, CoHID- Birth Statistics[2]; and the CoHID – Birth Defect Statistics[9] will be used to obtain the following for Battlement Mesa (in zip codes 81635 and 81636), Garfield County, and Colorado:

- Number of births
- Preterm births (Gestational age less than 37 weeks)
- Low birth weight-at gestational age: less than the 10th percentile for the specific gestational age in the National Center for Health Statistics 1999 and 2000 Natality Data Sets[11]
- Oral clefts
- Neural tube defects
- Major cardiovascular anomalies

In addition, the following co-variables will be obtained from the vital birth statistics: gender, maternal age, and race. Maternal age will be collapsed into three categories, less than 20 years, 20 – 39 years, and greater than 39 years.

5.2.1.4 Inpatient Hospital Diagnosis and Emergency Room Diagnosis

Annually, the Colorado Hospital Association discharge registry and emergency room discharge[12] registry will be used to obtain the following from aggregated International Classification of Diseases ninth revision or ICD-9 codes for Battlement Mesa (in zip codes 81635 and 81636), Garfield County, and Colorado:

- Total Hospitalizations
- Total Emergency Room Visits
- Depression
- Nervous system
- Ear nose and throat
- Vascular system
- Pulmonary system

In addition, the following co-variables will be obtained from the hospital discharge registry: gender, age, and race. The Colorado Hospital Association collects discharge data for inpatient hospitalizations from participating hospitals throughout the state of Colorado. Each hospital

discharge record collected can contain up to 15 diagnoses. For purposes of this analysis, the total hospitalizations will be counted by including ICD-9 codes listed in top diagnosis only.

5.2.2 Medical Monitoring Study Design Aim 2

The survey will prospectively collect information on self-reported exposures to NGD operations and specific health information, including mental health and substance abuse, from residents of Battlement Mesa. A questionnaire with close-ended questions suitable for quantitative analysis will be developed. Open ended questions will also be included to provide qualitative context and detail not captured by open ended questions. Questions specific to the community, including demographics, household composition, perceived exposures to natural gas development and production processes, and other exposures will be developed. For example, potential questions for perceived exposures would include questions examining perception of odor emanating from well-sites, noise, traffic, etc. The survey will be conducted once prior to well development, annually during the 5-year well development period and every 5 years during the 30-year production period.

In keeping with established questionnaire development methodology, a pilot test will be conducted to evaluate a list of potential questions that map the domain of "exposure perception related to natural gas development," test questions for repeatability (consistency of response), inter-correlation, and for their ability to contribute to map this area of personal perception while minimizing redundancy. Checks for question reliability will be performed, by calculating Cronbach's alpha and the Kappa coefficient between a test and re-test results. After the pilot test, respondents will be interviewed concerning question comprehension and their overall impression of the test. The questionnaire then will be revised based on the results of the reliability tests, re-analysis of the exposure questions for inter-correlation and variance, and respondent comprehension and overall impression of the test. Validity of the health-related questions will be conducted by examining correlation between characteristics expected to be related. The external validity of this new exposure perception questionnaire will be tested against data from the field sampling efforts in this community. For example, it will be possible to assess a subset of exposure perception questions (e.g. to noise, odor, traffic volume) to near-time or real-time measurements in the neighborhood.

An English and Spanish version of the questionnaire will be developed because the population of Garfield County is estimated to be up to 30% Hispanic. Questions will be translated from English into Spanish, and reading level and potential for comprehension assessed. To validate the translation, questions will be independently back-translated into English by a translator who was not involved in the original translation.

A secure web-based survey vehicle, such as SF-tools, will be selected for administering the questionnaire and compiling questionnaire data. Features of the survey vehicle will include anonymity of participant response, password access for both participants and researchers, and varying levels of security and access. Strict adherence and compliance with Health Insurance Portability and Accountability Act (HIPAA) standards for handling of personal health information, confidentiality, and data security will be maintained. Necessary Institutional Review Board (IRB) consent will be obtained.

Once the questionnaire is designed and refined (as described above), it will be and loaded into the web-based survey vehicle and a second pilot test will be conducted with 100 volunteers aged 18 years or older who are current residents of Garfield County. Approximately 20 of the

volunteers will be Spanish speakers. Then checks for reliability will be performed by calculating Cronbach's alpha and the Kappa coefficient between a test and re-test results. The volunteers will be interviewed concerning question comprehension and their overall impression of the test. The web-based questionnaire will be revised based on the results of the reliability tests, re-analysis of the exposure questions for intercorrelation and variance, and respondent comprehension and overall impression of the test.

After successful refinement and validation of the survey instrument, all residents of Battlement Mesa will be recruited to participate. Recruitment will include press releases to local media outlets, public and private health facilities, local schools, the recreation center and other mechanisms as they become available.

An example questionnaire is provided in Appendix C. This example is intended to demonstrate the variety of information that will be collected, including environmental exposure, physical and mental health status, change in health status, health symptoms, and disease diagnosis. In addition, the example questionnaire includes questions regarding the residential experience of living in a NGD community and other psychosocial outcomes. (See section 6). The example questionnaire provides examples of questions that are both closed ended for quantitative analysis and open ended for qualitative analysis. The example questionnaire includes a portion of a validated questionnaire designed to diagnose asthma in young teenage children.[13] Other portions of existing validated questionnaires could be included as well.

5.3 Data Analysis

5.3.1 Data Analysis Medical Monitoring Study Design Aim1

Annual, 5 year, 10 year, and 20 year incidence, prevalence, and mortality rates will be calculated for Battlement Mesa, Garfield County, and Colorado by dividing the number of incidents of a specific health effect by the population at risk and grouped by gender, race, and age. Standardized incidence ratios will be calculated by dividing number of a specific health effect in the Battlement Mesa/Parachute zip code compared to an expected number of the specific health effect based on statewide Colorado rates, adjusted for age, race, and gender. The state of Colorado will be used as a comparison to provide a large population base to generate stable, reliable rates. When the number of events is less than 3 the data will not be reported to preserve confidentiality; this is a policy of the Health Statistics and Vital Record Division at CDPHE.

When interpreting a standardized incidence, prevalence, or mortality ratio, size and stability need to be taken into consideration. Ratios based on greater numbers of events produce estimates that are more stable, meaning that there is greater confidence in the conclusions being drawn from the information. Because the population of Battlement Mesa is small and the number of cases is small, determining the statistical significance is extremely important. Confidence intervals will be calculated, in order to determine if the number of observed cases is significantly different from the number of expected cases or whether the difference may be due to chance alone. For these analyses, a 95% confidence interval will be calculated for each ratio. Table 5-1 describes how the standardized incidence ratio will be interpreted and deemed statistically significant or statistically insignificant.

Annual and cumulative rates, adjusted for co-variables, for each health effect will be calculated based on the U.S. Census Bureau counts as described in the Community Monitoring Study Design.

5.3.2 Data Analysis Medical Monitoring Study Design Aim 2

Survey results will be summarized as counts of answers of specific responses for each survey question and annual, 5 year, 10 year, and 20 year summaries of the survey results will be reported. Qualitative responses will be analyzed for common themes and then summarized. Because the target population for the survey is small (approximately 5,000 people) and completion rate for the survey can be anticipated to be substantially less, it is likely that the number of returned surveys will not be sufficient to draw statistically valid conclusions about the relationship between symptoms and exposures. However, results of the survey will provide officials with information to guide public health interventions and industry mitigations. The county may decide to expand the survey to other areas of NGD and areas without NGD, thus potentially obtaining sufficient information to draw statistically valid conclusions regarding health symptoms and exposures.

5.3.2.1 Protection of Sensitive Information

All medical monitoring results will be presented in aggregated, de-identified format. Counts of health effects in Battlement Mesa and Garfield County below 3 will be suppressed.

5.4 Data Management

The Medical Monitoring Study will utilize existing databases housed in public agencies (CDPHE). Colorado Hospital Association Discharge Data will be purchased from the Colorado Hospital Association. All datasets will be downloaded onto secured, password controlled computers. Access to datasets will be limited to only those researchers directly involved in the Medical Monitoring Study.

5.5 Expected Outputs

The outcomes of the medical monitoring will be summarized in annual reports. The annual reports will provide comparisons to the State of Colorado as well and provide trends over time. Reports will be available on the Garfield County website.

5.6 References

[1]Witter, R., L. McKenzie, et al. *Draft health impact assessment for battlement mesa, Garfield County, Colorado*. 2011.

[2] Bradham, K., Highsmith, R., Sheldon, L., Friedman, W.,; Pinzer, E., Ashley, P., Stout, D., Harper, S., Vesper, S., Jones, P., Medina-Vera, M., Fortmann, R., Coppedge, E., Croghan, C., Cox, D., Dewalt G. *American Healthy Homes Survey: A National Study of Residential Related Hazards*. Epidemiology 17 (6): S433. 2006.

[3] Aatamila, M., Verkasalo, P., Korhonen M., Suominen A., Hirvonen M., Viluksela M., Nevalainen A. *Odour annoyance and physical symptoms among residents living near waste treatment centres*. Environmental Research 111(1):164-70. 2011.

[4]Centers for Disease Control, Behavior Risk Factor Surveillance System http://www.cdc.gov/brfss/

[5] Frei, P., Mohler, E., Braun-Fahrländer, C., Fröhlich, J., Neubauer G., Röösli, M. *Cohort study on the effects of everyday life radio frequency electromagnetic field exposure on non-specific symptoms and tinnitus.* Environmental International 38 (1): 29-36. 2012.

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[7] Torén, K., Brisman, J., Järvholm, B. *Asthma and asthma-like symptoms in adults assessed by questionnaires. A literature review***.** Chest 10 (2): 600—608. 1993.

[8]Bowler, R. and Schwarzer, R. *Environmental anxiety: Assessing emotional distress and concerns after toxin exposure*. Anxiety Research 4 (2): 167-180. 2007.

[9] Colorado Department of Public Health and Environment. Colorado Health Information Dataset http://www.cdphe.state.co.us/cohid/. 2011.

[10]Colorado Department of Public Health and Environment. Colorado Central Cancer Registry. http://www.cdphe.state.co.us/pp/cccr/. 2011.

[11]Oken E, Kleinman K, Rich-Edwards J, Gillman M. *A nearly continuous measure of birth weight for gestational age using a United States national reference*. *BMC Pediatrics.* (1):6. 2003.

[12]Colorado Hospital Association. Colorado Hospital Discharge Dataset. http://www.cha.com/index.php?option=com_content&task=view&id=14&Itemid=28. 2011.

[13] Asher, M., Keil, U., Anderson, H., Beasley, R., Crane, J., Martinez, F., Mitchell, E., Pearce, N., Sibbald, B., Stewart, A., et. al. *International study of asthma and allergies in childhood (ISAAC): rationale and methods*. Eur Respir J 8:483-491. 1995.

Table 5-1 Interpretation of Standardized Ratios

Ratio (SIR/SMR/ SPR)	**Interpretation**	**95% Confidence Interval**	**Significance**
< 1.00	The number of events observed is less than expected	The lower and upper limits of the interval are < 1.00	Ratio is considered statistically significant.
		The upper limit of the interval is > 1.00	Ratio is not considered statistically significant.
= 1.0	The number of events observed is equal to the number of events expected for the population		Ratio is not considered statistically significant.
> 1.00	The number of events observed is greater than expected	The lower limit of the interval is < 1.00	Ratio is not considered statistically significant.
		The lower limit of the interval is > 1.00	Ratio is considered statistically significant.

SIR = standardized incidence ratio; SMR = standardized mortality ratio; SPR = standardized prevalence ratio

6.0 Community Monitoring: Study Design 5

The purpose of the "Community Monitoring Study is to track ongoing community health status and identify community effects of NGD in the Battlement Mesa community.

The Community Monitoring Study design addresses one of the information gaps identified in the HIA[1]: We don't have community health measures.

Ongoing surveillance of community measures in areas exposed to NGD, using existing data sources, will allow public health officials to understand associated community changes. Systematic application of questionnaires to members of communities exposed to NGD will also provide information about the psychosocial impact of NGD on community life. Public health officials, regulators, policy makers and industry professionals will be able to use this information to support existing community structures and develop new interventions that support the community.

The zip codes and other community specific information sources (e.g. Battlement Mesa Fire Department) presented in this study design are specific to Battlement Mesa. If this design were to be applied to another NGD project elsewhere in the county, zip codes and community specific information sources would need to be revised.

6.1 Specific Aims and Objectives

This Community Monitoring study aims to gather information from the U.S. Census Bureau[2], Garfield County Sheriff's Office (GCSO)[3], Parachute Police Department (PPD)[4], Battlement Mesa Fire Department, Colorado State Patrol (CSP)[5], Colorado Department of Education (CDE)[6], Garfield County Assessor's (GSA) office[7], and the CDPHE[8], to actively monitor traffic, school enrollment, population growth, economic health, crime rates, and sexually transmitted disease rates in Battlement Mesa. The specific objectives are to: (1) identify changes in indicators of community health over time; (2) compare rates of specific community health indicators in the Battlement Mesa Community to other communities in Colorado; and (3) gauge industrial risks that may be associated with NGD.

The mental health of the community is addressed in the Medical Monitoring Study design.

6.2 Technical Approach

The following indicators will be monitored to meet the objectives listed in Section 6.1.

6.2.1 Demographics

Population counts by gender, age, and race will be obtained from the U.S. Census Bureau for zip codes 81635 and 81636, as well as Battlement Mesa census tracts[2]. Zip code 81635 denotes physical addresses in both the Battlement Mesa and the town of Parachute, while 81636 is used solely for PO boxes. Because the town of Parachute shares a zip code with Battlement Mesa, it will not be possible to distinguish between the two for some indicators in the Community Monitoring Study (i.e., sexually transmitted infections [STIs]). Annual changes in school enrollment will be used to adjust annual census counts.

6.2.2 Traffic

For comprehensive monitoring of the impact of the NGD project on traffic associated health effects with the boundaries of the planned unit development PUD, this design includes collecting data on the number of vehicles entering the PUD and the motor vehicle accidents and violations within the PUD. Vehicle counter systems capable of recording vehicle weights and speeds will be installed inside both entrances to Battlement Mesa and operated from one year prior to the project start through the completion of the project.

A database will be created to compile and manage data on motor vehicle accidents (including single vehicle, multiple vehicles, and vehicle/pedestrian) and violations within the Battlement Mesa PUD in cooperation with the GCSO, PPD, and CSP.[3, 4, 5] The traffic database will include the following fields:

- Date of incident
- Time of incident
- Type of incident
- Number of vehicles involved
- Type of vehicles involved
- Age of drivers
- Ages of passenger
- Ages of pedestrians
- Description of property damage
- Number of minor injuries (not requiring medical treatment),
- Number of major injuries (requiring medical treatment)
- Number of fatalities.

6.2.3 NGD incident responses

To understand the number and variety of industrial incidents and malfunctions associated with NGD, this design includes collection of data from the local fire department on the responses to calls associated with the industry. Annual review of data collected by the fire department will include:

- Number of incidents
- Type of incident (e.g. spill, fire)
- Potential exposures, (e.g. water contamination, air emissions)
- Injuries and/or health impacts to citizens and/or firefighters
- Transport to medical facility
- Other information gathered by the department

A database will be created to compile and manage data on fire department responses.

6.2.4 Schools

School enrollment indicates the overall health of community as a measure of population growth, and employment opportunities. To monitor the impact of the NGD project on the local school system and local employment, annual data on school enrollment and number of teachers,

administrators, and other school employees will be collected from the CDE[6] and will include number of children enrolled by age, gender, and race in Garfield County School District 16 at Grand Valley High School (9th-12th), Grand Valley Middle School (6th-8th), St. John Elementary School (4th-5th), and Bea Underwood Elementary School (1st-3rd).

6.2.5 Economy and Employment

This design involves collecting annual data on housing prices and sales, construction, household income, and employment within the PUD. This will begin with collection of baseline data prior to the start of the project and continue through the end of the project. For housing prices and sales, the following information will be collected annually from the County Assessor's office:

- Number of homes sold (or titles issued)
- Price of each home sold (as recorded on title)
- Square footage of each home sold

For information on construction, the number of building permits will be collected annually from the County Assessor's office.[7] Information on employment and household income will be collected through the Health Survey and at each National Census (every 10 years) starting with 2010.

6.2.6 Crime

To monitor crime during the NGD project, this design involves working with the Garfield County Sheriff's Office to collect crime statistics specific to Battlement Mesa, as reported to the Colorado Bureau of Investigation (CBI) in the annual Crime in Colorado report. All Colorado law enforcement agencies are required to submit crime and arrest data to the CBI through the federally mandated Uniform Crime Reporting (UCR) Program[9]. Incident data follow the national UCR Summary Hierarchy Rules and the National Incident-Based Reporting System reporting and counting guidelines, broadly interpreted to mean the arrest for the most serious charge is counted.[10] Adult and juvenile arrests will be included. Specifically, information on assault, rape, burglary, theft, vandalism, weapons offenses, fraud, forgery, driving under the influence, and drug violations will be collected and compiled annually.

6.2.7 Sexually Transmitted Infections

To monitor the whether or not the NGD project has an impact on the incidence of STIs within the community, this design involves the annual collection of the number of Chlamydia and Gonorrhea cases reported to the CDPHE by zip code for the state of Colorado.[8] Using population data from the U.S. Census Bureau, annual STI incidence rates will be calculated for Battlement Mesa residents (zip codes 81635 and 81636), the rest of Garfield County, and Colorado, as well as SIRs for Battlement Mesa and Garfield County.

6.2.8 Community Livability

The Health Survey described in the "Medical Monitoring Study Design" will include a section that addresses aspects of community life not otherwise captured in state and local databases. Questions will include residents' perceptions of improving and/or declining community attributes and facilities will be included as well as questions asking about how changes impact resident's feelings of well-being.

6.3 Data Analysis

Table 6-1 summarizes the data that will be collected, as well as statistics that will be reported in the Community Monitoring Study. Survey results for community livability will be summarized as counts of answers of specific responses for each survey question and annual, 5 year, 10 year, and 20 year summaries of the survey results will be reported.

6.4 Data Management

The collected data will be downloaded into a Microsoft Office ACCESS (or other appropriate database manager) and maintained on secured password protected computers. Access to datasets will be limited to only those researchers directly involve in the Community Monitoring Study.

6.5 Expected Outputs

The outcomes of the Community Monitoring Study will be summarized in annual reports. The annual reports will provide comparisons to the State of Colorado as well and provide trends over time. Reports will be available on the Garfield County website.

6.6 References

[1]Witter, R., L. McKenzie, et al. *Draft health impact assessment for battlement mesa, Garfield County, Colorado*. 2011.
[2]U.S. Census Bureau, Denver Regional Office. http://www.census.gov/regions/denver/.
[3]Garfield County Sheriff's Office. Glenwood Springs, Colorado. http://www.garcosheriff.com/.
[4]Parachute Police Department. Parachute Colorado. http://www.parachutecolorado.com/index.aspx?nid=67.
[5]Colorado State Petrol. http://www.colorado.gov/cs/Satellite/StatePatrol-Main/CBON/1251593174849.
[6]Colorado Department of Education. http://www.cde.state.co.us/ index_stats.htm.
[7]Garfield County Assessor's Office. Online database. http://www.garfield-county.com/assessor/search-database.aspx.
[8]Colorado Department of Public Health and Environment. STI/HIV surveillance. http://www.cdphe.state.co.us/dc/hivandstd/surveillance.html.
[9]Colorado Bureau of Investigation. *CBI-. Crime in Colorado*. http://cbi.state.co.us/CNC/index.html.
[10]US Federal Bureau of Investigation. http://www2.fbi.gov/ucr/.

Table 6-1. Measurements, Sources, and Statistics Calculated for Community Monitoring Study

Measurement	**Source (s)**	**Statistics**
Demographics		
People	U.S. Census Bureau	Count by gender, age and race in Battlement Mesa and zip codes 81635 and 81636[4]
Traffic		
Vehicles > 10,000 pounds	Vehicle Counter	Monthly count and mean speed
Vehicles < 10,000 pounds	Vehicle Counter	Monthly count and mean speed
Single vehicle accidents	GCSO, PPD, CSP	Monthly count and mean speed
Multiple vehicle accidents	GCSO, PPD, CSP	Monthly count and mean speed
Accidents involving pedestrians	GCSO, PPD, CSP	Monthly count and mean speed
Truck accidents	GCSO, PPD, CSP	Monthly count and mean speed
Property Damage	GCSO, PPD, CSP	Monthly count and mean speed
Minor injuries	GCSO, PPD, CSP	Monthly count and mean speed
Major injuries	GCSO, PPD, CSP	Monthly count and mean speed
Fatalities	GCSO, PPD, CSP	Monthly count and mean speed
Moving vehicle violations	GCSO, PPD, CSP	Monthly count and mean speed
Industrial incidents	BMFD	Annual count
Spills	BMFD	Annual count
Fires	BMFD	Annual count
Other	BMFD	Annual count
Exposures	BMFD	Annual count
Resident injuries	BMFD	Annual count
Responder injuries	BMFD	Annual count
Transport	BMFD	Annual count
Schools[1]		
Enrollment	CDE	Annual count for each school grouped by gender, age, and race
Teachers	CDE	Annual count for each school
Administrative and other staff	CDE	Annual count for each school
Economy and Employment		
Homes Sold	GCA	Annual count, range of selling prices per square foot, 5th, 25th, 50th, 75th, and 95th percentile selling price per square foot, mean selling price per square foot
Number of building permits	GCA	Annual count
Employment	HS	Percentage employed
Household Income	HS	5th, 25th, 50th, 75th, and 95th percentile and mean

Table 6-1 Continued

Measurement	Source (s)	Statistics
Crimes		
Assaults	GCSO	Annual count
Rapes	GCSO	Annual count
Burglary	GCSO	Annual count
Theft	GCSO	Annual count
Vandalism	GCSO	Annual count
Weapons offenses	GCSO	Annual count
Fraud	GCSO	Annual count
Forgery	GCSO	Annual count
Drug violations	GCSO	Annual count
DUI	GCSO	Annual count
Sexually Transmitted Infections		
Chlamydia	CDPHE	Annual count of cases reported in year and incidence rate[2] for zip codes 81635 and 81636, Garfield County, and Colorado grouped by gender, age, and race; Standardized incidence ratio[3]

CDE = Colorado Department of Education; CDPHE = Colorado Department of Public; CSP = Colorado State Petrol; Health and Environment; DUI = driving under the influence; GCA = Garfield County Assessor; GCSO = Garfield County Sheriff's Office; PPD = Parachute Police Department

[1] Grand Valley High School, Grand Valley Middle School, St. John Elementary School, and Bea Underwood Elementary School

[2]Incidence rate = count of cases reported in year/population

[3]Standardized incidence ratio = incidence rate in zip codes 81635 and 81636/ incidence rate Colorado, adjusted for age, race, and gender

[4]Counts between censuses may be adjusted based on changes in school enrollment.

7.0 Conclusion

This Environmental and Health Monitoring Study design provides Garfield County five separate study designs. These study designs can be conducted independently, although several designs are more effectively and efficiently combined, as described in the introduction. The designs may be used in Battlement Mesa or may be implemented with minor modifications to other locations in Garfield County. The implementation of these study designs will provide information that is not currently available about the emissions and exposures associated with NGD as well as related physical, psychosocial, and community impacts.

7.1 Revised Scope of Work for the EHMS

These study designs meet the requirements outlined in the Revised Scope of Work approved by the BOCC on June 20, 2011 (Appendix C). All the designs include a design for a strategy for the management and statistical analysis of health and exposure data. Specifically:

- Study Design 1 meets the requirement for:
  - A comprehensive design for on-going monitoring of air, water, and soil quality for well sites during all phases of operation, addressing stressors of concern in air, water and soil. Monitoring design will address data gaps in sources of air emission levels during well development and production operations and baseline to post development water and soil contamination.
- Study Designs 2 and 3 meet the requirements for:
  - Design for an air sampling study for VOCs and PM to further characterize chemicals being emitted into the air by the natural gas industry. A study to characterize air emissions will address gaps in knowledge regarding chemicals emitted to the air by the natural gas industry.
  - Design for a study to evaluate the dispersion of air emissions from the well sites and environmental and exposure pathway for air emissions. This study will address gaps in knowledge regarding levels chemicals to which people are exposed, as well as providing data to build a model for predicting exposures in the future.
  - Design for a study to examine buffer zones for stressors of concern via the air pathway and to estimate if these zones adequately protect human health. A buffer zone study will address the gaps in knowledge regarding safe distances for natural gas well development from occupied structures and levels chemicals people are exposed to.
- Study Designs 4 and 5 meet the requirements for :
  - Design for a medical monitoring system using available health data, for monitoring the health of Battlement Mesa and/or Garfield County residents. A medical monitoring system is needed to track health trends over time and to identify health effects of natural gas operations in residential areas.
  - Design for a monitoring system for the community health using available community measures, of Battlement Mesa and/or Garfield County. A community health monitoring system is needed to track ongoing community health status and identify community effects of natural gas operations in residential areas.

The CSPH obtained all chemical material safety data sheets (MSDS) from Antero Resources for chemicals anticipated to be used in Battlement Mesa. Furthermore, the Colorado Oil and Gas Conversation Commission is currently in rulemaking for disclosure of hydraulic fracturing chemicals.[1] This rule making will make this same information available to the public. This meets the requirement for:

- Make requests to appropriate agencies and operators to obtain lists of materials used in the drilling, hydraulic fracturing and production processes. This information will guide future air and water sampling and monitoring efforts.

The CSPH is currently releasing this report directly to and only to GCPH. This meets the requirement:

- Provide final draft to GCPH for review by BOCC's Contract Manager and otherwise not release the EHMS design without permission of BOCC.

7.2 Information gaps identified in the Battlement Mesa HIA

These study designs, when implemented, will address the following information gaps identified in the Battlement Mesa HIA[2]:

Study Designs 1, 2 and 3 will address the following data gaps:

- We don't know all chemicals emitted during NGD or used by the industry.
    - We need to know about the chemicals being used and emitted in order to predict health effects and know how to respond in an emergency.
- We don't know all the know sources of emissions to air, water, and soil in NGD.
    - We need to know the sources of emissions in order to engineer better pollution prevention methods and to understand short- and long-term exposures. We need to know when water is contaminated.
- We don't know the levels of chemicals people are exposed to.
    - We need to know exposure levels in order to know what kinds of health effects to expect and if there would be short term or long term health effects. We need to know exposure levels to know if mitigation is needed. We need to determine safe setbacks.

Study Designs 4 and 5 will address the following data gaps:

- We don't have physical or mental health tracking data.
    - We need to have health tracking data to follow health trends over time.

- We don't have community health measures.
    - We need community health measures to monitor community well-being.

Expansion of Study Design 4 to include a larger regional area, such as Garfield County as a whole, will address the following data gaps:

- We don't know the full health impact of cumulative air pollution from the sum of natural gas development and production activities in the region.
    - We need to know if declining ambient air quality is having adverse effects on Garfield County residents

7.3 Battlement Mesa citizen requests

These study designs, when implemented, will address the following requests made by the Battlement Concerned Citizens petition.

Study Design 1 will fulfill the request for:

- Comprehensive and continuous air, water and soil quality monitoring at all well sites during all phases of operation

Study Designs 2 and 3 will fulfill the request for:

- Test whether a buffer zone of not less than one thousand feet between any well operation and any residence, business, or pubic building will protect health standards.

Study Designs 4 and 5 will fulfill the request for:

- Establish a medical monitoring system to identify any changes in the baseline data or trends and/or anomalies in medical practices

The CSPH has provided the BOCC an EHMS Study Final Design, with the objective of collecting unbiased, scientifically rigorous data for future environmental exposure assessment and health outcomes research. Results of these studies will provide much needed information for public health officials, regulators, policy makers and industry professionals to protect public health during natural gas development and production.

7.4 References

[1] Colorado Oil and Gas Conservation Commission (COGCC): http://cogcc.state.co.us/.
[2]Witter, R., L. McKenzie, et al. *Draft health impact assessment for battlement mesa, Garfield County, Colorado*. 2011.

APPENDIX A

EHMS SCOPE OF WORK

SCOPE OF WORK

The CSPH will use faculty expertise to design an Environmental and Health Monitoring Study (EHMS). Scientific considerations may lead CSPH to design the EHMS to include only Battlement Mesa, or to include all of Garfield County or a combination of both. This conceptual design phase does not include conduct of the study, but will include the following components:

- A comprehensive design for on-going monitoring of air, water, and soil quality for well sites during all phases of operation, addressing stressors of concern in air, water and soil. Monitoring design will address data gaps in sources of air emission levels during well development and production operations and baseline to post development water and soil contamination.
- Design for an air sampling study for volatile organic compounds (VOC) and particulate matter (PM) to further characterize chemicals being emitted into the air by the natural gas industry. A study to characterize air emissions will address gaps in knowledge regarding chemicals emitted to the air by the natural gas industry.
- Design for a study to evaluate the dispersion of air emissions from the well sites and environmental and exposure pathway for air emissions. This study will address gaps in knowledge regarding levels chemicals to which people are exposed, as well as providing data to build a model for predicting exposures in the future.
- Make requests to appropriate agencies and operators to obtain lists of materials used in the drilling, hydraulic fracturing and production processes. This information will guide future air and water sampling and monitoring efforts.
- Design for a study to examine buffer zones for stressors of concern via the air pathway and to estimate if these zones adequately protect human health. A buffer zone study will address the gaps in knowledge regarding safe distances for natural gas well development from occupied structures and levels chemicals people are exposed to.
- Design for a medical monitoring system using available health data, for monitoring the health of Battlement Mesa and/or Garfield County residents. A medical monitoring system is needed to track health trends over time and to identify health effects of natural gas operations in residential areas.
- Design for a monitoring system for the community health using available community measures, of Battlement Mesa and/or Garfield County. A community health monitoring system is needed to track ongoing community health status and identify community effects of natural gas operations in residential areas.
- Design for a strategy for the management and statistical analysis of health and exposure data.
- Provide final draft to GCDPH for review by BOCC's Contract Manager and otherwise not release the EHMS design without permission of BOCC.

The GCDPH shall review the EHMS design prior to delivery to the BOCC or public release.

APPENDIX B:

EPA PROPOSAL[1]

[1]The Colorado School of Public Health (CSPH) prepared this proposal in collaboration with the Colorado Department of Public Health and Environment (CDPHE) and the Garfield County Department of Public Health (GCPH), at the request of GCPH. On May 18, 2011, CSPH submitted the material in this Appendix to CDPHE. CDPHE then included these materials in their proposal application submitted to the United States Environmental Protection Agency's (EPA) Community- scale Air Toxics Ambient Monitoring Program (CFDA No. 66.034, EPA-OAR-OAQPS-11-05) prior to the May 23, 2011 proposal closing date. Dr. Chris Urbina, CDPHE's Executive Director and Chief Medical Officer, withdrew the proposal application on August 12, 2011 in a letter addressed to James B. Martin, EPA Region 8's Regional Administrator.

WORK PLAN
RFP (EPA-OAR-OAQPS-11-05)

Project Title

Source Profiles and Dispersion of Hazardous Air Pollutants
from Natural Gas Development in Garfield County, Colorado

Applicant Information
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from Garfield County Public Health
and Colorado School of Public Health)

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DUNS Number
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A. Basis and Rational

A1. Background on Natural Gas Development

The United States holds large reserves of unconventional natural gas resources in coalbeds, shale, and tight sands. With recent technological advances, such as directional drilling and hydraulic fracturing, development of these resources is rapidly increasing. The number of producing unconventional natural gas wells rose from 18,485 in 2004 to 25,145 in 2007 and it is expected that expansion in the development of these unconventional resources will continue through 2020 (Vidas and Hugman 2008). With this expansion, it is becoming increasingly common for natural gas development (NGD) to occur near where people live, work, and play. Limited information is available on emissions of air pollutants from NGD or the risk these emissions may pose to public health. The U.S. Environmental Protection Agency (EPA) has identified the need to characterize emissions from various NGD activities as part of its review of New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAPs) mandated by the Clean Air Act (EPA 2010).

NGD activities are divided into two phases, well development and production. Well development involves pad preparation, well drilling, and well completion. Data indicate that well completion is the period of highest emissions (CDPHE 2009a, Howarth 2011). The well completion process has three primary stages: 1) completion transitions (well plugs are installed as an activity is completed or delayed and then removed before the next activity begins); 2) hydraulic fracturing (the injection of water and chemicals into the drilled well to release the natural gas); and 3) flowback (the return of fracking water, liquid hydrocarbons known as well condensate and natural gas to the surface). Production involves the collection and distribution of "salable" gas once the development process is complete.

Garfield County, CO is one area experiencing the rapid expansion of NGD. Natural gas production in Garfield County increased eightfold from 70 billion cubic feet (BCF) in 2000 to 550 BCF in 2008 (COGCC 2011). The Colorado Oil and Gas Conservation Commission (COGCC) has noted that people are increasingly raising public health concerns as rapid NGD growth exposes more people to the industry (COGCC 2009).

A2. Garfield County Ambient Air Studies

As evidenced by ambient air studies in Garfield County, NGD activities emit several hazardous air pollutants (HAPs), including benzene, toluene, ethylbenzene, and xylenes (BTEX). Toluene and xylene concentrations measured in grab air samples averaged 105 and 138 $\mu g/m^3$, with maximum concentrations reaching 540 and 1500 $\mu g/m^3$, respectively. Benzene concentrations averaged 32 $\mu g/m^3$, reaching a maximum of 180 $\mu g/m^3$ (CDPHE 2007). BTEX measurements from Garfield County's 2009 ambient air study were compared to regional measurements from 37 sites across the US. Levels of benzene, toluene, and xylenes at three out of four sites in Garfield County were higher than levels measured at most of the other sites (GCPH 2010). One of these sites is located in Parachute, CO, with over 40% of the population being of Hispanic origin (2010 US Census), as discussed in Part D of our proposal. The Colorado Department of Public Health and Environment's (CDPHE) 2007 emissions inventory for Garfield County indicates that the oil and gas industry is the primary contributor to benzene (CDPHE 2009b).

The 2008 Garfield County Air Toxics Study, which monitored four sites each undergoing drilling activities and well completion activities, concluded that the well completion activities emit larger volumes of volatile organic compounds (VOCs), including several HAPs, than drilling activities. The report indicated that the high concentrations of VOCs could be of great concern, as many of the well pads are located close to populated areas in Garfield County. In addition, the report indicated local wind speeds, directions and surrounding topography were important factors in influencing levels of pollutants at any one sampling site (CDPHE 2009a).

Ozone levels in Garfield County appear to have some relationship to pollutant emissions from NGD activities. CPDHE's 2007 emission inventory for Garfield County indicates that the NGD industry is the primary contributor to NOx emissions as well as the primary non-biogenic contributor of VOC, as

noted above (CDPHE 2009b). Garfield County's 2009 Air Quality Monitoring Summary Report attributes NGD activities as the largest contributing source of ozone precursors, such as light alkanes (GCPH 2010). In 2008, the 8-hr average ozone concentrations measured at Garfield County's monitoring station in Rifle, CO surpassed the 75 ppb National Ambient Air Quality Standard (NAAQS) on one day and the proposed 60 -70 ppb NAAQS on five days in March and April 2009 (GCPH 2010).

A3. Garfield County Health Studies

CDPHE and the Colorado School of Public Health (CSPH) scientists conducted a series of screening level human health risk assessments (HHRAs) using ambient air data collected in the studies described above. Collectively, these risk assessments have identified several HAPs, including BTEX, hexane, 1,3-butadiene, crotonaldehyde, acetaldehyde, and formaldehyde, as chemicals of potential concern in ambient air within Garfield County's NGD area. These HHRAs found cancer risks to typically fall within the 1 and 100 in a million range and chronic non-cancer hazard indices to be less than one (CDPHE 2007, CDPHE 2010, CSPH 2011). However, the HHRAs indicated that acute and sub-chronic risks may be a concern and reported acute and sub-chronic hazard indices exceeding one.

Based on the preponderance of evidence from the ambient air data collected by GCPH and CDPHE from 2005 to 2010, the CPSH Health Impact Assessment (HIA) concluded that the health of residents in a Garfield Community town, Battlement Mesa, "will most likely be affected" by exposures to HAPs emitted from NGD activities (CPSH 2011). Battlement Mesa has a larger percentage of residents aged 65 and older than the US population, as discussed in Part D of our proposal. The Agency for Toxic Substances and Disease Registry's (ATSDR) 2008 Health Consultation for Garfield County also concluded that that inhalation of ambient air in the monitored areas of Garfield County is associated with a low increased risk of developing cancer, chronic non-cancer health effects, and acute non-cancer health effects (ATSDR 2010).

A4. Information Gaps

While there are data on HAPs in Garfield County's ambient air, there is little data suitable for profiling the NGD sources (i.e., well pads) or for modeling dispersion of HAPs from NGD sources. These two data types are needed to determine risk of health impacts for residents living in close proximity to NGD activities. The screening level HHRAs, HIA, and ATSDR Health Assessment for Garfield County all identified lack of data on emissions during specific stages of well development activities and lack of emission factors from NGD as key gaps in addressing better understanding of health effects from HAP exposures. The 2008 Air Toxics Study concluded that additional research is needed to understand the local effects that drilling and completion activities can have on the public at large.

The health risks from emission sources during many NGD activities are not fully addressed by existing state or federal air rules. The applicable COGCC rules specify distances ("set backs") between wells and residences. However, these set backs are primarily based on concerns about safety (e.g., accidents, explosions) during NGD and it is not known if the set back distances protect public health from HAPs exposure. In its purpose statement accompanying their rules, the COGCC specified the need for further information on which to base regulator rules for set back distances (COGCC 2009).

A5. Specific Aims and Objectives

The CDPHE, in partnership with our community partners, GCPH and CSPH, is submitting this proposal as a **community-scale monitoring project** to better assess the degree and extent of HAPs emitted from NGD during well completions and their impact on human health. This study aims to build on data from previous and on-going ambient air monitoring studies in Garfield County and collect new data to address gaps identified in previous studies. This proposal addresses all five community-scale monitoring goals specified in the RFP: (1) delineate local scale pollutant concentration gradients in proximity to natural gas well completions; (2) characterize near-source pollutant concentrations from natural gas well completions; (3) provide data to investigate the relationship between HAPs and health impacts; (4) provide a baseline for which to compare the effect of pollution reduction measures and long-term monitoring; and (5) evaluate the effectiveness of air quality models in describing dispersion of HAPs from natural gas wells.

As described in Part F of this proposal, this project directly supports Goal 1, Objective 1.1 of EPA's Strategic Plan: Clean Air and Global Climate Change, Healthier Outdoor Air. This project will supplement the National Air Toxics Assessment (NATA) with valuable information on the contribution of NGD to air toxics emissions from outdoor sources and for characterizing potential public health risks due to inhalation of air toxics on both a national and regional scale. This information will aid EPA in characterizing NGD well pads as emission sources of air pollutants. Outcomes from this project will serve as a model for other areas in the country experiencing extensive NGD (e.g., Barnett Shale in TX, Jonah Field in WY, and Marcellus Shale in PA).

B. Technical Approach

The specific objectives for our proposed study are to:

1. Develop source profiles and emission factors specific to the three emission stages (i.e., well completion transitions, hydraulic fracturing, and flowback) of NGD activities.
2. Develop local scale dispersion profiles by measuring concentration gradients of HAPs from well sites to determine concentrations of HAPs at COGCC set-back distances and nearby residential structures
3. Model HAPs dispersion and compare to measurements to evaluate the performance of existing regulatory air models.
4. Estimate sub-chronic and acute risks to human health as a result of well completion activities.

These objectives will be met as follows.

B1. Source Profiles

We will directly measure concentrations of HAPs adjacent to three well pads to capture operator, terrain, and seasonal variability in emissions. At each pad we will collect emission data for HAPs from four directions: (1) the predominant downwind direction, (2) the truck access direction, and (3) the next two dominant downwind directions. We will collect meteorological data (wind direction and speed, temperature, relative humidity, and precipitation) for each pad, as well as data from a centralized fixed monitoring station for comparison. To develop each well source profile we will directly measure emissions in these four directions at 150 feet from the well head for 3 days each during hydraulic fracturing and flowback and 2 days during well completion transitions (8 days total at each well pad). Sample collection will include integrated 24-hour samples for determination of HAPs by EPA's compendium methods TO-15 for volatile organic compounds (VOCs) and TO-11a for carbonyls. This will result in a total of 96 samples (3 wells * 8 days * 4 directions).

B2. Dispersion Profiles

Dispersion profiles for HAPs will be determined with the data from the samples collected for the source profiles and additional integrated 24-hour samples collected in the four directions at 350, 1000, and 2500 feet set backs from the well head during 3-days of flowback operations. These additional 108 samples (3 pads * 3 set backs * 4 directions * 3 days) will be analyzed for VOCs. To augment this data, we will also collect 27 (3 residences * 3 days * 3 well pads) integrated 24-hour ambient air samples at the nearest three residences downwind of the well pad during flowback operations. The meteorological data collected for the source profiles will be applied for the dispersion profiles.

B3. Ambient Air and Background Sampling

Currently, GCPH collects ambient air samples every 6-days for speciated non-methane organic compounds (SNMOCs) by EPA's compendium method TO-12 and every 12-days for carbonyls EPA's compendium method TO-11a from a fixed centralized monitoring locations within the NGD area. The SNMOCs, which include HAPs most likely to be associated with the natural gas resource, are on the method TO-15 target analyte list. Therefore, we will be able to compare our results to results from GCPH ambient air monitoring program. A fixed location from a similar rural residential area located outside the natural gas development area will be selected as a background location. 24 (1 sample * 8 days *3 well pads) background samples will be analyzed for the same parameters as for near source characterization.

B4. Modeling

We will collect information on emission characteristics (e.g., types and numbers of diesel engines on the well pads and dimensions of flowback and fracturing tanks), chemical composition of condensate and gas (collected by oil and gas operators for permitting), and data from available land use and topographical maps and aerial photographs. We will use this information, along with the emission factors from the source profile to build a dispersion-transport model using the EPA recommended steady-state plume AERMOD modeling system (http://www.epa.gov/ttn/scram/dispersion_prefrec.htm#aermod) for describing dispersion of pollutants from surface sources over complex terrain. The dispersion profiles will be used to calibrate the model. We will test our model performance by comparing modeled results to data collected at residences.

B5.Tier 2/3 Human Health Risk Assessment

We will perform a Tier 2/3 assessment of sub-chronic and acute risks for HAPs associated with well completions according to EPA's Air Toxics Risk Assessment Reference Library using residential exposure results as well as results collected at 150 and 350 feet from the well pads. We will provide our risk assessment and model results for informing regulatory decisions on health-protective set-back distances.

B6. Quality Assurance/Quality Control

Prior to sample collection, we will prepare a quality assurance project plan (QAPP) per EPA QA/R5 2001. The QAPP will ensure sample collection and analyses methods provide data that is appropriate to support our project objectives. All team members and the subcontracted analytical laboratory(s) will be provided with a copy of the QAPP. We will provide EPA with a copy of the QAPP as a performance measure, prior to sample collection. For evaluation of precision and accuracy, we will collect field duplicates and trip blanks samples at a rate of 5%. All project outputs will be thoroughly peer reviewed, and also reviewed by CDPHE.

B7. Performance Measures

In addition to the quarterly, interim, and final reports, we will provide two performance measures in year one. These will be our QAPP and summarized results with a precision, accuracy, representativeness, comparability, completeness, and sensitivity (PARCCS) summary after completion of the sampling and analysis for the first well pad. In the second year we will provide PARCCS summaries after completion and analysis of the second and third well pads. In the third year, we will provide: (1) source profiles and emission factors; (2) dispersion profiles; (3) a transport and dispersion model; and (4) a Tier 2/3 assessment of sub-chronic and acute risks from well completions in the final report.

C. Data Analysis

Data analysis will begin with data validation for PARCCS through evaluation of field duplicates, blanks, chain-of-custody records, sample receipt records, and sample quantification limits. This will be followed by a statistical evaluation of the data using EPA's ProUCL software and SAS.

For the source profile, we will compare results from the samples collected at 150 feet to results from the ambient air samples collected at the fixed monitoring station and background location using ProUCL to identify emissions of HAPs associated with each of the three stages of well completions. We will compute emission factors in mass of pollutant per day of activity for these HAPs for completion transitions, hydraulic fracturing, and flowback. We also will compare emissions of HAPs to available data on gas and condensate composition and diesel emissions, as well as chemical compositions of materials used in the well completions, such as hydraulic fracturing fluids.

We will evaluate dispersion and transport from the well pad with the dispersion profiles from samples collected at 150, 350, 1000, and 2500 feet and meteorological results, as well as data from available land use and topographical maps and aerial photographs. We will use this information, along with the emission factors from the source profile to build a dispersion-transport model using AERMOD. The emission profiles will be used to calibrate the model. We will test our model performance by comparing modeled results to data collected at the residences.

We will prepare results collected at 150 and 350 feet (COGCC regulatory set-backs) from the well pads, according to EPA's ProUCL technical guidance for our Tier2/3 risk assessment.

D. Environmental Justice Impacts

Our project will address environmental risks due to HAPs emitted from NGD in Garfield County, CO. According to the EPA map EJView, Garfield County has over 850 Air Facility System (AFS) sites, most of which are related to the NGD. This number of sites is in contrast to the approximately 170 AFS sites in nearby Moffat County, which has minimal NGD impact (EPA 2011). Garfield County has the following characteristics of an Environmental Justice community.

Two environmental justice at risk groups in Garfield County's NGD area may potentially be exposed to emissions of HAPs. The first group is residents of Hispanic origin. The percentage of Garfield County residents of Hispanic origin has grown from 17% at the 2000 census to 26% at the 2010 census (2010 US Census). Much of the growth in the Hispanic population has occurred in children aged less than 18 years. In the Garfield County towns located in the NGD area, over 40% of the children are of Hispanic origin. Parachute, CO, where some of the highest ambient concentrations of benzene have been measured, has more than 40% of the population of Hispanic origin. In addition, 50% of children are of Hispanic origin (2010 US Census). Actual percentages of people of Hispanic origin may be higher because counts among Hispanics may be low due to language barriers and deportation fears among undocumented immigrants.

The second at risk group is elderly adults. The community of Battlement Mesa, situated in the midst of NGD activity and facing the development of 200 natural gas wells directly in their community, has a population that is 19.6% over the age of 65 (US 12.4%). Environmental risk and health impacts associated with air emissions from NGD will impact these at risk groups within Garfield County as well as the general population.

Our project will provide information for concentrating pollution reduction efforts where they will be most effective in reducing exposures to at risk pollutions, as well as providing information to local and state regulators to develop health protective strategies for individuals in these communities. Such regulation is needed to ensure that all people in Colorado enjoy the same degree of protection from environmental and health hazards associated with NGD and are considered equally in decision making processes.

E. Community Collaboration and Outreach

There are many levels to our community collaboration and outreach. CDPHE has a longstanding relationship with our community partner, GCPH. The CDPHE has served on the GCPH Air Quality Technical Workgroup since 2006. In addition, CDPHE has served as technical consultants on a variety of air quality efforts in Garfield County as well as authored local emissions inventories, HHRAs, and Health Consultations on behalf of GCPH. CSPH and GCPH have interacted with community groups in Garfield County, including the Grand Valley Citizens Alliance and the Battlement Concerned Citizens, to address public health concerns around NGD.

GCPH contracted CSPH to conduct a Health Impact Assessment (HIA), a stakeholder driven policy tool designed to assist decision makers incorporate health into policy decisions. As a result of the HIA process, the CSPH has forged strong community ties with both residents and GCPH and this project will build upon these established relationships. Throughout this project, CSPH will hold community meetings to inform GCPH and citizen groups of the project and its goals and methods; to solicit resident participation in air sampling; and to provide updates and results to the community in a timely manner. CPSH will provide GCPH with project outputs, meeting dates, agendas, and minutes, and other relevant information to post on their established web page on the county website (http://www.garfield-county.com/public-health/index.aspx).

In addition, CSPH and GCPH will closely collaborate in the collection of air samples. GCPH will train and employ environmental science students from a local state college to assist with air sampling

efforts. This educational outreach will provide the community with local experience on air quality science. CSPH and GCPH will work closely the county oil and gas liaison, and the local industry outreach group, Community Cares, and the regional trade group, Western Slope Colorado Oil and Gas Association, to gain access to and information about NGD sites.

F. Environmental Results

OUTPUTS	OUTCOMES/ LINKAGE TO STRATEGIC PLAN	PERFORMANCE MEASURES
Source Profiles and Emission Factors for HAPs from NGD completions (completion transitions, hydraulic fracturing, and flowback) for EPA's Air Quality System Database	*Short Term*: Advance understanding of impacts to air quality from NGD well completion activities by characterizing emissions of HAPs associated with NGD well completions. *Mid Term*: Provide inputs for contribution of well completions in local and regional air quality and source apportionment models. Identify long term monitoring goals. *Long Term*: Provide a baseline for evaluation of HAP emission reduction strategies.	QAPP per EPA QA/R5/2001 PARCCS summary reports Spreadsheet (or database) with emission factors
Dispersion Profiles for HAPs emitted from NGD completions (transitions, hydraulic fracturing, and flowback)	*Short Term:* Advance understanding of air toxics science by determining extent of HAP dispersion and transport from NGD well pads. *Mid-Term*: Provide insight for developing health protective strategies and rules applicable to well completions, for example through reducing HAP emission or adjustment of set backs. *Long-Term*: Reduce human exposure and adverse health effects from HAPs.	QAPP PARCC summary reports Spreadsheet (or database) with emission profiles
Dispersion Model	*Short Term*: Advance understanding of air toxics science by building and evaluating a model to predict extent of HAP dispersion and transport from NGD well pads under varying conditions for use in exposure assessments. *Mid-Term*: Provide insight for developing health protective strategies and rules applicable to well completions, for example through reducing HAP emission or adjustment of set backs. *Long-Term*: Reduce human exposure and adverse health effects from HAPs.	Model Results Final Report
Tier 2/3 HHRA	*Short Term*: Advance understanding of health risks to Battlement Mesa residents from NGD development activities by providing estimated cancer risks and acute, sub-chronic, and acute health hazards, based on ambient and residential measurements and community exposure data. *Mid-Term*: Provide insight to residents and risk managers for consideration in risk mitigation measures. *Long-Term*: Protect Battlement Mesa residents from adverse health effects from HAPs during NGD.	Final Report

G. Programmatic Capability and Past Performance

G1. Colorado Department of Public Health and Environment:

(1) National Air Toxics Trends Sites (NATTS): Since 2004, CDPHE has been a part of the NATTS program by operating a site in Grand Junction, Colorado. Originally sampling for VOCs, carbonyls and metals, semi-volatile organic sampling and hexavalent chromium sampling have been added.

(2) Ozone precursor sampling: CDPHE has conducted two sampling projects for ozone precursor compounds in the North Front Range area of Colorado, one in 2003 and the other in 2006. This

sampling was primarily focused on oil and gas development activities. CDPHE is planning on performing additional sampling for ozone precursor compounds, commencing in 2011.

G2. Garfield County Public Health:

(1) EPA Regional Geographic Initiatives (RGI) Grant Program: From 2007 to 2010, GCPH was the lead sponsoring agency and fiscal agent of this RGI project. The overarching goal of this study was to further develop the basis for decisions on how Garfield County can best manage impacts of air pollution caused by energy development. Through a well-timed combination of targeted ambient air quality monitoring, emission inventory development and community education and outreach, Garfield County and its partners were able to begin understanding effects of emissions from one of Colorado's most active NGD regions. GCPH was able to successfully manage and complete this agreement by achieving the expected outputs and outcomes. All quarterly reporting requirements were successfully met and a final technical report was submitted on time.

(2) *EPA Community Action for a Renewed Environment (CARE) Grant Program:* From 2007 to 2010, GCPH was the lead sponsoring agency and fiscal agent of this CARE Grant Level 1 project. The project's goal was to better understand community perception of key environmental health issues during a period of active energy development and community growth, effectively work with all community interests to identify priorities for addressing them, to begin implementing mitigation measures and to establish the foundation for continued community involvement even after this project was completed. GCPH was able to successfully manage and complete this agreement by achieving the expected outputs and outcomes. All quarterly reporting requirements were successfully met and a final technical report was submitted on time.

H. Budget Narrative

The CDPHE will administrate the award and provide QA oversight for the project. CDPHE will contract with our partners, GCPH, and CSPH to perform the bulk of the project. The table below provides budget details for the project.

CDPHE	**EPA Funding**	**Cost Share**
Personnel (year 1, year 2, year 3)		
Program Manager: @ 0.03 total FTE	$3,477	$0
Research Scientist @ 0.15 total FTE	$9,776	$0
Grants/Contracts Manager: @ 0.05 total FTE	$3,899	$0
Fringe Benefits		
Fringe Benefits vary by position (Retirement, Health, FICA, holiday, vacation)	$3,865	$0
Indirect		
Federal negotiated indirect cost rate = 19.6% for on-site and 1.70% for flow-thru	$15,982	$0
Total Funding for CDPHE:	**$36,999**	**$0**
GCPH **	**EPA Funding**	**Cost Share**
Personnel (year 1, year 2, year 3)		
Senior Environmental Specialist: @ $34.00, $35.02, $36.07/hr x 6 hrs/wk x 156 wks	$0	$33,100
Fringe Benefits		
Fringe Benefits @41% of salary and wages (Retirement, Health, FICA, SUI, holiday, vacation)	$0	$13,571
Subcontracts		
Laboratory Analysis of ambient air samples for SNMOCs (120 @$328/sample) and carbonyls (60@$137/sample) over 2 years*	$0	$47,580
Laboratory Analysis of 114 source profile samples for VOCs and carbonyls@$527/sample*	$60,078	$0
Laboratory Analysis of 153 dispersion profile samples for VOCs @$390/sample*	$59,670	$0
Laboratory Analysis of 24 background samples for VOCs and	$12,648	$0

carbonyls@$527/sample*		
Local student support for collection of samples during well completions (3 students @$18/hour x 40 hours/week x 6 weeks)**	$12,960	$0
Technical support for building and evaluation of AERMOD model ($110/hr x 238 hours in year 3).	$26,180	$0
Indirect Charges		
Citywide indirect Cost rate = 24.01% (indirect rate x (personnel + benefits) = indirect rate)	$0	$11,206
Total Funding for GCPH:	**$171,536**	**$105,457**
CSPH	**EPA Funding**	**Cost Share**
Personnel (year 1, year 2, year 3)		
Lead Investigator: @$55.99, 56.64, 58.33/hr x 8 hrs/wk x 156 wks**	$70,710	$0
Co-investigator: @$33.65, $34.66, $35.70/hr x 24 hrs/wk x 156 wks	$129,818	$0
Co-investigator: @ $79.23, $81.61, $84.06/hr x 2 hrs/wk x 156 wks	$25,469	$0
TBD Student assistant @20/hr x 20 hrs/wk x 26 wks in year 3 only	$10,400	$0
Fringe Benefits		
Fringe Benefits @29% McKenzie, Adgate, 30%,Witter and 1%, student of salary and wages (Retirement, Health, FICA, SUI, holiday, PTO)	$66,350	$0
Travel		
Co-investigator to Parachute, CO for sample collection (Year 1, 1 trip: [10 nights lodging @$77/night, 11 days per diem @$46/day and 2 week van rental @$2500]; Year 2, 2 trips: 1.03* year 1 costs)	$11,555	$0
Lead Investigator to Parachute, CO for community outreach meetings (Year 1, 4 trips: [1 night lodging@$77/night, 2 days per diem@$46/day and 2 day car rental at $45]; Year 2, 4 trips: 1.03*year 1 costs; Year 3 4 trips: 1.03 * year 2 costs).**	$2,646	$0
(2) Lead and co-investigator to RTP for presentation of final report (Year 3: 2 nights lodging @$99/night, 3 days per diem @$66, air fare @$450, and 3 day car rental @$100).	$1,892	$0
Supplies		
10 SKC AirChek XR5000 sampling pumps adaptors and chargers (5 from CSPH)	$5,629	$5,629
1 SKC pump calibrator	$0	$1,300
1 Meteorology station	$0	$1,800
Field Sampling Supplies	$8,000	$2,000
Office Supplies @ $1666/year	$4,998	$0
Other		
Communications (long distance) @ 500/year	$1,500	$0
Sample shipments to laboratories	$5,000	$0
Indirect		
Federal negotiated indirect cost rate = 53% (Indirect rate x (total direct costs)	$182,303	$0
Total Funding for CSPH:	**$526,270**	**$10,729**
	EPA Funding	**Cost Share**
TOTAL PROJECT FUNDING	**$734,805**	**$116,186**

*Includes costs for sample containers (i.e. Summa canisters and cartridges), field duplicates, and trip blanks.
**Community Collaboration and Outreach

Paul Reaser, MS: Mr. Reaser is a senior environmental specialist at GCPH. His responsibilities will include administering project subcontracts, oversight of ambient air sample collection at fixed monitoring stations, Garfield County meeting logistics, and community outreach through posting of updates to county environmental health web page.

Roxana Witter, MD, MSPH: Dr. Witter is a Research Assistant Professor at CSPH and will be the lead investigator for this project. She will be the primary liaison to CDPHE and GCPH, as well as the citizen groups, industrial partners, and property owners. Her responsibilities will include oversight of the research team, coordination of community collaboration and outreach, and partner communications and review all project outputs.

Lisa McKenzie, PhD, MPH: Dr. McKenzie is a Research Associate at the CSPH and will be a co-investigator for this project. She will prepare the QAPP, quarterly, interim, and final reports, manage ambient air sample collection during well completions, evaluate analytical results, compute emission factors and dispersion profiles, and prepare the HHRA.

John Adgate, PhD, MSPH: Dr. Adgate is Professor and Chair of the Department of Environmental and Occupational Health at the CSPH and will be a co-investigator for this project. His responsibilities will include CSPH QA/QC oversight, reviewing all CSPH project outputs and providing technical expertise as needed.

TBD Student Assistant: In year 3, a student will be hired to assist the investigators in evaluating and compiling data.

Gordon Pierce, MS: Mr. Pierce is the Technical Services Program Manager for the CDPHE. He will serve as the overall manager for the project.

Alicia Frazier, MS: Ms. Frazier is a Research Scientist for the CDPHE. Her responsibilities will include providing overall project QA/QC, technical assistance and final output reviews for CDPHE.

Debbie McCrorie: Ms. McCrorie is a fiscal officer with the CDPHE. Her responsibility will be to provide grant and contract management and support for the project.

I. Leveraging

To date, the Garfield County Board of County Commissioners has committed up to $354,000 of county general funds to finance the HIA and Phase 1 (design phase) of an environmental health monitoring project that provided the supporting information on which this proposal is based. In addition, as part of their ongoing air toxics monitoring program, Garfield County will provide $105,457 to fund collection and analysis of 120 ambient air samples from a fixed monitoring station, as well personnel in support of this project. Mr. Reaser brings over 10 years of air sampling and source and dispersion profiling experience to our team.

The investigators at the CSPH bring extensive experience in air sampling and analysis, QA/QC, evaluation of air data, human health risk assessment, exposure assessment, and community outreach to our project. As a board-certified Occupational and Environmental Medicine Specialist, Dr. Witter's experience spans both clinical and public health arenas. She has extensive community ties in Garfield County. As Principal Investigator on the Battlement Mesa HIA and her previous whitepaper/literature review, she is in the forefront of the discussion of health impact of NGD. In her 27 years of professional experience, Dr. McKenzie has developed methods for analyzing VOCs in air samples, coordinated large scale air sampling projects, and authored numerous QAPPs, data evaluation reports, and HHRAs. Dr. Adgate is an internationally recognized expert in exposure and risk assessment of air pollutants, and has conducted numerous field sampling studies as well as modeling of air pollutant dispersion. CSPH will contribute $10,729 in sampling and field supplies to the project.

References:

ATSDR *Health Consultation: Public Health Implications of Ambient Air Exposures to Volatile Organic Compounds as Measured in Rural, Urban, and Oil & Gas Development Areas, an Analysis of 2008 Air Sampling Data Garfield County*, Colorado. 2010.

Colorado Department of Public Health and Environment (CDPHE). Environmental Epidemiology Division. *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.

CDPHE Air Pollution Control Division. *Analysis of Data Obtained for the Garfield County Air Toxics Study Summer 2008*, October 2009a.

CDPHE Air Pollution Control Division. *Garfield County 2007 Emissions Inventory*. 2009b.

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Witter, R., L. McKenzie, et al. *Draft health impact assessment for battlement mesa, Garfield County, Colorado*. 2011.

Attachments

Bio-sketches

Letters of support

BIOGRAPHICAL SKETCH - DR. WITTER

NAME	POSITION TITLE
Roxana Zulauf Witter	Assistant Research Professor Colorado School of Public Heath

EDUCATION/TRAINING

INSTITUTION AND LOCATION	*DEGREE (if applicable)*	*YEAR(s)*	*FIELD OF STUDY*
Georgetown University, Washington, D.C.	BS	1981-1984	Biology
University of Colorado Health Sciences Center, Denver, Colorado.	MS	1989-1992	Immunology and Microbiology
University of Colorado Health Sciences Center Denver, Colorado	MD	1990-1996	Medicine
Saint Joseph Hospital, Denver, Colorado.	Intern	1996-1997	Internal Medicine
University of Colorado Health Sciences Center/National Jewish Research Center, Denver, Colorado	Resident	2003-2005	Occupational and Environmental Medicine
University of Colorado Health Sciences Center/National Jewish Research Center, Denver, Colorado.	MSPH	2003-2005	Public Health

Summary of Relevant Experience.

Roxana Z. Witter, MD, MSPH, MS is a Research Assistant Professor in the Department Occupational and Environmental Health, in the Colorado School of Public Health. She has served on the University of Colorado faculty since 2006. Dr. Witter's research on identifying and mitigating the potential effects of natural gas drilling on human health focuses on understanding the impacts of chemical emissions on physical health as well as the impacts of community change on psychosocial health. She teaches Occupational and Environmental Toxicology and has been a preceptor for Occupational and Environmental Medicine residents. She currently serves on the board of the Rocky Mountain Academy of Occupational and Environmental Medicine and on the advisory committee of the Colorado Occupational Health and Safety Surveillance System. Dr. Witter completed her BS at Georgetown University and earned an MS degree in Microbiology and Immunology, an MD degree, a residency in Occupational and Environmental Medicine and MSPH degree at University of Colorado School of Medicine. Dr. Witter has also spent several years in private clinical occupational and environmental medicine practice and working as medical director for a Denver based international corporation.

Positions and Honors.

Professional Positions

1997-2003 Staff Physician, Concentra Medical Centers, Denver, Colorado.
2005-2008 Clinic Physician, Injury Care of Colorado, Englewood, Colorado.
2005 Diplomat in Occupational and Environmental Medicine, American Board of Preventive Medicine.
2005 Medical Review Officer, Medical Review Officer Certification Council.
2006-2009 Medical Director, Gates Corporation, Denver Colorado.
2007- Physician Reviewer, National Supplemental Screening Program.
2006-2009 Clinical Instructor, Department of Preventive Medicine, School of Medicine;

Department of Environmental and Occupational Health, School of Public Health
University of Colorado Denver, Denver, Colorado (2006-2007: unpaid position, 2007-2009:
paid position).

2009-2010 Instructor, Department of Environmental and Occupational Health, School of Public Health,
University of Colorado Denver, Denver, Colorado

2010- Assistant Research Professor, Department of Environmental and Occupational Health, School of Public Health, University of Colorado Denver, Denver, Colorado

Honors and Awards

2005 Recipient, American Conference of Occupational and Environmental Medicine, Resident Research Award.

Selected Publications and Presentations.

RZ Witter, L McKenzie, M Towle, K Stinson, K Scott, L Newman, JL Adgate. Health Impact Assessment for Battlement Mesa, Garfield County, Colorado. 2011. http://www.garfield-county.com/public-health/battlement-mesa-health-impact-assessment-draft2.aspx

R Witter, K Stinson, H Sackett, S Putter, G Kinney, D Teitelbaum, L Newman. Potential Exposure Related Health Effects of Oil and Gas Development: A Literature Review (2003-2008). http://maperc.ucdenver.edu/images/Documents/literaturereview.pdf http://maperc.ucdenver.edu/images/Documents/lit%20review%20nrdc%20appendices.pdf

R Witter, K Stinson, H Sackett, S Putter, G Kinney, D Teitelbaum, L Newman. Potential Exposure Related Health Effects of Oil and Gas Development: A White Paper. 2008. http://maperc.ucdenver.edu/images/Documents/white%20paper%20final%209-15-08.pdf

RZ Witter, JW Martyny, K Mueller, B Gottschall, LS Newman. Symptoms Experienced by Law Enforcement Personnel During Methamphetamine Lab Investigations. Journal of Occupational and Environmental Hygiene, 2007, 4:12, 895 – 902.

RC Duke, **RZ Witter**, PB Nash, JD Young, DM Ojcius. Cytolysis Mediated by Pore Forming Agents: The Role of Intracellular Calcium in Apoptosis. FASEB 1994, 8:237-46.

BIOGRAPHICAL SKETCH - DR. MCKENZIE

NAME	POSITION TITLE and ASSOCIATION
Lisa McKenzie, PhD MPH	Research Associate Colorado School of Public Heath

EDUCATION/TRAINING

INSTITUTION AND LOCATION	*DEGREE (if applicable)*	*YEAR(s)*	*FIELD OF STUDY*
University of Colorado, Boulder Colorado	BA	1980-1984	Chemistry
University of Montana, Missoula Montana	PhD	1991-1996	Environmental Chemistry
Post-Doctoral Fellow, University of California, Irvine California	-	1996-1997	Climate Change
University of Colorado, Denver Colorado	MPH	2008-2010	Public Health

Summary of Relevant Experience.

Dr. McKenzie's 27 years of professional experience include teaching, research, and consulting. In her 15 years of academic, laboratory, and research experience, she has focused on health effects of natural gas development and climate change research. Her research has contributed to the understanding of how air pollutants in effect the health of wild land firefighters and people living in natural gas development areas, as well as how the smoldering combustion of biomass (forest fires and slash and burn agriculture) impacts global climate change and stratospheric ozone depletion. Dr. McKenzie's 12 years of industry experience were as an environmental chemist and human health risk assessor at EPA and in the Environmental Consulting Industry. She developed methodology for the State of Alaska for the characterization of oil from the Exxon Valdez oil spill. She has lead teams of professionals in conducting numerous human health risk assessments. In addition, Dr. McKenzie has taught graduate level risk assessment as an adjunct professor.

Positions and Honors.

Professional Positions

2010-present Research Associate University of Colorado Denver, Aurora Colorado
2009 - 2010 Teaching Assistant University of Colorado Denver, Aurora Colorado
2003 - 2009 Senior Scientist and Chemistry Group Manager, AECOM, Denver Colorado
2003 Human Health Risk Assessor, Foothill Engineering Company, Inc Golden Colorado
2003 Adjunct Professor, Colorado School of Mines, Golden Colorado
1997 - 2003 Environmental Chemist and Human Health Risk Assessor, URS, Denver Colorado
1996 - 1997 Post Doctoral Fellow, University of California, Irvine California
1991 - 1996 Research Assistant, University of Montana, Missoula Montana
1998 – 1991 Analytical Chemist, USEPA, National Enforcement Investigation Center, Denver Colorado
1987 - 1998 Analytical Chemist, USEPA Region 9, Las Vegas Nevada
1984 - 1986 High School Teacher, US Peace Corps Swaziland

Honors and Awards

2000 3rd Quarter Award for Outstanding Teamwork, URS

1993-1996	NASA Global Change Research Fellowship
1994	Lola Mae Walsh Anacker Scholarship, University of Montana
1994	Bertha Morton Scholarship, University of Montana
1992, 1993	Fuson-Howard Summer Research Fellowship, University of Montana

Selected Publications and Presentations.

RZ Witter, **L McKenzie**, M Towle, K Stinson, K Scott, L Newman, JL Adgate. Health Impact Assessment for Battlement Mesa, Garfield County, Colorado. 2011. http://www.garfield-county.com/public-health/battlement-mesa-health-impact-assessment-draft2.aspx

McKenzie, L.M., "Birth Prevalence of Oral Clefts in Rural Communities Near Natural Gas Operations", Fall Public Health Forum, University of Colorado, 2010.

McKenzie, L.M. and Bicksler, C., "Vapor Intrusion Analysis Case Study at Fort Carson Military Reservation", Environmental Monitoring and Data Quality Workshop, Atlanta, Georgia, 2008.

McKenzie, LM., "Performance Based Subcontracting of Environmental Laboratories," Environmental Monitoring and Data Quality Workshop, San Antonio, Texas, 2006.

Nicola J., Blake N., Blake D., Wingenter O., Sive B. **McKenzie L**., Lopez J., Simpson I., Fuelberg H., Sachse G., Anderson B., Gregory G., Carroll M., Albercook G., Rowland S. Influence of southern hemispheric biomass burning on midtropospheric distributions of nonmethane hydrocarbons and selected halocarbons over the remote South Pacific. *Journal of Geophysical Research*, 104, 13, 16213-116232, 1999.

McKenzie, L.M., "Measuring and Modeling of Pollutants and Toxics From Smoldering Biomass," *Encyclopedia of Environmental Analysis and Remediation,* Robert A. Meyers, ed., Wiley, 1997.

McKenzie, L.M., Ward, D.E., Hao, W.M., "Chlorine and Bromine in the Biomass of Tropical and Temperate Ecosystem," *Biomass Burning and Global Change, Volume, I,* J.S. Levine, ed., MIT Press. Cambridge, Mass. 241-248, 1997.

McKenzie, L.M., Hao, W.M., Richards, G.N., Ward, D.E., "Measurement and Modeling of Air Toxins from Smoldering Combustion of Biomass," *Environmental Science and Technology,* 29, 2047-2054, 1995.

McKenzie, L.M., Hao, W.M., Richards, G.N., "Emissions from Burning Biomass: Development of a Model," *Conversion and Utilization of Waste Materials,* R. Khan, ed., Taylor and Francis Publishing Company, pp. 189-197, 1996.

McKenzie, L.M., Hao, W.M., Richards, G.N., Ward, D.E., "Quantification of Major Components Emitted From Smoldering Combustion of Wood," *Atmospheric Environment,* 28 20, 3285-3292, 1994.

BIOGRAPHICAL SKETCH – Dr. Adgate

NAME	**POSITION TITLE and ASSOCIATION**
John L. Adgate	Colorado School of Public Health Professor

EDUCATION/TRAINING

INSTITUTION AND LOCATION	***DEGREE (if applicable)***	***YEAR(s)***	***FIELD OF STUDY***
Calvin College, Grand Rapids, MI	B.S.	1981	Biology
University of North Carolina at Chapel Hill	M.S.P.H.	1987	Environmental Science
University of Medicine and Dentistry of New Jersey/ Rutgers University, Environmental and Occupational Health Sciences Institute (EOHSI)	Ph.D.	1996	Environmental Health
Post Doctoral Fellow, EOHSI	--	1996-7	Environmental Health Sciences

Summary of Relevant Experience.
John L. Adgate, PhD is Professor and Chair of the Department of Environmental and Occupational Health at the Colorado School of Public Health. His research on exposure science, risk analysis, and children's environmental health has focused on improving exposure estimation in epidemiologic studies by documenting the magnitude and variability of human exposures to chemical and biological stressors. He has taught graduate level courses in environmental health, risk analysis and advanced methods in exposure science. Dr. Adgate has served on multiple science advisory panels for the U.S. Environmental Protection Agency as well as NRC/IOM committees exploring technical and policy issues related to residential exposure, air pollution and public health. He received a BA from Calvin College, an MSPH degree in environmental science from the School of Public Health of the University of North Carolina at Chapel Hill, and a PhD degree in environmental health sciences granted jointly by the University of Medicine and Dentistry of New Jersey and Rutgers University.

Positions and Honors.

Professional Positions

2010- Professor and Chair, Department Environmental and Occupational Health, Colorado School of Public Health, University of Colorado Denver, Aurora, Colorado
2005-2009 Associate Professor, Division of Environmental Health Sciences (DEHS), University of Minnesota School of Public Health UMSPH
1997-2006 U.S.EPA Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panels on Exposure and Risk Assessment.
1997-2005 Assistant Professor, DEHS, UMSPH.
1996-1997 Post-Doctoral Fellow, Environmental and Occupational Health Sciences Institute (EOHSI), Rutgers University/University of Medicine and Dentistry of New Jersey.
1991-1996 Graduate Fellow, EOHSI.
1987-1991 Senior Associate (1989-91), Staff Scientist (1987-89), Environ Corporation, Arlington, VA.
1986-1987 Research/Teaching Assistant, University of North Carolina at Chapel Hill
1982-1984 Peace Corps Volunteer, Kenya, Forestry/Renewable Energy Development.

Honors and Awards

2006-2007 Fulbright Visiting Scholar, Pontificia Universidad Católica de Chile
2004 International Society for Exposure Analysis: Joan M. Daisey Outstanding Young Scientist Award
2004 Delta Omega: Honorary Public Health Society
1986-1987 U.S. Public Health Service: Training Grant Award

Selected Publications and Presentations.

Adgate JL, CA Clayton, JJ Quackenboss, KW Thomas, RW Whitmore, ED Pellizzari, PJ Lioy, P Shubat, C Stroebel, NCG Freeman, and K Sexton. 2000. Measurement of multipollutant and multipathway exposures in a probability-based sample of children: Practical strategies for effective field studies. J. Expos. Anal. Environ. Epi. 10: 650-661.

Adgate JL, DB Barr, CA Clayton, LE Eberly, NCG Freeman, PJ Lioy, LL Needham, ED Pellizzari, JJ Quackenboss, A Roy, and K Sexton. 2001. Measurement of children's exposure to pesticides: analysis of urinary metabolite levels in a probability-based sample. Environ. Health Perspect. 109:583-590.

Adgate JL, G. Ramachandran, GC Pratt, LA Waller, and K. Sexton. 2002. Spatial and temporal variability in outdoor, indoor, and personal PM2.5 exposure. Atmos. Environ. 36(20): 3255-3265.

Sexton, K, **JL Adgate**, TR Church, IA Greaves, G. Ramachandran, AL Fredrickson, MS Geisser, and AD Ryan. 2003. Recruitment, retention, and compliance results from a probability study of children's environmental health in economically disadvantaged neighborhoods. Environ. Health Perspect. 111:731-736.

Adgate JL, G Ramachandran, GC Pratt, LA Waller, and K. Sexton. 2003. Longitudinal variability in outdoor, indoor, and personal PM2.5 exposure in healthy nonsmoking adults. Atmos. Environ. 37(7):993-1002.

Sexton, K, **JL Adgate**, G Ramachandran, GC Pratt, SJ Mongin, TH Stock, and MT Morandi. 2004. Comparison of personal, indoor, and outdoor exposures to hazardous air pollutants in three urban neighborhoods. Environ. Sci. Technol. 38: 423-430.

Adgate JL, LE Eberly, C Stroebel, ED Pellizzari, and K Sexton. 2004. Personal, indoor, and outdoor VOC exposures in a probability sample of children. J. Expos. Anal. Environ. Epi. 14: S4-S13.

Sexton, K, **JL Adgate**, TR Church, SS Hecht, G Ramachandran, IA Greaves, A Fredrickson, AD Ryan, SG Carmella, and MS Geisser. 2004. Children's exposure to environmental tobacco smoke: using diverse exposure metrics to document ethnic/racial differences. Environ. Health Perspect. 112:392-397.

Adgate, JL, TR Church, AD Ryan, G Ramachandran, A Fredrickson, MT Morandi, TH Stock, and K Sexton. 2004. Outdoor, indoor, and personal exposure to VOCs in children. Environ. Health Perspect. 112:1386–1392.

Sexton, K **JL Adgate**, TR Church, DL Ashley, LL Needham, G. Ramachandran, AL Fredrickson, AD Ryan. 2005. Children's exposure to volatile organic compounds as determined by longitudinal measurements in blood. Environ Health Perspect. 113: 342-349.

Ramachandran G, **JL Adgate**, S Banerjee, TR Church, D Jones, and K. Sexton. 2005. Measurements of fungal bioaerosols, carpet allergens, CO_2, temperature, and relative humidity levels in two elementary schools. J Occup Environ Hyg. 2(11):553-66.

Sexton, K, **JL Adgate**, AL Fredrickson, AD Ryan, LL Needham, DL Ashley. 2006. Using biological markers in blood to assess 10exposure to multiple environmental chemicals for inner-city children 3-6 years old. Environ Health Perspect Mar 114:453-9.

Hoppin, JA, **JL Adgate**, M Nishioka, M Eberhart, PB Ryan. 2006. Environmental exposure assessment of pesticides in farmworker homes. Environ. Health Perspect. 114 (6): 929-935.

Greaves, IA, K Sexton, MN Blumenthal, TR Church, JL Adgate, G Ramachandran, AL Fredrickson, AD Ryan, and MS Geisser. 2007. Asthma, atopy, and lung function among racially diverse, poor inner-urban Minneapolis schoolchildren. Environ Res 103(2): 257-66 .

Scher, DP, BH Alexander, **JL Adgate**, LE Eberly, JS Mandel, JS Acquavella, and MJ Bartels. 2007. Agreement of pesticide biomarkers between morning void and 24-hour urine samples from farmers and their children. J Expo Sci Environ Epi 17(4):350-7

Adgate, JL, SJ Mongin, GC Pratt, G Ramachandran, JJ Zhang, MP Field, and K Sexton. 2007. Relationships between personal, indoor, and outdoor exposures to trace elements in PM2.5. Sci Tot Environ 386(1-3):21-32.

Cho, SJ, G Ramachandran, J Grengs, AD Ryan, LE Eberly, and **JL Adgate**. 2008. Longitudinal evaluation of allergen concentrations in inner-city households. J Occup Environ Hyg Feb 5(2):107-18.

Cho, SJ, G Ramachandran, S Banerjee, AD Ryan, and **JL Adgate**. 2008. Seasonal variability of culturable fungal genera in the house dust of inner-city residences. J Occup Environ Hyg. Dec 5(12):780-9

Adgate, JL, G Ramachandran, SJ Cho, AD Ryan, and J Grengs. 2008. Allergen levels in inner-city homes: baseline concentrations and evaluation of intervention effectiveness. J Exposure Sci Environ. Epi. 18(4):430-40.

Adgate, JL, A Barteková, PC Raynor, JG Griggs, AD Ryan, BR Acharya, CJ Volkmann, DD Most, S Lai, and MD Bonds. 2009. Detection of organophosphate pesticides using a prototype liquid crystal monitor. J. Environ. Monit. 11(1) 49-55.

BIOGRAPHICAL SKETCH - Paul R. Reaser

NAME	POSITION TITLE and ASSOCIATION
Paul R. Reaser	Senior Environmental Health Specialist Garfield County Public Health

EDUCATION/TRAINING

INSTITUTION AND LOCATION	*DEGREE (if applicable)*	*YEAR(s)*	*FIELD OF STUDY*
Central Michigan University, Mt. Pleasant, MI	BS	1993-1997	Biology
University of Michigan, Ann Arbor, MI	MS	1998-2000	Industrial Health

Summary of Relevant Experience:

Mr. Reaser has over 10 years of professional experience including local environmental health and air quality management, public health and academic research, safety and compliance, and consulting. In his nearly 4 years with Garfield County Public Health, Mr. Reaser has served as the lead program manager and technical consultant for the County's ambient air quality management program. He has assisted the environmental health manager in the development and implementation of a fully functional community-based environmental health program. In addition, Mr. Reaser has directed special projects designed to assess potential community health risks associated with local oil and gas development. In nearly 4 years with Harvard University, Mr. Reaser served as lead project manager on a variety of occupational exposure projects totaling almost 4 million dollars in grant funding. He contributed as a co-author (or was acknowledged) in several peer reviewed scientific research papers and articles.

Positions and Honors.

Professional Positions

2007 - present Senior Environmental Health Specialist, Garfield County Public Health
2002 - 2005 Research Specialist, Harvard School of Public Health
2000 – 2001 Safety and Compliance Coordinator, Transfreight, LLC
1998 – 1999 Student Intern, University of Michigan Occupational Safety and Environmental Health

Honors and Awards

1998 NIOSH Trainee Fellowship Recipient
1993 Board of Trustees Honors Scholarship Recipient, Central Michigan University

Selected publications and Presentations.

"Driver Exposure to Combustion Particles in the U.S. Trucking Industry". Journal Occupational & Environmental Hygiene. 2007 November; 4(11): 848–854. M.E. Davis, T.J. Smith, F. Laden, J.E. Hart, A.P. Blicharz, **P. Reaser**, and E. Garshick.

"Effects of Wind on Background Particle Concentrations at Truck Freight Terminals". Journal of Occupational and Environmental Hygiene. 2007 Jan; 4(1): 36- 48. Hart J., Garcia R., Davis M., **Reaser P.R.**, Natkin J., Laden F., Garshick E., Smith T.J.

"Overview of Particulate Exposures in the US Trucking Industry". Journal of Environmental Monitoring. 2006 Jul; 8(7): 711-20. Thomas J. Smith, Mary E. Davis, **Paul Reaser**, Jonathan Natkin, Jaime E. Hart, Francine Laden, Allan Heff and Eric Garshick.

"Exposure of Trucking Company Workers to Particulate Matter During the Winter". Chemosphere. 2005 Dec; 61(11): 1677-90. Lee B.K., Smith T.J., Garshick E., Natkin J., **Reaser P.**, Lane K., Lee H.K.

BCC Battlement Concerned Citizens

Battlement Mesa, Colorado 81635

May 23, 2011

To: EPA Community-Scale Air Toxics Ambient Monitoring Proposal Review Committee

We are writing on behalf of the Battlement Concerned Citizens to express our support for the *Source Profiles and Dispersion of Air Pollutants from Natural Gas Development in Garfield County*, *Colorado* study proposal submitted to you by the Colorado Department of Public Health (CDPHE) in partnership with the Garfield County Department of Public Health (GCPH) and the Colorado School of Public Health (CSPH).

Battlement Mesa is an unincorporated community of approximately 5,000 people in Western Colorado, with a large senior population. On May 27, 2009 Battlement Mesa Co., the developer of Battlement Mesa, made a public announcement that they had reached an agreement with Antero Resources for exploration and development of natural gas within the Battlement Mesa planned unit development (PUD), and that Antero was planning to drill 200 natural gas wells within our community.

The Battlement Concerned Citizens was formed in August, 2009 by a group of residents that felt that their concerns over health, safety and welfare were not being adequately addressed. We circulated a petition throughout the community, obtaining over 400 signatures, requesting that Garfield County, the Colorado Oil and Gas Conservation Commission and the Colorado Department of Public Health and Environment defer action on any applications to allow natural gas development to occur within Battlement Mesa until a Health Impact Assessment (HIA) had been completed. The petition was presented to the County in October, 2009 The commissioners contracted the Colorado School of Public Health (CSPH) to conduct the HIA in May 2010.

We have been an active stakeholder in the HIA, regularly meeting with the CSPH research team and providing comments on the HIA report. We commend the CSPH's effort on the HIA and support the recommendations therein. The HIA identified a lack of information on emissions of air pollutants during specific natural gas development activities and dispersion of air pollutants from natural gas wells as a serious gap in understanding impacts to public health. We are very concerned that without further study, such as proposed here by CDPHE, impacts to public health may not be adequately considered in land use decisions regarding natural gas development within our community. We believe it is imperative that these information gaps are filled as quickly as possible in order to provide our County Commissioners with the

information they need to protect our health as we face the prospect of living with natural gas development next door.

The people of Battlement Mesa want a well-founded decision related to natural gas production within our PUD, and in so doing, public health risks need to be studied in more detail to ensure public health protection during all stages of development.

The natural gas industry is hazardous and our community deserves additional levels of protection if multiple wells are to be developed. Therefore, we fully endorse the proposed Community-Scale Air Toxics Ambient Monitoring study by the CDPHE, in partnership with GCPH and CSPH. We look forward to continuing to share our thoughts, concerns, and resources with them. We encourage EPA to fund this very important and worthy study.

Sincerely,

(signed) *Dave Devanney* (signed) *Paul Light*
Co-Chairs, Battlement Concerned Citizens

Garfield County
BOARD OF COUNTY COMMISSIONERS

May 9, 2011

To the United States Environmental Protection Agency (EPA):

Garfield County has seen significant natural gas development over the last ten years. Community members continue to raise concerns regarding rapid industrial development and the potential to impact the health of people. Garfield County has dedicated a substantial amount of resources (financial and personnel) to better understand potential health effects associated with hazardous air pollutants, particularly in densely populated areas. As County Commissioners we also sit as the County Board of Health and among our responsibilities in this role, we work to address community health concerns.

We anticipate that the proposed Community-Scale Air Toxics Ambient Monitoring grant would provide us with information that will guide future air quality management decisions in our County. This project would fit in nicely with the design of a proposed environment health monitoring study (EHMS) that that is currently under development. This study would help us to begin filling significant data gaps to better understand short term health risks associated with hazardous air pollutants within the County.

The Garfield County Board of County Commissioners endorses the Colorado Department of Public Health and Environment's application for a Community-Scale Air Toxics Ambient Monitoring grant and respectfully requests that the EPA fund this request.

Thank you,

John Martin, Chair
Board of County Commissioners

108 8th Street, Suite 213 • Glenwood Springs, CO 81601
(970) 945-5004 • Fax: (970) 945-7785

Colorado School of Public Health

Department of Environmental and Occupational Health

13001 E. 17th Place
Campus Box B-119
Aurora, CO 80045
Main: 303-724-5678

May 18, 2011

Gordon Pierce
Colorado Department of Public Health and Environment
APCD-B1
4300 Cherry Creek Drive South
Denver, CO 80246-1530

Dear Gordon:

As Chair of the Department of Environmental and Occupational Health at the Colorado School of Public Health I am pleased to write this letter of commitment in support of Colorado Department of Public Health and Environment's grant application "*Source Profiles and Dispersion of Hazardous Air Pollutants from Natural Gas Development in Garfield County, Colorado" under the EPA's* Community-Scale Air Toxics Ambient Monitoring (RFP # EPA_OAR_OAQPS-11-05) .

The proposed study will provide much needed data for understanding public health risks from natural gas development.

We look forward to working with CDPHE and the Garfield County Department of Public Health on this important project.

Sincerely,

John L. Adgate, PhD
Professor and Chair
Department of Environmental and Occupational Health
Colorado School of Public Health
303.724.4692
john.adgate@ucdenver.edu

University of Colorado Denver | Colorado State University | University of Northern Colorado

APPENDIX C

EXAMPLE COMMUNITY SURVEY QUESTIONNAIRE

How Are You Doing?

Individual Health Survey

ID#_____

General Health Information

In general, what is the quality of your health?

Outstanding____ Good_____ Some chronic issues_____ Poor_____

To your best recollection, what was the quality of your health one year ago?

Outstanding____ Good_____ Some chronic issues_____ Poor_____

Would you consider your health to be:
_____much better than 1 year ago
_____somewhat better than 1 year ago
_____same as 1 year ago
_____somewhat worse than 1 year ago
_____much worse than 1 year ago

How often have you visited your primary care doctor or caregiver in the last year?

1 Visit_____ 2-5 Visits_____ 6 or more Visits_____

Have you visited any medical specialists in the last year?

Yes	Specialist	More or less than last year?
	Lung specialist (Pulmonology)	
	Heart specialist (Cardiology)	
	Ear, nose and throat specialist (ENT)	
	Brain, nervous system specialist (Neurologist)	
	Digestive system specialist (Gastroenterology)	
	Cancer/blood disorder specialist (Oncology/hematology)	
	(Endocrinology)	
	Mental health specialist (Psychology)	

Health History
Please tell us about your health status.

A doctor or health care provider has told me I have or have had:

YES	DIAGNOSIS	Treated by a doctor	New since 1 year ago
	Emphysema, Chronic Obstructive Pulmonary Disease (COPD)		
	Bronchitis		
	Pneumonia		
	Tuberculosis		
	Asthma		
	Allergies		
	Heart Disease		
	Stroke		
	High Blood Pressure, Hypertension		
	Elevated Cholesterol		
	Diabetes		
	Hepatitis A		
	Hepatitis B		
	Hepatitis C		
	Cirrhosis		
	Anemia		
	Thyroid Trouble		
	Gallbladder Disease		
	Ulcers		
	Frequent Urinary Tract Infection		
	Sexually Transmitted Infection		
	Prostate Trouble		
	Cancer		
	Arthritis		
	Osteoporosis		
	Fractures		
	Headaches, Migraines		
	Depression		
	Anxiety		
	Panic Disorder		
	Post-traumatic Stress Disorder		
	Alcohol or Substance Use Problem		
	Other:_____		
	Other:_____		
	Other:_____		

Health Systems Review

Please check any of the following symptoms that you have experienced. Tell us if you attribute any of these symptoms to an exposure associated with gas or oil well exposure and describe this exposure.

GENERAL		In the last month	In the last year	Attribute to gas/oil well exposure?	Describe exposure (odors, dust, water quality, etc)
	Weight loss				
	Weight gain				
	Fatigue				
	Current Weight_____				
	Fever				
	Increased appetite				
	Decreased appetite				
	Night sweats				
Skin	Rashes				
	Lumps				
	Color change				
	Hair loss				
	Nail changes				
Head	Headaches				
	Head injuries				
	Dizziness				
Eyes	Irritation/redness				
	Pain				
	Itching				
Nose	Frequent colds				
	Nasal stuffiness				
	Nosebleeds				
	Sinus trouble				
	Hay fever				
	Dust/ animal allergies				
Ears	Hearing trouble				
Mouth and	Bleeding gums				

Throat					
	Frequent sore throats				
	Hoarseness				
Neck	**Swollen glands**				
	Pain				
Respiratory	**Cough**				
	Wheezing				
	Shortness of breath				
	Cough up blood				
Cardiac	**Heart murmur**				
	Chest pain				
	Palpitations				
	Swelling of feet				
	Heart attack				
	Abnormal heart rhythm				
Gastro-intestinal	**Trouble swallowing**				
	Heartburn				
	Nausea				
	Vomiting				
	Abdominal pain				
	Diarrhea				
Urinary	**Blood in urine**				
	Kidney stones				
Musculo-skeletal	**Joint stiffness**				
	Muscle pains/cramps				
	Arthritis				
	Leg cramps while walking				
Neurological	**Fainting**				
	Weakness				
	Tingling hands or feet				
	Blackouts				
	Numbness				
	Change in memory				

	Seizures				
	Tremors				
Psychological	**Anxiety**				
	Depression				
	Feel stressed				
	Sleep problems				
	Family problems				
	Physical abuse				
	Psychological abuse				
Hematologic	**Anemia**				
	Easy bruising				
Endocrine	**Heat/cold intolerance**				
	Excessive sweating				
Gynecologic	**Abnormal bleeding**				
	Miscarriage # times_____				
	Abnormal pap				

*** For each symptom that you attribute to gas/oil well activity, please describe what kind of activity was going on at the well pad, to the best of your ability.**

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Visits and Hospitalizations

Have you been seen in the Emergency Room in the last month?
No_____ Yes_____ Number of times_____
List reasons for your ER visit(s)
_____
_____

Have you been seen in the Emergency in the last year?
No_____ Yes_____ Number of times_____
List reasons for your ER visit(s)
_____
_____

Have you been admitted to the Hospital in the last month?
No_____ Yes_____ Number of times_____
List reasons for your Hospital admission(s)
_____
_____

Have you been admitted to the Hospital in the last year?
No_____ Yes_____ Number of times_____
List reasons for your Hospital admission(s)
_____
_____

Have you had surgery(ies) in the last year?
No_____ Yes_____

List reasons for your surgery(ies)
_____
_____

Alternative forms of Medical Care
In the last year, have you seen

Yes	
	Chiropractor
	Osteopathic doctor
	Naturopathic doctor
	Massage therapist

Yes	
	Medical Marijuana caregiver

Medications
Please list your prescription medications

Medication	Dose/frequency	Date/year first prescribed

Please list over the counter and herbal medications you use

Over the Counter Medications and Herbal Medications	Dose/frequency	Date/year first used

Substance Use History

How many alcoholic drinks do you consume per week?
None_____ 1-2_____ 3-6_____ 7-10_____ over 10_____

Have you ever been concerned about your drinking? Yes_____ No_____
Has anyone you know (a family member, friend or co-worker) been concerned about your drinking or suggest you cut down? Yes_____ No_____

Do you currently smoke cigarettes? Yes_____ No_____

If no,
Are you exposed to second hand smoke? Yes_____ No_____
If yes,
How many cigarettes do you smoke per day? _____
How many years have you been smoking?_____
Have you tried to quit smoking? Yes_____ No_____

Have you quit smoking? Yes_____ When?_____
How many years did you smoke?_____

Have you/do you use any of the following:

	How often	Last time	How (smoke, inject, etc)
Marijuana			
Cocaine			
Methamphetamine			
Heroin			
Ecstasy, Mushrooms, LSD			
Other_____			

To your knowledge, have you ever shared needles, cooker, rinse water?
Yes_____ No_____

Have you had problems related to your drug use? (ie relationships, problems at work, depression, anxiety, physical health)?

_____
_____
_____

Lifestyle History
Please check all that apply and provide details where possible:

____I exercise_____ hours per week
Kinds of exercise_____
_____I increased exercise in the last year
_____I decreased exercise in the last year

____ I watch TV, movies, or online entertainment _____ hours per week

____ I have pets at home
Kinds of pets_____
Do the pets live in the house? Yes_____ No_____
Some (describe) _____

Family circumstances
Please tell us about your family:

Married_____ Separated_____ Divorced_____
Describe any changes in status in the last year_____
Birth/adoption in the last year? Yes_____ No_____
Financial problems Yes_____ No_____ Legal problems Yes_____ No_____
Severe family illness Yes_____ No_____ Family death Yes_____ No_____
Physical violence in the home? Yes_____ No_____
Parent out of town for work? Yes_____ No_____
Other changes in the family?
_____
_____

Occupations (list all occupations, including work in the home)
Current_____Unemployed_____
1 year ago_____ Unemployed_____
5 years ago_____Unemployed_____
More than 5 years ago
_____
_____
_____

Have you been exposed to substances at work that you think could harm your health?
_____
_____

Environmental Exposures

Yes	
	Drinking water
	Well water
	City water
	My water quality has improved over the last year
	My water quality has deteriorated over the last year

Exposure to natural gas/ oil wells:

____ I live in a county where natural gas/ oil is currently being developed.
____ I do not live in a county where natural gas/ oil is currently being developed.

I live____ work ____ go to school ____ near gas wells. (check all that apply)

I live____ work ____ go to school ____ near oil wells. (check all that apply)

I live:	Developed this year	Producing this year	Re-stimulated this year
Less than ¼ mile from gas/oil wells			
¼- ½ mile from gas/oil wells			
½ mile- 1 mile from gas/oil wells			
1-2 miles from gas/oil wells			
More than 2 miles from gas/oil wells			

Please describe any other well development, production, or maintenance activities that have been occurring near your home, work or school over the last year.

_____
_____
_____
_____

Over the last year, I have noticed odors in my home that I attribute to natural gas well development and/or production
0 times_____ 2-5 times_____ 10-20 times ____ more than 20 times_____

Over the last year, I have noticed lights at night in my home that I attribute to natural gas well development and/or production
0 times_____ 2-5 times_____ 10-20 times ____ more than 20 times_____

Over the last year I have noticed noise in my home that I attribute to natural gas well development and/or production
0 times_____ 2-5 times_____ 10-20 times ____ more than 20 times_____

Over the last year I have noticed noise *at night* in my home that I attribute to natural gas well development and/or production
0 times_____ 2-5 times_____ 10-20 times ____ more than 20 times_____

Over the last year I have noticed dust in my home that I attribute to natural gas well development and/or production
0 times_____ 2-5 times_____ 10-20 times ____ more than 20 times_____

Over the last year I have noticed engine exhaust fumes in my home that I attribute to natural gas well development and or production
0 times_____ 2-5 times_____ 10-20 times ____ more than 20 times_____

Over the last year I have noticed a change in my water quality that I attribute to natural gas well development and or production
0 times_____ 2-5 times_____ 10-20 times ____ more than 20 times_____

For Children under age 12:
Month/ year of birth_____
Sex Male_____ Female_____

Full term Yes_____ No_____ Premature: how many weeks at birth? _____
Birth weight _____lbs. _____oz In NICU Yes_____ No_____
Type of delivery: Spotaneous_____ Cesarean_____ Induced_____
Twins/Mulitple_____ Head first_____ Breech_____ Insturments/forceps_____

List complications at birth
_____
_____

Any concerns about your child's development? (Circle all that apply)
Motor development (sit alone, walk, clumsy, gross or fine motor delay, writing/drawing, eating)

Cognitive development (age delay, delayed thinking, delayed learning)

Speech and language development (first word delay, 3 word phrase delay, difficulty with pronunciation, hearing concerns)

Adaptive skills (feeds self, toilet training, sleep problems, lost skills that had previously)

Social skills (poor eye contact, doesn't point, doesn't seek out attention from others, doesn't play with children, poor social skills compared to others, difficulty making friends)

Current Behavior (circle all that apply)
impulsive, overactive, short attention span, distractible, daydreams, classroom disruption, easily frustrated, easily overstimulated, doesn't follow directions, oppositional/defiant, destructive, aggressive, mean/bully, poor school work, low self-esteem, withdrawn/isolated, excessive worries/fears, unable to separate from parent, depressed, suicidal thoughts, strange thoughts/behaviors, psychiatric problems, emotional problems, poor eye contact, more interested in things than people, rocking/spinning/hand flapping, overreacts with problems, self-injurious, drug/alcohol use, sexualized behavior

School Problems (circle all that apply)
Problems in school over the last year? (suspended, expelled, repeated a grade, below expectations for grade, other _____)
Problems in school before the last year? (suspended, expelled, repeated a grade, below expectations for grade, other_____)

Community Life

Over the last year, has your community experienced any changes?

Yes	
	Noticeable increase in the number of people
	Noticeable decrease in the number of people
	Noticeable change in the demographics of the community (check any that apply) **Change in average age____** **Change in ratio of males to females____** **Change in ratio of race/ethnicity ____**
	Noticeable improvements in the livability of the community
	Noticeable deterioration in the livability of the community
	Traffic is better than it was a year ago
	Traffic is worse than it was a year ago

Please describe both positive and negative changes to your community over the last year:

_____
_____
_____

Over the last year, how have you felt about living in your community?

Yes	
	I like living here more this year compared to last year
	I like living here less this year compared to last year
	I like living here and this has not changed over the last year
	I don't like living here and this has not changed over the last year
	My community provides
	activities that connect me with other people
	physical activities that improve my health

Please describe your impressions of the livability of your community:

_____
_____
_____

Reactions to positive changes in my community

Positive changes in my community	
	make me feel more relaxed sometimes_____ often_____
	make me feel rested sometimes_____ often_____
	make me feel happy sometimes_____ often_____

Please describe the positive changes in your community that support your well-being

_____
_____
_____

Reactions to negative changes in my community

Problems in my community	
	cause me stress sometimes_____ often_____
	worry me enough to disrupt my sleep sometimes _____ often_____
	cause me to feel anxious sometimes_____ often_____
	cause me to feel depressed sometimes _____ often_____
	worry me enough to seek mental health support _____

Please describe the community problems that cause you stress

_____
_____
_____

Schools

For families with school age children:
Please tell us about the your children's school(s). (check all that apply)

_____I am pleased with my children's school
_____I am not pleased with my children's school

_____I have noticed the schools are more able to educate children
_____I have noticed the schools are less able to educate children

_____I have noticed that the classrooms are less crowded this year compared to last year
_____I have noticed that the classrooms are more crowded this year compared to last year

_____I have noticed that the teachers are able to maintain a positive classroom environment
_____I have noticed that the teachers are not able to maintain a positive classroom environment

_____I have noticed that services for children of special needs are improved in my children's schools since last year
_____I have noticed that services for children of special needs are worse in my children's schools since last year

_____I have noticed that the facilities at my child's schools have improved over the last year
_____I have noticed that the facilities at my child's schools are worse or less adequate than they were last year

Please describe positive and negative changes you have noticed in your children's schools:
_____
_____
_____