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**Summary of Assessment of the Air Quality Modeling
Efforts in Southwest Wyoming**

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SUMMARY

Lawrence Berkeley National Laboratory (and Envair, in a subcontract to LBNL) and Radian International collaborated on this study. Part I represents the findings of LBNL that emphasize examining the modeling system and supporting data bases. Part II represents the finding of Radian that emphasize emissions and trends in emissions in the oil and gas industry.

PART I.

The Department of Energy has sponsored the Atmospheric Program of the Environmental Energy Technologies Division at Ernest Orlando Lawrence Berkeley National Laboratories (LBNL) to examine modeling and analysis procedures associated with evaluating the current and future air quality and visibility impacts of oil and gas development in southwestern Wyoming. The first phase of LBNL's and Envair's effort is an assessment of modeling plans and practice and a survey of the regulatory issues. This document presents the main findings of this assessment; however, the main findings are summarized in the next *four paragraphs*. A longer report has been written for the Department of Energy that discusses our finding in substantially more detail.

Source-oriented models are based on fundamental or empirical representations of pertinent physical and chemical atmospheric processes. They predict ambient concentrations of particulates given relevant source characteristics and emission rates of primary particulates and precursor gases and suitable representations of meteorological phenomena. Source modeling of visibility consists of two parts. First, one must build a model to determine the net formation of aerosols (particulates) having a given set of properties. The model must include an approach to calculating the properties of the particles. The properties of interest include the type of aerosol (e.g., nitrate, sulfate, or secondary organic aerosol), aerosol size, aerosol composition (this might be accomplished using some sort of reduced scheme), and whether or not the aerosol is hygroscopic or hydrophobic. Second, using the output of the model, an aerosol distribution would be developed where the particles would be classified according to their properties. The properties would be used to evaluate optical properties using Mie theory [Bohren and Huffman, 1983]. The optical properties and concentrations of particles having specific values of the optical properties would be major inputs into a visibility model that is based upon Mie theory.

In this context, it is important to recognize that a model of the type described in the previous paragraph is extremely complex and beyond the current-state-of-the-art. Building such a particle model requires a correct formulation as well as supporting databases for developing inputs and for evaluating model performance. The model must contain a proper formulation of the gas phase chemistry, the heterogeneous chemistry, and the meteorology. In addition there must be a description of the aerosol formation and growth physics that includes nucleation (gas-to-particle conversion), coagulation, condensation/evaporation, and the partitioning of organic compounds between the particle (liquid) and gas-phases. Aerosol concentrations are also affected by removal through wet and dry deposition processes, and these must be described properly as well. Input

data for emissions, aerosol thermodynamics, meteorology, ambient concentrations of particles and gases are needed both at ground-level and aloft.

Visibility modeling in the Central Rocky region presents an extreme challenge to the modeler because visibility concerns are “clean air issues” where the effort is directed toward maintaining a pristine environment. Supporting emissions and aerometric data for these areas are woefully inadequate. Since the allowed change in visibility is very small, there is no source model in existence in today’s suite of models that has this degree of accuracy associated with it [Seigneur et al., 1997]. Furthermore, a visibility model would most reasonably be regional in scale because aerosol (particle) lifetimes are commensurate with regional scales. Additionally, a most likely requirement would be that visibility would need to be evaluated over a longer period, for example, a year rather than a few days. This combination of spatial and temporal requirements and the associated data requirements imposes a significant strain on the modeling system.

There are significant uncertainties associated with the current modeling study, with respect to input data (emissions and meteorology), model formulation (treatment of gas phase chemistry, aerosol chemistry, and aerosol dynamics) as well as a sparsity of data for model performance evaluation. The final model documentation should be thoroughly scrutinized in light of these concerns. This is especially important for establishing the utility of the present modeling system and the adequacy of its results for accurately characterizing the impacts of oil and gas development on visibility in southwestern Wyoming.

1. PRIMARY CONCERNS

During the past twenty years air quality modeling has made the transition from a research and development endeavor (in the 1970s) to an activity commonly employed in planning and analysis and required in specifications of the 1990 Clean Air Act Amendments. In the best of circumstances modeling poses numerous challenges to the investigator. [See Roth (1998) for a discussion of issues to consider in planning and conducting a modeling study.] Restrictions of budget, schedule and permissible duration of the work, staff availability, and data availability generally exacerbate the difficulties. Thus, considerable thought must be given to the enterprise at the start to ensure that a “best effort” is launched. At the same time one cannot assume that this effort will be “good enough”. It is entirely possible that, despite best intentions and effort, undetected errors (perhaps undetectable, given the availability of data) will taint the modeling study and result in incorrect findings. This is both the challenge and the fear.

Three key limitations must be confronted in conducting modeling for southwestern Wyoming: (a) a very sparse aerometric data base, (b) a plan for and commitment to only limited model evaluation (in part due to the paucity of data) despite a very real possibility that the “best available” model may not be “good enough”, and (c) a very small budget to support the work. In the “best of circumstances”, based on past experience, we can expect that considerable uncertainty will accompany the modeling and analyses of both the base cases and control strategies. This uncertainty typically will be due to errors in model inputs and formulation and to

the inevitable contribution of intrinsic variability attributable to natural and anthropogenic stochastic processes. These three challenges comprise the core of our concerns about modeling currently being carried out by the Southwestern Wyoming Technical Air Forum (SWYTAF).

The Department of Energy has concerns about the model choice, model performance, and the use of the model in the policy arena. Of particular note is the lack of scientific understanding required to model visibility and the inadequacy of the supporting data. This has lead to additional concerns about the process by which other oil and gas development impacts will be evaluated and managed throughout the country. The application of CALPUFF by SWYTAF has raised a number of technical questions. The first phase of LBNL's effort is an assessment of the modeling effort, the supporting data, and a survey of the regulatory issues. The initial findings of this assessment are documented in a draft interim report (Lunden et al., 1999).

Properly addressed, the concerns presented in this study would enhance the prospects for improved modeling. However, unless the core challenges outlined are seriously confronted and surmounted, uncertainty is likely to dominate findings, issues will probably not be resolved, and the potential for conflict or differences among interested parties unfortunately will remain.

2. KEY TECHNICAL ISSUES

To properly define the questions that need to be addressed, it is necessary to unambiguously define the air quality issues targeted by the regulatory agencies, and then to identify the pollutants and atmospheric processes of concern that contribute to the problem. In southwest Wyoming, the environmental impacts of primary concern are degradation of visibility and the acid neutralizing capability of surface waters due to present and future oil and gas development in the region. The primary focus of the LBL assessment is on visibility degradation not lake acidification.

Visibility is a complex phenomenon that encompasses physical processes such as meteorology, gas phase chemistry, and a number of aerosol formation and growth routes and as such, poses numerous challenges. The salient points defining visibility and the challenges associated with characterizing it are outlined below.

- Visibility degradation lessens the contrast between an object and its background. It is caused by the interaction of light with aerosol particles and gasses present in the atmosphere. This interaction, called light extinction, is primarily due to the scattering and absorption of light by aerosol particles in the atmosphere.
- Visibility degradation is caused by a complex mixture of aerosol species. The key variables that determine the light extinction caused by any individual particle are the particle's size and optical properties, which depend upon particle composition. The chemical composition of an aerosol can vary with size, or between particles of the same size. The amount of information necessary to characterize this complexity is rarely, if ever, measured.

- The presence of water in the atmosphere is an additional and significant variable affecting extinction.

Thanks to federally financed visibility monitoring programs, such as IMPROVE, some statistics about the current visibility conditions in southwest Wyoming are available.

- Fine aerosol particles (less than 2.5 μm) contribute about half of the light extinction in the area. Of the fine mass, organic and sulfate aerosol are the largest contributors.
- Extinction due to natural conditions in the atmosphere accounts for approximately 40 percent of the light extinction in the area, indicating a relatively clean atmosphere.
- Given the relatively clean conditions, only a small increase in aerosol mass is necessary to produce a noticeable degradation in visibility that will result in an increase of 1 deciview. Therefore, when evaluating the model output, it is important to carefully analyze the uncertainties in the calculations. Such uncertainties could lead to estimated changes in visibility that range from unnoticeable to significant.

2.1 The Available Data Base

Monitoring plays a central role in any air quality assessment program. Measurements are employed to support data analysis activities, to develop model inputs, and to evaluate model performance. We have several concerns about the adequacy of the existing air quality, meteorological, and emissions data bases.

a) Air Quality

- There are limited monitoring data for southwestern Wyoming. Extinction (or scattering) and the aerosol chemistry necessary to apportion the extinction according to aerosol species is measured at only three locations in Wyoming. Of these, the only monitoring station that is located in the current SWYTAF modeling domain is in the Bridger Wilderness. The limited data make it impossible to assess air quality model performance for this region.
- Sources of gaseous and particulate pollutant measurements include IMPROVE, Clean Air Status and Trends Network (CASTNet), National Atmospheric Deposition Program/National Trends Network (NADP), and the EPA State and Local Air Monitoring Stations (SLAMS) Network.

b) Meteorology

- Sources of meteorological data collected in the 1995 modeling period in Wyoming and the immediately surrounding area include National Weather Service surface and upper air measurement sites, the Department of Interior Remote Automatic Weather Stations, IMPROVE, U.S. Forest Service Visibility Program, National Park Service Gaseous Pollutant Monitoring Program, Wyoming State Department of Transportation sites, National Dry Deposition Network, industrial sites, and the Mount Zirkel Reasonable Attribution Visibility Study [Watson

et al., 1996]. With the exception of the Mt. Zirkel study, no special meteorological measurements were conducted in the southwestern Wyoming area to support planned air quality modeling activities.

- A key issue influencing the adequacy of the simulated meteorological fields is the availability of suitable input data. Of particular concern is the absence of information on the vertical structure of the wind and temperature fields in key areas of the modeling domain. The potential complexity of the meteorological fields can be surmised from a review of the Mt. Zirkel Reasonable Attribution Visibility Study where special efforts were undertaken to characterize such phenomena. The paucity of suitable independent measurements in southwest Wyoming will make it difficult to evaluate the performance of the meteorological modeling system.

c) Emissions

- The emissions inventory for the SWYTAF modeling study is not fully documented. All emission factor and activity estimates should be clearly described and referenced so that they may be evaluated by independent review. The uncertainty of each emission estimate should also be stated.
- There is a paucity of direct measurements of organic compound emissions for two important sources in southwest Wyoming: *(1) the oil and gas industry, and (2) vegetation*. The methods used to develop emission factor estimates for oil and gas industry equipment and several of the processes are poorly documented in the current inventory, and in some cases may be based on highly uncertain engineering assumptions. Specific concerns include:
 - ◆ The uncertainties introduced through the use of EPA's AP-42 emission factor database to estimate emissions from oil and gas industry equipment, including diesel engines, in southwest Wyoming.
 - ◆ The unsupported engineering assumptions, especially regarding the quantity and composition of the organic compound fraction, used to estimate emissions from blowdown and flaring of gas wells.
 - ◆ The lack of speciated measurements of C₈+ organics (compounds having more than 8 carbon atoms) from oil and gas industry processes.
 - ◆ The lack of uncertainty estimates for all emission sources.
 - ◆ The assumption that activity and emission factors reported and measured in two gas fields (Moxa and Wamsutter) are representative of all gas fields in the area.
- There is a need to develop more accurate estimates of oil and gas industry emissions, as well as the associated uncertainty of these emission estimates. This need may be met by collecting activity data from a broader sample of gas wells and expanding programs to directly measure the total mass and speciation of emissions in the field. Production data would also be valuable for validation of emissions.

2.2 The Modeling Approach

A suitable modeling approach provides an adequate representation of all key atmospheric processes. We have reviewed the selected modeling framework, CALPUFF, and identified some concerns regarding its application in southwestern Wyoming.

a) Air Quality Modeling Framework

Four issues are of particular concern regarding the use of CALPUFF to provide air quality assessments in southwest Wyoming:

- CALPUFF is based on a time-varying, expanding puff approach that has primarily been employed to treat the dispersion of pollutants emitted from large point sources. While it is also applied to aggregates of point sources (i.e., area sources), it is unclear that this approach is as well suited for such applications as the traditional grid-based model. In southwestern Wyoming, “build-out” scenarios include up to 10,000 individual sources. Grid models are designed to address this type of source situation; further work is needed to demonstrate the suitability of the CALPUFF approach for such applications.
- Grid models were designed and are applied to situations in which the treatment of gas phase chemistry is a primary feature of the dynamic system in which pollutants are formed in the atmosphere. They simulate these dynamics explicitly by a detailed description of fundamental chemical interactions. In contrast, CALPUFF is primarily a multi-source plume model that treats transport downwind and dispersion along the transport path. The representation of gas phase chemistry is highly simplified, relying on linearization and parameterization of the chemical relationships. These simplifications are likely to be deficient when applied to situations in which complex chemistry dominates the processes responsible for formation of secondary air pollutants. Such secondary air pollutants are an important source of visibility degradation in southwestern Wyoming. (Refer to our more detailed discussion of gas phase chemistry below.)
- Grid models provide a framework for accommodating more fundamental treatment of aerosol dynamics and gas phase chemistry. CALPUFF cannot incorporate such treatments; instead, derived correlations are used. Generally, these are less able to describe the dynamic behavior of aerosol formation.
- Application of CALPUFF in southwestern Wyoming entails the modeling of a large number of plumes, which inevitably will overlap in many cases. The chemistry of overlapping plumes is not treated directly in CALPUFF, or for that matter, in any model. In grid-based modeling systems, the chemical reactions that occur in areas of plume overlap can only be represented insofar as such models can provide adequate spatial resolution of the individual plumes. (In many instances this resolution is limited by the grid cell dimensions, which are usually of the order of several kilometers). While the plume orientation of CALPUFF provides some means for spatially resolving individual plumes, it is not designed to treat the chemical reaction phenomena that may occur in the area where plumes overlap.

b) Meteorological Modeling

In reviewing the meteorological data base and modeling approach, we make several observations.

- Data analyses conducted as part of the Mt. Zirkel Reasonable Attribution Visibility Study indicate that complex wind flow and mixing conditions are likely to occur in the southwestern Wyoming area. The adequacy of air quality and visibility model performance will be contingent on the availability of suitable measurements and the ability of the meteorological modeling system to adequately represent these transport phenomena.
- The development of meteorological inputs for CALPUFF involves using both the CALMET diagnostic model and the MM5 prognostic model. Although MM5 represents the state-of-the-science in meteorological modeling, it was deemed impractical to apply on a spatial grid sufficiently fine to resolve important terrain-induced features in the flow fields. Instead, MM5 is being applied to a nested domain with 60 and 20 km grid resolutions. The MM5 results are then used as inputs to the CALMET model, which is being applied on a grid with 4 km horizontal resolution.
- The combined use of CALMET and MM5 is a pragmatic means for developing meteorological inputs for air quality and visibility modeling. The approach might be improved by a full nested grid application of MM5 to the 4 km horizontal grid resolution being employed in CALMET. However, it is unclear that significantly more reliable meteorological fields would result from such an approach. Considerably more computing time would be required to develop the meteorological inputs needed for annual air quality modeling.
- The adequacy of the simulated meteorological fields is related to the availability of suitable input data. Of particular concern is the absence of information on the vertical structure of the wind and temperature fields in key areas of the southwestern Wyoming. The potential complexity of the meteorological fields can be surmised from a review of the Mt. Zirkel study where particular efforts were undertaken to characterize such phenomena. The paucity of suitable independent measurements in southwest Wyoming will make it difficult to evaluate the performance of the meteorological modeling system.

c) Emissions Modeling

While the development of an accurate emissions inventory is a difficult endeavor, the following issues are of particular concern for the SWYTAF study

- The current modeling approach considers secondary organic aerosol production from only four species: toluene, xylene, alpha-pinene and beta-pinene. The current emission inventory speciates emissions of total organic compounds to estimate these four compounds. Secondary organic aerosol (SOA) can form from many additional organic compounds, some of which are prominent components of emissions from oil and gas operations. Both the chemical mechanism and the emissions inventory should include an assessment of SOA production from additional organic compounds.

- Biogenic sources have been estimated to contribute a large majority of the organic compounds that form secondary organic aerosol in southwest Wyoming [EarthTech, Inc. and Air Sciences, Inc., 1998]; as a result it is crucial that the biogenic VOC inventory be as accurate as possible and include uncertainty estimates. While it is impractical to measure directly the emissions of the varied biota in southwest Wyoming over a full growing season (emissions depend on growing season, temperature, moisture, atmospheric composition, and light), it is important to understand the limitations and uncertainties of the model predictions. These include uncertainty in measurements on which the model's emission factors are based, uncertainty in the parameterization of the emission factor-activity relationships (e.g. the effect of temperature), and the degree to which vegetation in southwest Wyoming is different than the vegetation used to develop model emission factors. The BEIS model does not consider many types of vegetation that are characteristic of the Western landscape, for example, sage brush.
- The biogenic inventory estimates are presented for "high" and "moderate" emission canopies. These two estimates, which differ by nearly a factor of 3, were developed by selecting different forest type and tree species emission factors included in the BEIS2 model. The process of selecting appropriate BEIS2 forest categories requires an understanding of the forest and tree species represented by each BEIS2 category and knowledge of the forested areas of southwest Wyoming. Given the uncertainty about which categories are most appropriate, the biogenic inventory should be presented as a mean, "best-estimate" value with uncertainty bounds. The BEIS2 categories, which were used to arrive at the mean, upper-, and lower-bound values, should be documented for independent evaluation. The overall uncertainty of the biogenic inventory should include uncertainty in the individual forest or tree species emission factors.

d) Modeling Chemical Transformations

We have several concerns about the representation of both gas phase and secondary organic aerosol transformations present in CALPUFF.

i) Representation of Gas Phase Chemistry

The treatment of gas phase chemistry employed in CALPUFF to describe the transformation of sulfur dioxide to sulfate, and nitrogen oxides to nitric acid and then to nitrate¹, is based on two simplifying assumptions: (1) the chemistry is linear, and (2) reaction rates are independent of temperature.

These assumptions are problematic for the following reasons:

- Simple pseudo-first order expressions (i.e., linear in concentration) were developed for the assumed linear transformations. In the atmosphere, however, the transformations actually occur through a number of elementary reactions. Describing these chemical transformations requires the solution of highly coupled non-linear differential equations. There is no evidence to suggest that an assumption of linearity is warranted or predicts correct transformation rates.

¹ The chemistry of these two transformations is: $\text{SO}_2 \rightarrow \text{SO}_4^{2-}$, and $\text{NO}_x \rightarrow \text{HNO}_3 \rightarrow \text{NO}_3$

- Chemistry based on knowledge extant in the early 1980s was used to derive the pseudo-first order expressions. The calculated nitrate and sulfate concentrations were assumed to react completely with ammonia (NH_3) to form ammonium sulfate (NH_4SO_4) and ammonium nitrate (NH_4NO_3) aerosols, an unwarranted assumption. Because the various assumptions are not substantiated and raise serious questions about accuracy of representation, we have concern about the approach adopted.
- The uncertainties in the NH_3 concentrations used in the study are important. NH_3 may be a limiting reagent in the formation of NO_3^{-1} and SO_4^{-2} aerosols. If the concentration of NH_3 is less than the sum of the concentrations of NO_3^{-1} and twice the concentration of SO_4^{-2} the NH_3 concentration will limit the amount of non-carbonaceous aerosol formed. This uncertainty should be given consideration, and if possible quantified, in future analyses conducted.
- The CALPUFF modeling approach was employed in the 1996 Mount Zirkel study to estimate NH_4SO_4 and NH_4NO_3 aerosols. Statistical bias (in percent) between measured and estimated concentrations, reported for four episodes, was:

Total PM-2.5	Sulfate	Nitrate	Primary PM-2.5	Elemental Carbon	Organic Aerosol
+21 to -71	+21 to - 71	+112 to -11	+12 to -79	-62 to -88	-17 to -77

The agreement between measured and estimated aerosol concentrations using this approach is random and poor. Thus, we are concerned that the simplistic approach to aerosol formation may produce significant errors in the current study as well.

ii) Treatment of Secondary Organic Aerosol Formation

We have the following concerns regarding efforts to estimate secondary organic aerosol formation:

- The yield of aerosol mass is the fraction of reacted organic species that produces aerosols. Yield formulae for secondary aerosols are used to calculate the mass of secondary organic aerosol when data are available that characterize emissions of organic compounds, their speciation, and their atmospheric reactivity. Currently, knowledge of organic aerosols and their optical properties is at a very primitive stage. It entails a leap of faith to estimate visibility based on aerosol mass data, particularly for organics.
- Visibility is estimated based on aerosol mass in the current modeling effort. Therefore, we reviewed available data on aerosol yields based on smog chamber experiments by Seinfeld and colleagues at Caltech. Extension of this work to the atmosphere has yet to be accomplished. However, were this extension valid, predicting secondary organic aerosol formation in the atmosphere would require knowledge of the following:
 - ◆ The concentrations of individual organic compounds that contain more than six carbon atoms,
 - ◆ The amount of each reactive organic gas (ROG) that reacts over time,

- ◆ Yield formulae for each organic compound; the yield relationships should be determined in experiments that mimic the atmospheric chemistry of interest. This is crucial because the yield formulae are strongly influenced by the ambient chemistry.
- Although the EarthTech investigators reference the work of Seinfeld and colleagues, they do not adhere to this procedure. They consider four organic compounds to be sufficiently representative. They estimate the concentrations of these four compounds by considering VOCs from anthropogenic and biogenic sources with partitioning of the anthropogenics according to the prescription associated with the CB-IV chemical mechanisms. They reduce gas phase chemistry to a few elementary rates for the parent organic compounds, with gas phase concentrations of OH, NO₃, and O₃ derived using linear chemistry and other approximations. Fitting parameters required in yield formulae were scaled from those determined in smog chamber experiments using relationships that have not been derived from scientific studies. In the report we raise a number of concerns about this approach, including partitioning the hydrocarbon emission inventory, treatment of the gas phase chemistry of the parent hydrocarbon that precedes aerosol formation, and derivation of the parameters in yield formula.

e) Modeling Visibility

There has been limited demonstrated ability to accurately model visibility impacts. Our primary concerns include:

- Calculating visibility degradation for a complex mixture of aerosol species is a difficult task. The amount of information necessary to support such calculations is rarely, if ever, available. This information includes how the chemical composition of the aerosol varies both within particles of the same size and between particles of different sizes. Typically, a number of assumptions are employed to calculate the extinction resulting from a mixture of aerosol species. These assumptions facilitate the comparison of calculated and observed visibility conditions.
- While simplifying assumptions allow for the calculation of visibility from field measurements, it is much more difficult to assess how current visibility conditions will change due to removal of one or more of the species. The removal of a species can affect both the size and the chemistry of the remaining aerosol. Calculating the change in extinction requires information about the size and composition of the aerosol that is usually unavailable. Given these uncertainties, estimating the change in visibility resulting from emissions controls can result in a range of values that depend upon the assumptions made concerning the structure of the aerosol. It is important to make appropriate assumptions for the specific conditions in the area under study, and to realize that there may still be significant uncertainties associated with any estimated visibility change.

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PART II.

1. SWYTAF EMISSION INVENTORY REVIEW

The purpose of the SWYTAF emission inventory review task is to provide a technical review of the existing inventory with an emphasis on understanding the basis for the inventory, determining if the inventory is sufficient to meet regional modeling objectives, and identifying those portions of the inventory whose accuracy could be improved through additional effort.

Emission Totals—The table below shows the emission summary for the entire modeling domain in calendar year 1995 for all emissions calculated or compiled by Air Sciences (i.e., excludes Wyoming I-80 corridor mobile source emissions, forest fire emissions, biomass emissions, and ammonia emissions).

Emission Source	NO _x (tpy)	SO ₂ (tpy)	PM ₁₀ (tpy)	PM _{2.5} (tpy)	VOC (tpy)
Wyoming					
Point Sources	72,829	75,824	17,749	13,754	11,193
Petroleum	3,781	68	71	71	35,743
Area Sources	4,582	2	568	568	7,612
Utah					
Point Sources	22,794	13,947	9,601	9,601	6,405
Area Sources	79,396	5,140	70,384	70,384	100,873
Idaho					
Point Sources	6,595	19,078	3,617	3,617	674
Area Sources	5,494	874	7,693	2,630	11,353
TOTAL	195,471	114,932	109,684	100,625	173,853

Point and Area Source Information—For point source emissions obtained from the WDEQ, the Utah Division of Air Quality, and the Idaho Department of Environmental Quality the emission values are provided in the inventory documents but information on the origins of those values is not. The values used represent 52% of total NO_x, 95% of total SO₂, 28 % of total PM₁₀, 27% of total PM_{2.5}, and 11% of total VOC emissions. For area sources in Idaho and Utah, emissions were obtained by subtracting the point source emissions from the inventory total and assuming that the remaining emissions are from area sources. These emissions account for 65% of total VOC emissions in the modeling domain area, 71% of total PM₁₀ emissions, and 73% of total PM_{2.5} emissions. Because of the significant size of these contributions relative to the overall inventory, further investigation into the point and area source inventories in Idaho and Utah and the point sources in Wyoming may be warranted.

Pollutants Included/Speciation—The pollutants for which emissions estimates were made is not consistent throughout the inventory. It is difficult to determine why emission estimates for some pollutants were made for some sources and not for others. Specifically, particulate and sulfur dioxide emissions are estimated for some sources but not for others. This occurs even when the

source types are known to emit the pollutant. In addition, VOC emissions are estimated for many sources, but speciation of the VOC emissions was obtained for only a few sources. For sources where VOC speciation was not obtained, speciation assumptions used were not included in the emission inventory document. VOC speciation is an area that can be improved. Speciation data is available for many of the source types in the inventory for which VOC speciation information was not included.

Oil and Gas Industry Emissions—Although specific information on the oil and gas emission estimates has not yet been obtained, the information provided was reviewed. Emissions from most oil and gas field sources are estimated on a per well basis. Therefore, the number of wells present in the study area in 1995 is very important. The number of wells in the four county region of southwest Wyoming (excluding Fremont County) used in the draft emission inventory was 3,361 based on information from the Wyoming Oil and Gas Conservation Commission (WOGCC). This number was changed to 2,237 wells in a five county (including Fremont County) region of southwest Wyoming for the final inventory. The decrease in the number of wells is attributed to exclusion of inactive gas wells. Data that Radian has obtained on CD (petroROM Rocky Mountain Region-June 1998 Production Data, Petroleum Information Dwigths) indicated that there were about 3,400 producing gas in the four county region in 1995, and more on the order of 3,700 producing gas wells in the five county region. The query done to obtain these well counts was for wells with non-zero production of either gas or condensate. Only about 10 wells had condensate production with no gas production in 1995.

Even if the number of wells can be accurately determined, the per well method of estimating emission can be improved. A more accurate estimate of VOC emissions can be obtained based on gas and condensate production rather than the number of wells. VOC emissions are directly related to the amount of gas or condensate produced at a particular well site. Total gas and condensate production can be obtained from the production data CD and VOC emission estimates made.

Estimates for emissions from well development flaring, blowdown, and gas compression are included in the inventory documents. The estimates for flaring and blowdown are based on several assumptions and little actual data. This is because the data necessary to calculate emissions from these source types is not typically kept. This is an area where additional effort could improve the emission estimates. Compressor emissions are estimated based on WDEQ records of the number of wellhead compressors operating in 1995. A verification of these records and the collection of additional compressor information such as engine type, size, and engine controls (i.e. low NO_x burners) would improve these estimates.

2. TRENDS ANALYSIS

The purpose of the trends analysis task is to focus on changes in southwest Wyoming oil and gas production and corresponding emissions over the past several years and into the near future. The objective is to examine how the oil and gas industry emissions have changed over time and whether

they will increase in the foreseeable future. Several areas of investigation were identified for this effort:

- Oil and Gas Production Trends;
- Oil and Gas Emission Location Changes;
- Control Equipment Requirements; and
- Oil and Gas Equipment Usage Trends.

Each of these subtasks is briefly described below.

Oil and Gas Production Trends—Oil and gas production data for Wyoming was been leased from P.I. Dwight's. Data for the four counties in southwest Wyoming was extracted and analyzed for years 1988 through 1997. Initial results show that well count increased by 110 percent over this 10-year period. Gas production rate increased by 62 percent and condensate production rate decreased by 14 percent over this period.

Oil and gas production data will be used to estimate the change in emissions from the oil and gas industry over time. Efforts are currently underway to develop emission estimation methods that can be applied over the large number of wells.

The currently accepted public view is that oil and gas emissions increase proportionately to the number of new wells. Glycol dehydrators and flash tanks are the dominant source of VOC emissions from the oil and gas industry. Based on current methods of estimating emissions from these sources, emissions are more closely related to the gas flow rate (for a glycol dehydrator) and condensate flow rate (for a flash tank) than the number of wells.

Assuming that glycol dehydrator volatile organic compound (VOC) emissions increase as gas production increases and that flashing emissions decrease as condensate production decreases, a rough estimate of the change in VOC emissions can be made using the current VOC emission rates from dehydrators and flash tanks from the SWYTAF emission inventory. This estimate shows an overall 10 percent increase in VOC emissions, which contrasts with the 120 percent increase in the number of wells since 1988. This analysis indicates that emissions from the oil and gas industry over the last 10 years have increased slightly, but not at the same high trend as well installation.

Oil and Gas Emission Location Changes—Well location data is included in the P. I. Dwight's database. This data has been used to prepare maps showing the shift in well location over time. Once emission estimates based on the production data have been prepared, the maps can be reviewed along with the regional wind field data to estimate the impact that changes in spatial distribution may have on regional air quality.

Control Equipment Requirements—Information on changes in regulations and regulatory policies has been collected and will be summarized. This information will be used in estimating emissions.

The changes in regulations will be one factor used in estimating the percentage of controlled emission sources in a given year.

Oil and Gas Equipment Usage— The addition of emission controls in more recent years will have caused emission reductions from the oil and gas industry in many instances. As an attempt to quantify these emission reductions, the Independent Petroleum Association of the Mountain States (IPAMS), Environmental Committee has agreed to assist us in conducting a survey of gas companies to request information on equipment changes over the last 10 years. Changes in regulations have prompted the development of new technologies with lower emissions. In many cases the changes have included the addition of a control device to an emission unit. One example of such is the addition of emission controls to glycol dehydrators in the last several years. The same trend of adding emission controls in recent years holds true for compressor engines and flash tanks. The survey is intended as a tool to compile data about when and how many emission units have been controlled.