

**APPENDIX A:**  
AIR QUALITY ASSESSMENT PROTOCOL

**AIR QUALITY IMPACT ASSESSMENT PROTOCOL,  
JONAH INFILL DRILLING PROJECT,  
SUBLETTE COUNTY, WYOMING**

*Prepared for*

**Bureau of Land Management  
Pinedale Field Office**  
Pinedale, Wyoming

and

**Bureau of Land Management  
Wyoming State Office**  
Cheyenne, Wyoming

*Prepared by*

**TRC Environmental Corporation**  
Laramie, Wyoming

September 2003  
Revised October 2003

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SUBLETTE COUNTY, WYOMING**

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**September 2003  
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**LIST OF ACRONYMS AND ABBREVIATIONS**

ANC	Acid neutralizing capacity
AQD	Air Quality Division
AQRV	Air Quality Related Value
ARS	Air Resource Specialists
BACT	Best Achievable Control Technology
BLM	Bureau of Land Management
C.F.R.	<i>Code of Federal Regulations</i>
CAAQS	Colorado Ambient Air Quality Standards
CDPHE/APCD	Colorado Department of Public Health and Environment/Air Pollution Control Division
CD/WII	Continental Divide/Wamsutter II
CO	Carbon monoxide
COGCC	Colorado Oil and Gas Conservation Commission
dv	Deciview
EIS	Environmental Impact Statement
EnCana	EnCana Oil & Gas (USA) Inc.
EPA	Environmental Protection Agency
FLAG	Federal Land Managers' Air Quality Related Values Workgroup
FLM	Federal Land Managers
GRI	Gas Research Institute
HAP	Hazardous air pollutant
HNO <sub>3</sub>	Nitric acid
IAAQS	Idaho Ambient Air Quality Standards
IDEQ	Idaho Division of Environment Quality
IDLH	Immediately Dangerous to Life or Health
IOGCC	Idaho Oil and Gas Conservation Commission
IWAQM	Interagency Workgroup on Air Quality Modeling
JIDPA	Jonah Infill Drilling Project Area
kg/ha/yr	Kilograms per hectare per year
LAC	Level of Acceptable Change
LOP	Life of Project
MEI	Maximally Exposed Individual
MLE	Most Likely Exposure
N	Nitrogen
NAAQS	National Ambient Air Quality Standards
NEPA	<i>National Environmental Policy Act</i>
NIOSH	National Institute for Occupational Safety and Health
NO <sub>2</sub>	Nitrogen dioxide
NO <sub>3</sub>	Nitrate
NO <sub>x</sub>	Oxides of nitrogen
NPS	National Park Service
NSR	New Source Review

**LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)**

NWS	National Weather Service
O <sub>3</sub>	Ozone
Operators	EnCana Oil and Gas (USA) Inc., BP America, and other oil and gas companies
PAPA	Pinedale Anticline Project Area
PFO	Pinedale Field Office
PM <sub>10</sub>	Particulate matter less than or equal to 10 microns in size
PM <sub>2.5</sub>	Particulate matter less than or equal to 2.5 microns in size
ppb	Parts per billion
Project	Jonah Infill Drilling Project
Protocol	Air Quality Impact Assessment Protocol
PSD	Prevention of Significant Deterioration
QA/QC	Quality Assurance/Quality Control
REL	Reference exposure level
RfC	Reference Concentrations for Chronic Inhalation
RFD	Reasonably foreseeable development
RFFA	Reasonably foreseeable future actions
RMP	Resource Management Plan
ROD	Record of Decision
S	Sulfur
SO <sub>2</sub>	Sulfur dioxide
SO <sub>4</sub>	Sulfate
SWWYTAF	Southwest Wyoming Technical Air Forum
TRC	TRC Environmental Corporation
UAAQS	Utah Ambient Air Quality Standards
UDEQ-AQD	Utah Department of Environmental Quality-Air Quality Division
UDNR-DOGM	Utah Department of Natural Resources-Division of Oil, Gas, and Mining
URF	Unit risk factor
VOC	Volatile organic compound
WAAQS	Wyoming Ambient Air Quality Standards
WAQSR	Wyoming Air Quality Standards and Regulations
WDEQ	Wyoming Department of Environmental Quality
WOGCC	Wyoming Oil and Gas Conservation Commission
WYDOT	Wyoming Department of Transportation
µeq/l	Microequivalents per liter
µg/m <sup>3</sup>	Micrograms per cubic meter

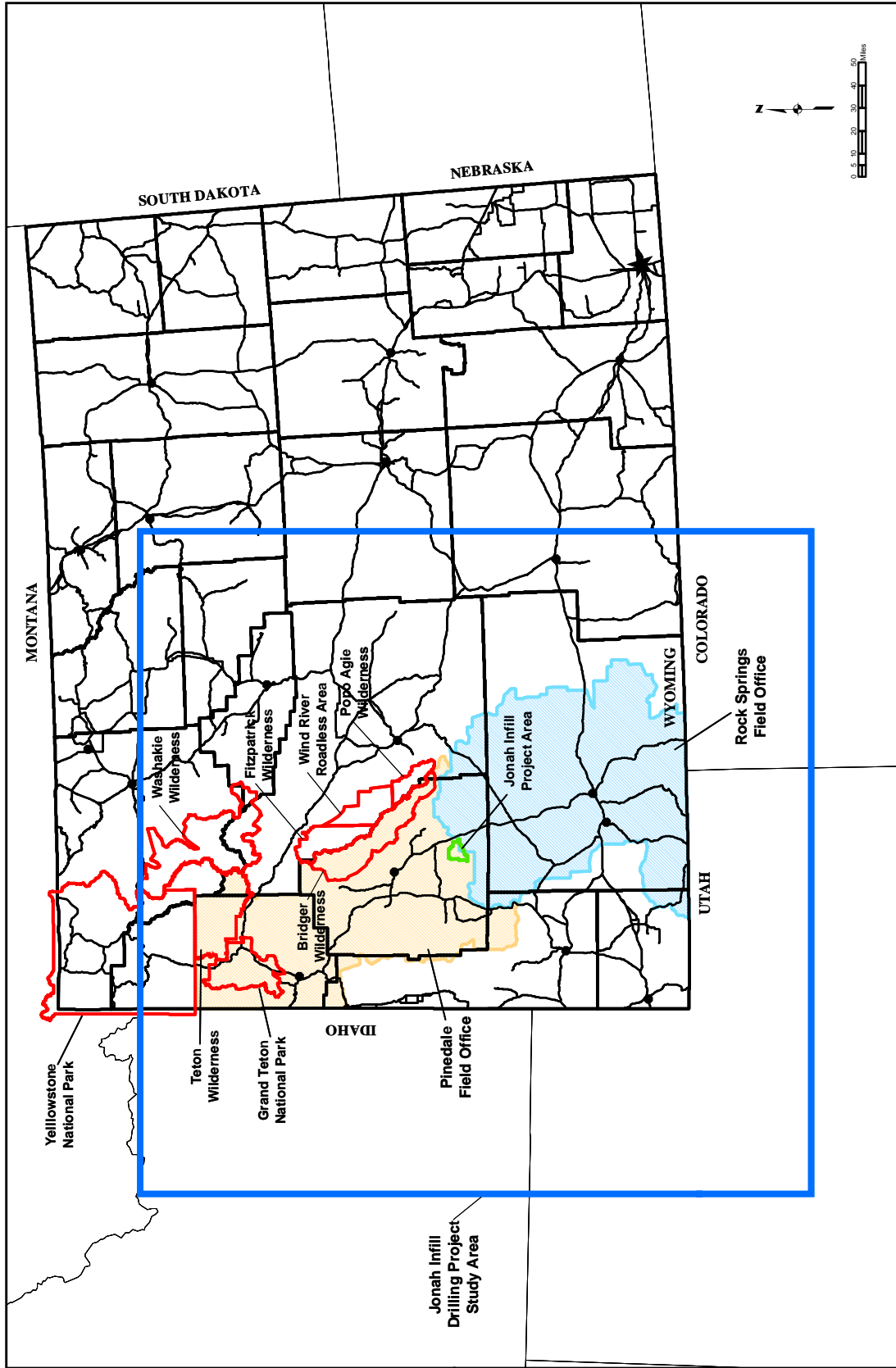


## **1.0 INTRODUCTION**

TRC Environmental Corporation (TRC) has prepared this Air Quality Impact Assessment Protocol (Protocol) to identify the methodologies for quantifying potential air quality impacts from the proposed Jonah Infill Drilling Project (the Project). These methodologies are being provided prior to study initiation to ensure that the approach, input data, and computation methods are acceptable to the Bureau of Land Management (BLM), and that other interested parties have the opportunity to review the Protocol and provide input before the study is initiated. The Project's location in west-central Wyoming will require the examination of Project and cumulative source impacts in Wyoming, northwestern Colorado, northeastern Utah, and southeastern Idaho within the study area shown on Map 1.1. The study area and a significant portion of the analysis are similar to cumulative analyses performed for previous natural gas development projects in Wyoming. However, the approach presented in this Protocol differs from previous regional cumulative analyses in two primary aspects. First, the analysis will utilize the most recent visibility and NO<sub>x</sub> background data available to more accurately reflect current conditions in the region and will advance the emissions inventory start-date to reflect this more recent background data. Second, the proposed Class I modeling approach will be consistent with recent federal guidance for performing regional Class I analyses and will comply with Wyoming Department of Environmental Quality-Air Quality Division (WDEQ-AQD) recommendations.

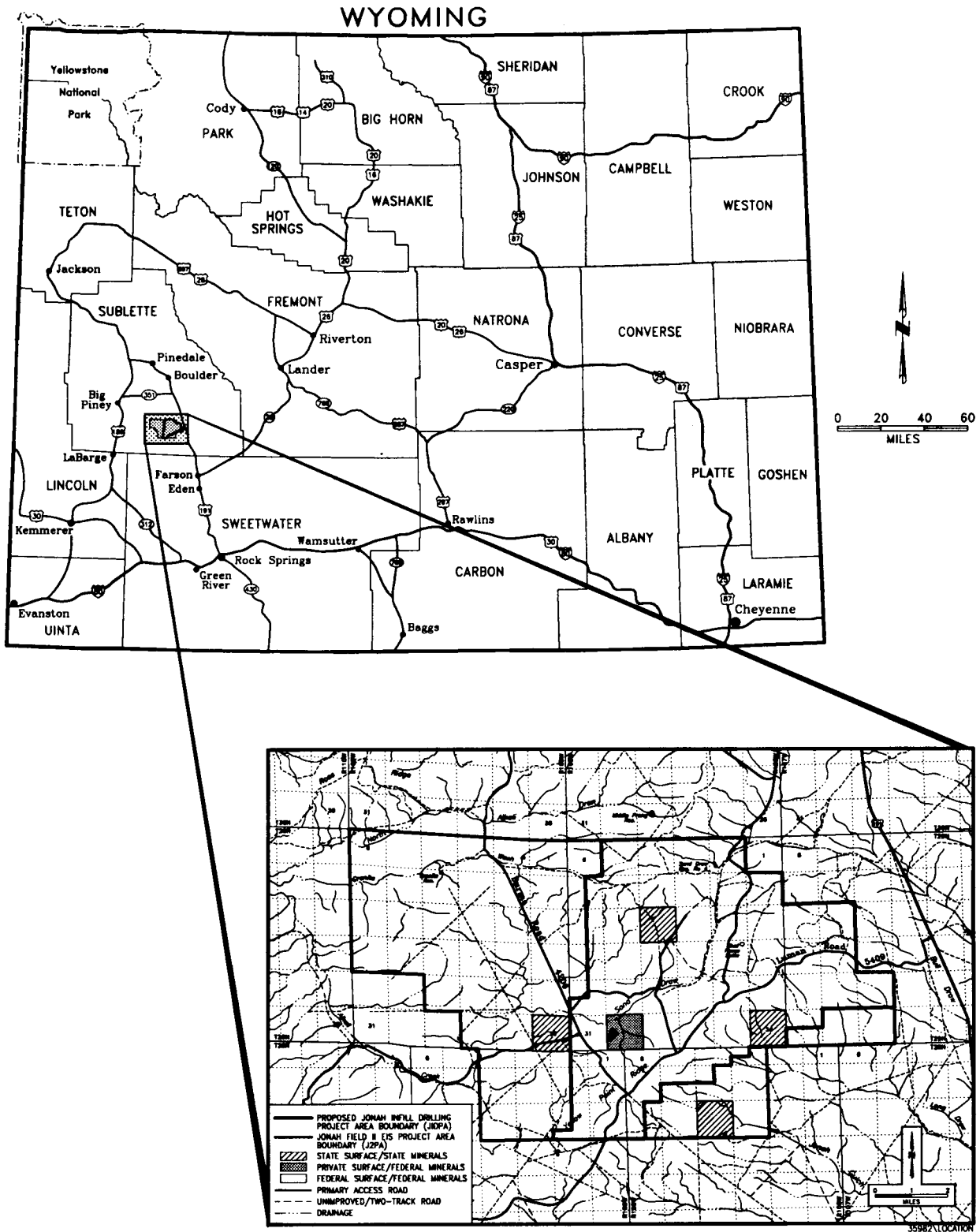
### **1.1 PROJECT DESCRIPTION**

EnCana Oil & Gas (USA) Inc. (EnCana) of Denver, Colorado, has notified the BLM, Pinedale Field Office (PFO), that it and other oil and gas companies including BP America (collectively referred to as the Operators), propose to continue development of natural gas resources located within the Jonah Infill Drilling Project area (JIDPA) (Map 1.2). The proposed project area is generally located in Townships 28 and 29 North, Ranges 107 through 109 West, Sublette County, Wyoming. The total project area encompasses approximately 30,200 acres, of which 28,280 acres are federal surface/federal mineral estate, 1,280 acres are State of Wyoming surface/mineral estate, and 640 acres are private surface/federal mineral estate.



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Map 1.1 Air Quality Study Area.



Map 1.2 Jonah Infill Drilling Project Location Map, Sublette County, Wyoming.

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The Operator Proposed Action for this Project involves the development of 1,250 new natural gas wells on 850 new surface locations in the JIDPA. However, additional alternatives involving greater well numbers will also be analyzed in the *National Environmental Policy Act* (NEPA) Environmental Impact Statement (EIS) for this project. The maximum number of wells would be 3,100, assuming an approximately 5- to 10-acre down-hole well spacing throughout the JIDPA. Drilling operations are expected to last from approximately 4 to 20 years, with a life-of-project (LOP) of 30-50 years. The JIDPA is currently accessed by existing developed roads.

Approximately 63-87 days would be required to develop each well (four days to construct the well pad and access road, from one to four days for rig-up, generally from 18 to 36 days for drilling [an average of 23 days is proposed for use in the air quality analysis], 35 days over a 60-day period for completion, from one to four days for rig-down, and four days for pipeline construction). The estimated size of each drill site location is 3.8 acres, of which approximately 2.9 acres would be reclaimed after the well is completed and the gas gathering pipeline is installed. A reserve pit would be constructed at each drill site location to hold drilling fluids and cuttings. Non-productive and non-economical wells would be reclaimed immediately to appropriate federal, state, or private landowner specifications.

The gas produced within the JIDPA would be transported by existing pipelines from the field. To facilitate a complete cumulative impact assessment and since gas compression needs for the proposed Project cannot reasonably be separated from those necessary for the adjacent Pinedale Anticline Project Area (PAPA), future compression requirements for the PAPA will also be considered in the air quality analysis. Projections of future compression requirements supporting both the JIDPA and the PAPA have been requested from pipeline companies working within these areas. This total regional compression estimate will be analyzed as part of both the Proposed Action and the Maximum Well Number Alternatives.

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## **1.2 RELATIONSHIP TO EXISTING PLANS AND DOCUMENTS**

The BLM Pinedale Resource Management Plan (RMP)/Record of Decision (ROD) (BLM 1988) and the Green River RMP ROD (BLM 1997) direct the management of BLM-administered lands within the JIDPA. Management of oil and gas resources, as stated in the RMPs, provides for leasing, exploration, and development of oil and gas while protecting other resource values. According to the RMPs, all public lands in the JIDPA are suitable for oil and gas leasing and development, subject to certain stipulations.

The study area for this impact analysis (CALMET/CALPUFF modeling domain) will be similar to the domain used for the Southwest Wyoming Technical Air Forum (SWWYTAF) (Earth Tech 2001) and the Pinedale Anticline EIS (BLM 1999a). These study areas were identical and included portions of southwest Wyoming, southeast Idaho, northeast Utah, and northwest/north-central Colorado and utilized the CALMET/CALPUFF modeling system to estimate regional air quality impacts. The proposed modeling domain not only includes these areas but also extends farther north to include Grand Teton National Park, Teton and Washakie Wilderness Areas, and the southern edge of Yellowstone National Park.

## **1.3 PROPOSED WORK TASKS**

The air quality analysis will address the impacts on ambient air quality and Air Quality Related Values (AQRVs) resulting from: 1) air emissions from construction and production activities proposed in the JIDPA 1,250 new wells; 2) 3,100 new wells; and 3) air emissions from other documented regional emissions sources within the study area. Ambient air quality impacts will be quantified and compared to applicable state and federal standards, and AQRV impacts (impacts on visibility [regional haze] and acid deposition) will be quantified and compared to applicable thresholds as defined in the Federal Land Managers' (FLMs') Air Quality Related Values Workgroup (FLAG), Interagency Workgroup on Air Quality Modeling (IWAQM) guidance documents (FLAG 2000; IWAQM 1998), and other state and federal agency guidance. Impact assessment criteria are discussed in further detail in Section 5.0 of this Protocol.

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The assessment of impacts will include the completion of the following five tasks.

- Develop Jonah Infill Drilling Project construction and production emissions inventories (see Section 2.1).
- Compile a cumulative emissions inventory within the study area, including new sources permitted through June 30, 2003, reasonably foreseeable development (RFD), and reasonably foreseeable future actions (RFFA) (see Section 2.2).
- Assess near-field ambient impacts from Project emissions sources (see Sections 3.0 and 5.1).
- Assess far-field ambient impacts (pollutant concentration, visibility, and acid deposition impacts) within the modeling domain and at Class I and other sensitive areas from Project emissions sources (see Sections 4.0 and 5.2).

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## **2.0 EMISSIONS INVENTORY**

### **2.1 PROJECT EMISSIONS**

The Proposed Action for the project includes the development of from 1,250 to 3,100 natural gas wells. Additional alternatives would also be proposed to represent intermediate development scenarios, scenarios designed to limit well pad numbers, and/or limit the rate of development. Drilling would continue for approximately 4 to 20 years, with an approximate 30- to 50-year LOP. Relevant production facilities associated with each well would include a separator, dehydrator, water tank, condensate tank, and methanol tank. Ancillary facilities would include new compressor engines at existing compressor stations inside and outside the JIDPA.

Emissions inventories for oxides of nitrogen (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), carbon monoxide (CO), particulate matter less than or equal to 10 microns in size (PM<sub>10</sub>), particulate matter less than or equal to 2.5 microns in size (PM<sub>2.5</sub>), volatile organic compounds (VOC), and hazardous air pollutants (HAPs) (benzene, toluene, ethyl benzene, xylene, n-hexane, and formaldehyde) will be developed for both construction and production activities and for ancillary facilities planned as part of the Project. Lead emissions will be considered negligible and not calculated in the inventory. The emissions inventory will be developed based on the Proposed Action and Maximum Development Alternative with assistance from the Operators, using reasonable but conservative scenarios identified for each activity. The inventory will be developed using manufacturer's emissions data, the Environmental Protection Agency's (EPA's) AP-42 (EPA 1995), Gas Research Institute (GRI) emission factors, and other accepted engineering methods as described below.

#### **2.1.1 Construction Emissions**

Emissions-generating construction activities include: wellpad and access road construction; drilling; flow-back/flaring; vehicle travel during the drilling and completion phase; and construction and vehicle travel during gas pipeline installation. Drilling engine and flaring

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emissions will be calculated using AP-42 or other acceptable engineering methods. Both controlled and uncontrolled flaring emissions will be calculated. Flaring emissions calculations and assumptions will be forwarded to WDEQ-AQD for review during development of the inventory. Fugitive particulate emissions from vehicle travel and construction activities, wind erosion emissions from areas disturbed during construction, and combustion source emissions will be calculated using AP-42 emission factors and GRI-HAPCalc® (GRI 1999). It will be assumed that adequate dust suppression (e.g., watering or dust suppressants) will be applied to achieve a control efficiency of 50%.

### **2.1.2 Production Emissions**

Sources of pollutant emissions during the production phase will include combustion emissions from well-site facilities and compressor engines, and VOC and HAP emissions from gas transmission operations. Fugitive particulate emissions from unpaved road travel and from wind erosion on disturbed areas (such as well pads) will also occur. Combustion equipment emissions will be calculated using AP-42, manufacturer's, and/or GRI emission factors, in accordance with WDEQ-AQD oil and gas permitting guidance (WDEQ 2001) where applicable guidance exists. Fugitive dust from unpaved roads and wind erosion emissions from disturbed areas will be calculated using AP-42 emission factors. VOC and HAP emissions from production (aside from those arising from combustion sources) will be generated by well-site dehydrators, fugitive leaks, and flashing emissions from stored liquids. Both fugitive and flashing emissions will be calculated using representative constituent analyses of natural gas and stored liquids, respectively, as well as a discussion of Best Achievable Control Technology (BACT) applicability and requirements, will be included for emissions sources as appropriate, in accordance with WDEQ-AQD oil and gas permitting guidance (WDEQ 2001).

## **2.2 CUMULATIVE EMISSIONS INVENTORY**

An inventory of existing and proposed emissions sources within the study area will be conducted and will include the identification of permitted sources, oil and gas wells, RFD, and RFFA. The



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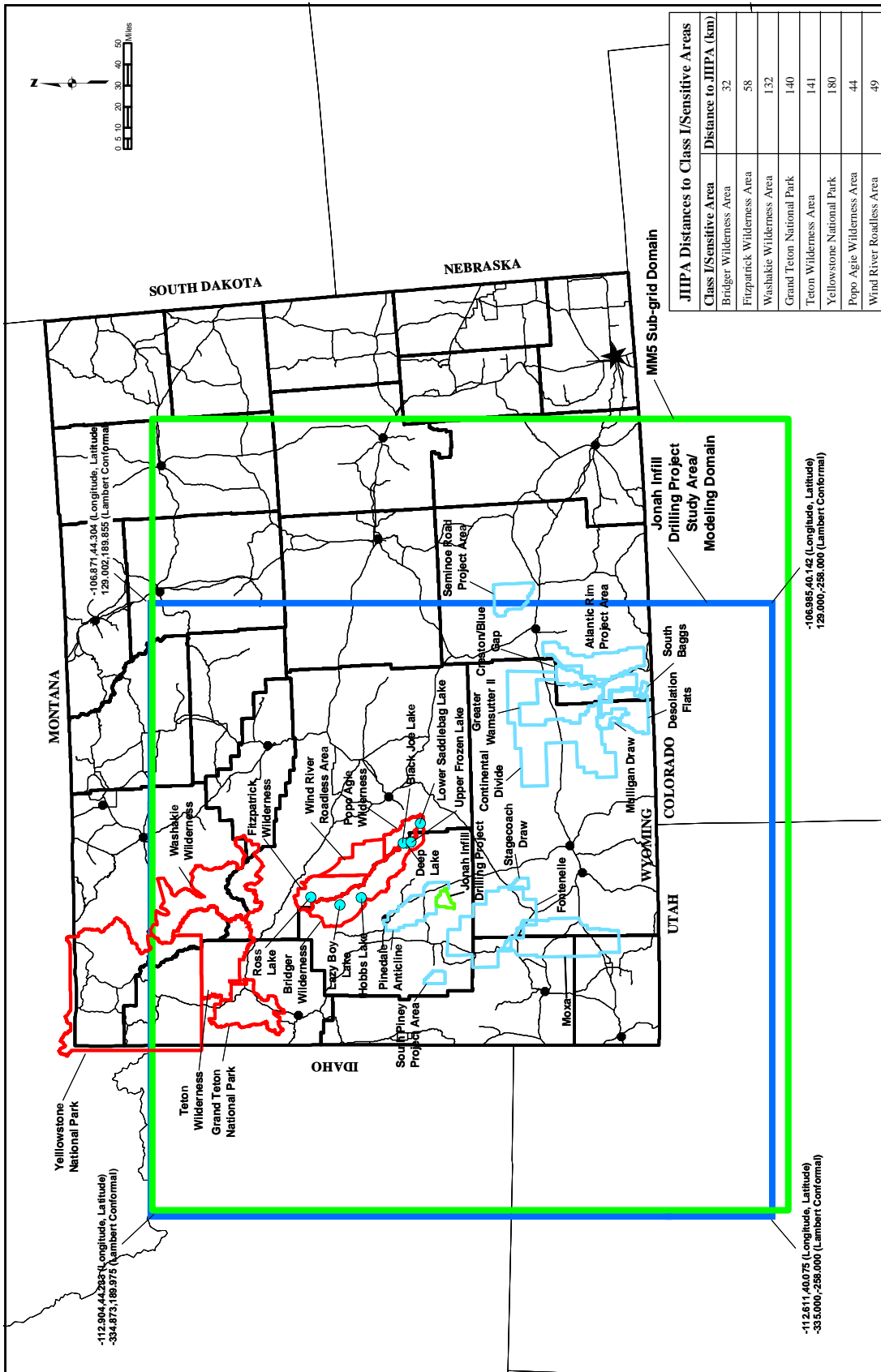
cumulative inventory will be completed using methods similar to previous inventories performed in support of regional analyses. The inventory will be developed using data obtained from WDEQ-AQD, Wyoming Oil and Gas Conservation Commission (WOGCC), Colorado Department of Public Health and Environment/Air Pollution Control Division (CDPHE/APCD), Colorado Oil and Gas Conservation Commission (COGCC), Utah Department of Environmental Quality-Air Quality Division (UDEQ-AQD), Utah Department of Natural Resources-Division of Oil, Gas, and Mining (UDNR-DOGM), Idaho Division of Environment Quality (IDEQ), Idaho Oil and Gas Conservation Commission (IOGCC), BLM, and other agencies as required.

The time period of emissions data to be inventoried will differ from that of previous regional studies in the use of updated visibility and NO<sub>x</sub> background data in the cumulative analysis. These data are described in greater detail in Sections 4.2.4.2 and 4.2.4.3 of this Protocol. The inventory period proposed in this Protocol has been selected based on the availability of current background data through 2001; as a result, the inventory will begin in January 2001 and end on a month-end date contemporary to this Protocol, June 30, 2003. If significant schedule changes occur as the analysis progresses, the cutoff dates will be adjusted to ensure that no data is unreasonably excluded from the analysis. Some overlap between emission sources which began operating in 2001 and background data monitored during 2001 will exist; however, this overlap provides additional conservatism to the analysis. Furthermore, the updated background values more accurately reflect current background conditions, and the reduction in years of emissions sources modeled helps to simplify the analysis.

Sources of PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>x</sub>, and SO<sub>2</sub> emissions within the study area (the CALPUFF/CALMET modeling domain), will be inventoried. The study area is shown in Map 2.1.

### **2.2.1 Existing Inventory**

Three cumulative inventories have been completed as part of NEPA projects in southwest Wyoming, and they all included a portion of the study area proposed for the Project. The first



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Map 2.1 Study Area/Modeling Domain, Jonah Infill Drilling Project.

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was completed as part of the Continental Divide/Wamsutter II (CD/WII) EIS (BLM 1999b) and the second was performed for the Pinedale Anticline EIS (BLM 1999a). A third cumulative inventory in the region has been prepared for the Desolation Flats EIS (BLM 2003). The Desolation Flats EIS study utilized the CD/WII EIS study area and built upon the previous studies listed above, and it included emissions sources permitted through December 31, 2000. The Desolation Flats EIS cumulative inventory will be consulted to obtain emissions data for sources proposed and operating during the time period that overlaps between the proposed inventory time-frame and the end-date of the Desolation Flats EIS study. Both the CD/WII EIS and Pinedale Anticline EIS study end-dates precede the start-date of the proposed JIDPA analysis.

### **2.2.2 Permitted Sources**

The cumulative emissions inventory for the Project will include emissions sources that:

- are located within the study area;
- emit NO<sub>x</sub>, SO<sub>2</sub>, or PM<sub>10</sub>/PM<sub>2.5</sub>;
- began operation on or after January 1, 2001;
- began operation or were permitted before June 30, 2003; and
- were permitted within 18 months of January 1, 2001, but are not yet operating (will be inventoried and included as RFFA [see Section 2.2.4]).

To illustrate the inventory cut-off date, an emissions source which was permitted *and* began operation in late 2000 would not be included in the inventory. However, an emissions source that was permitted in late 2000 but began operation in early 2001 would be included in the inventory. An emissions source permitted in late 2000 (and therefore within 18 months prior to January 1, 2001), but not yet operating would be included as RFFA. An emission source that begins operation in July 2003, after the inventory cut-off date, would be included only if it was permitted on or before June 30, 2003.

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Actual emissions will be used if a minimum of 1 year of actual data is available; otherwise, potential-to-emit (maximum permitted) emission rates will be used. Emissions decreases will be included only if the decrease occurs at a major source and if the decrease is verifiable by WDEQ-AQD. Sources operating under permit waivers will not be inventoried due to their insignificant nature, and a qualitative discussion of waivers will be presented in the Technical Support Document. Mobile source emissions not directly resulting from the Proposed Action, biogenic sources, urban sources, and other non-industrial emission sources are assumed to be included in monitored background concentrations and are not included in this analysis.

### **2.2.3 WOGCC/COGCC/UDNR-DOGM/IOGCC Sources**

A list of well drilling permits issued between January 1, 2001, and June 30, 2003, will be compiled using permit data obtained from WOGCC, COGCC, UDNR-DOGM, and IOGCC. Information regarding well type and equipment, and historic and current field production will be used to create a representative emission factor in pounds per well for all emitted pollutants. This average emission factor will be multiplied by the number of wells installed during the study period in each county within the study area to calculate total well emissions by county.

### **2.2.4 RFD and RFFA**

An inventory of RFD and RFFA sources will be performed for inclusion in the cumulative dispersion modeling. For the purposes of this project, RFFA is defined as a source which possesses an unexpired air permit issued on or after July 1, 1999, but the source is not yet operating. The primary source of RFFA information will be state permit records obtained through a file data search.

RFD is defined as 1) air emissions from the undeveloped portions of authorized NEPA projects, and 2) air emissions from not-yet-authorized NEPA projects (if emissions are quantified when modeling for the JIDPA commences). RFD information will be obtained from final NEPA documents that have been submitted to BLM for planned project development, specifically, from

the air quality analyses performed for these projects. Undeveloped portions of these authorized projects will be obtained from BLM records tracking project development to determine total wells or other equipment yet undeveloped. For instance, for an authorized gas field development area for which 2,000 wells were projected and analyzed but only 250 wells have been developed as of the inventory end-date of this study, 250 wells would be included under permitted oil and gas wells and the remaining 1,750 would be considered RFD. RFD information from not-yet-authorized projects will be obtained from contractors working on ongoing air quality analyses for NEPA projects.

Full development of proposed projects inventoried as RFD may or may not coincide with full development of the Project. As a result, the inclusion of RFD in the cumulative analysis may result in overly conservative impact estimates. To ensure "reasonable, but conservative" analysis results for all stages of Project development, the cumulative modeling analysis discussed later in this Protocol will be performed both with and without RFD sources. A preliminary listing of RFD projects which may be examined in this study, as defined in the paragraph above, is presented in Table 2.1. All development areas will be reviewed for inclusion, and those projects with significant pollutant emissions during production activities will be included as RFD. The BLM will be consulted to determine the existence of additional NEPA-authorized projects

Table 2.1 Potential RFD in the Study Area.

Big Piney-LaBarge	Desolation Flats	Jonah II	Road Hollow
Bird Canyon	Dripping Rock/Cedar Breaks	Kennedy Oil Pilot	Sierra Madre
Bird-Opal Loop Pipeline	East LaBarge	Merna Pipeline	Soda Unit
BTA Bravo	Essex Mountain	Moxa Arch	South Baggs
Burley	Fontenelle II	Mulligan Draw	South Piney
Castle Creek	Hay Reservoir	Opal Loop Pipeline	Stagecoach
Continental Divide/Wamsutter II	Hickey-Table Mountain	Pinedale Anticline	Vermillion Basin
Copper Ridge	Horse Trap	Pioneer Gas Plant	
Creston-Blue Gap	Jack Morrow Hills	Riley Ridge	

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or the necessity for including as RFD any additional projects that do not meet the above definition. During completion of this analysis, more detailed development and operations data will be compiled for all RFD and presented in the Technical Support Document. To ensure a timely, complete modeling analysis, only development authorized through the inventory end-date of June 30, 2003, or quantified as of the beginning of the modeling analysis, will be included in the JIDPA analysis. For RFD quantified after the inventory end-date, a qualitative discussion will be presented describing the proposed development(s). Similarly, a qualitative discussion will be presented for development currently proposed in the Powder River Basin Coalbed Methane Development Project, located outside of the JIDPA study domain in northeast Wyoming's Powder River Basin.

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### **3.0 CRITERIA POLLUTANT NEAR-FIELD MODELING**

#### **3.1 MODELING METHODOLOGY**

The near-field ambient air quality impact assessment will be performed to quantify maximum pollutant impacts in the vicinity of the project area resulting from construction and production emissions. EPA's proposed guideline model, AERMOD (version 02222), will be used to assess these near-field impacts.

One year of meteorological data will be used that includes hourly surface meteorology data (wind speed, wind direction, standard deviation of wind direction [ $\sigma$  theta], and temperature) collected in the Jonah Field from January 1999 through January 2000. A wind rose for these data is presented in Figure 3.1.

The AERMOD preprocessor AERMET will be used to process Jonah Field meteorological data into formats compatible with AERMOD. In addition to the data collected in the Jonah Field, AERMET requires an upper air, twice daily sounding, meteorological data set and, at a minimum, cloud cover parameters or net radiation data. If net radiation data is available, AERMET will accept it in lieu of cloud cover data. If solar radiation data is available, AERMET will use it in combination with cloud cover data. Twice daily sounding data collected from Riverton, Wyoming; cloud cover data collected at Big Piney, Wyoming; and solar radiation measurements collected at Pinedale, Wyoming, are available and will be used for this analysis.

#### **3.2 BACKGROUND DATA**

Background concentration data collected for criteria pollutants at regional monitoring sites will be added to concentrations modeled in the near-field analysis to establish total pollutant concentrations for comparison to ambient air quality standards. The most representative monitored regional background concentrations available for criteria pollutants are shown in

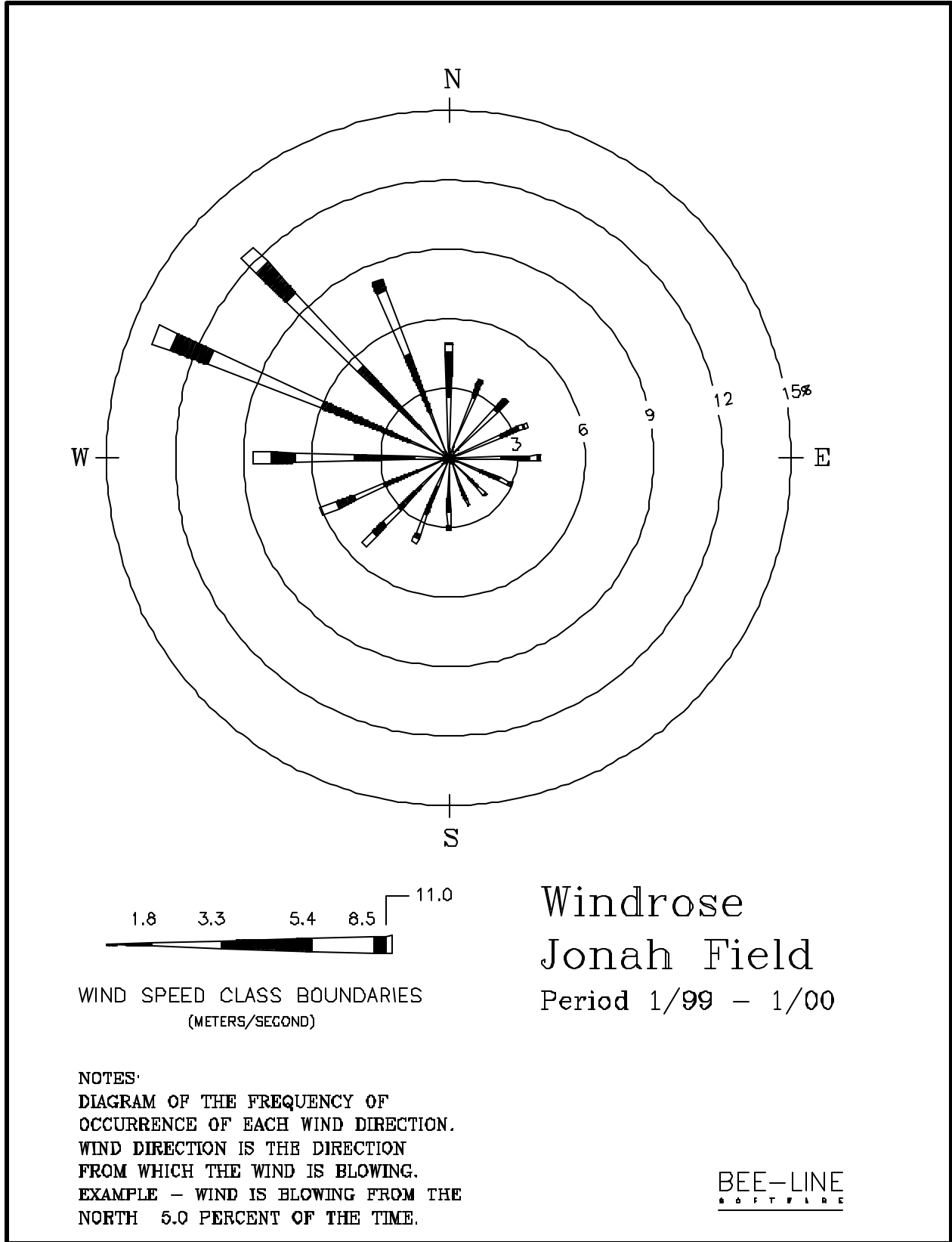


Figure 3.1 Wind Rose, Jonah Field, 1999.



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Table 3.1. Further research will be conducted to determine if more recent CO and/or SO<sub>2</sub> background data are available at alternative monitoring sites and if those data are suitable for this analysis. Background concentrations of HAPs are not available and are assumed to be minimal; furthermore, comparison thresholds are based on incremental exposure rather than total exposure, as discussed in Section 5.0 of this Protocol.

### **3.3 CRITERIA POLLUTANT IMPACT ASSESSMENT**

Criteria pollutants PM<sub>10</sub>, PM<sub>2.5</sub>, NO<sub>x</sub>, SO<sub>2</sub>, and CO will be modeled with AERMOD. Ozone (O<sub>3</sub>) formation and impacts will not be modeled using AERMOD; rather, ozone impacts will be estimated from NO<sub>x</sub> and VOC emissions using a screening methodology developed by Scheffe (1988) and provided in Appendix A of this Protocol. For all other pollutants, emissions of each pollutant will be examined to determine the development phase (i.e., construction or production) during which emissions will be greatest, and it will be this development-phase/emission-rate combination that will be modeled to determine near-field project impacts. Based on previous analyses, it is expected that construction activities will generate the greatest PM<sub>10</sub>, PM<sub>2.5</sub>, and SO<sub>2</sub> emissions, and that production activities will generate the greatest NO<sub>x</sub> and CO emissions.

For construction activities, a representative well pad and resource/access road will be developed for modeling which represents a reasonable but conservative well pad/road layout. Hourly emission rate adjustment factors will be applied to sources emitting only during specific diurnal periods. For PM<sub>10</sub> and PM<sub>2.5</sub> this layout will be modeled, using the meteorological data described above, 36 times, once at each of 36 10° rotations to ensure that impacts from all directional layout configurations and meteorological conditions are assessed. In accordance with averaging periods for which ambient standards exist, PM<sub>10</sub> and PM<sub>2.5</sub> concentrations will be calculated for 24-hour and annual averaging periods, and SO<sub>2</sub> concentrations will be calculated for 3-hour, 24-hour, and annual averaging periods.

Table 3.1 Near-Field Analysis Background Ambient Air Quality Concentrations ( $\mu\text{g}/\text{m}^3$ ).

Pollutant	Averaging Period	Measured Background Concentration
Carbon monoxide (CO) <sup>1</sup>	1-hour	3,336
	8-hour	1,381
Nitrogen dioxide (NO <sub>2</sub> ) <sup>2</sup>	Annual	3.4
Ozone (O <sub>3</sub> ) <sup>3</sup>	1-hour	169
	8-hour	147
PM <sub>10</sub> <sup>4</sup>	24-hour	47
	Annual	16
PM <sub>2.5</sub> <sup>4</sup>	24-hour	15
	Annual	5
Sulfur dioxide (SO <sub>2</sub> ) <sup>5</sup>	3-hour	132
	24-hour	43
	Annual	9

<sup>1</sup> Data collected by Amoco at Ryckman Creek for an 8-month period during 1978-1979, summarized in the Riley Ridge EIS (BLM 1983).

<sup>2</sup> Data collected at Green River Basin Visibility Study site, Green River, Wyoming, during period January-December 2001 (Air Resource Specialists [ARS] 2002).

<sup>3</sup> Data collected at Green River Basin Visibility Study site, Green River, Wyoming, during period June 10, 1998, through December 31, 2001 (ARS 2002).

<sup>4</sup> Data collected by WDEQ-AQD at Emerson Building, Cheyenne, Wyoming, Year 2002.

<sup>5</sup> Data collected at LaBarge Study Area, Northwest Pipeline Craven Creek Site 1982-1983.

Four production scenarios will be analyzed. Each scenario will include an existing infill compressor station and representative well configuration. The first production scenario will analyze a well configuration based on 10 wells on a single pad (approximately 13 pads/640-acre section), the second scenario will analyze five wells on a single pad (approximately 26 pads/640-acre section), the third scenario will analyze two wells on a single pad (64 well pads per 640-acre section), and the fourth scenario will include 128 single-well pads per 640-acre section. Analyzing these scenarios will ensure that maximum possible production impacts from wells and compression combined are identified. For each production scenario, annual average nitrogen dioxide (NO<sub>2</sub>) concentrations and 1-hour and 8-hour CO concentrations will be predicted.

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Point sources will be used for modeling NO<sub>x</sub> and CO emissions from compressors and well-site combustion equipment, and for modeling SO<sub>2</sub> emissions from drilling rigs during construction activities. Volume sources will be used for modeling PM<sub>10</sub> and PM<sub>2.5</sub> emissions from road travel and wind erosion during construction activities.

Model receptors will be located a minimum of 100 m from construction emission sources at 100-m grid spacing. Following WDEQ-AQD compressor modeling guidance, model receptors will be placed at 25-m intervals along anticipated compressor facility fencelines. Compressor stack heights will be set at actual or proposed heights but no greater than 1.5 times compressor building heights. Receptors beyond the compressor facility fenceline will be placed at 100-m intervals or at intervals appropriate to decreased well spacing.

### **3.4 HAP IMPACT ASSESSMENT**

Near-field HAP concentrations will be calculated for assessing impacts both in the immediate vicinity of Project area emission sources for short-term (acute) exposure assessment and at greater distances for calculation of long-term risk. Sources of HAPs are expected to include well-site fugitive and smokeless flare emissions and compressor combustion emissions. Because HAPs will be emitted predominantly during the production phase, only HAP emissions from production will be analyzed.

The modeling methodology for the short-term and long-term HAP impact assessments is nearly identical to the methodology outlined in Section 3.1. Volume sources will be used for modeling well-site fugitive HAP emissions during production, and point sources will be used to represent compressor engine emissions. The four representative production scenarios described in Section 3.3 will also be analyzed in this HAPs analysis.

Receptors will be placed a minimum of 100 m from production wells and at 100-m spacing beyond. Receptors will be placed at 25-m intervals along compressor fence lines and at 100-m spacing beyond. The short-term HAP assessment will consist of modeling formaldehyde emissions from a representative natural gas-fired compressor station and modeling all other

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natural gas constituent-based HAPs in the representative area developed for the criteria pollutant modeling as described in Section 3.3. For the long-term assessment, receptors will be placed on a polar grid at 10°-intervals equidistant from the emissions source and the nearest residence or expected residence. The nearest residence is expected to be located along the New Fork River.

Short-term (1-hour) HAP concentrations will be compared to acute Reference Exposure Levels (RELs), shown in Table 3.2. RELs are defined as concentrations at or below which no adverse health effects are expected. No RELs are available for ethylbenzene and n-hexane; instead, the available Immediately Dangerous to Life or Health (IDLH) values are used. These IDLH values are determined by the National Institute for Occupational Safety and Health (NIOSH) and were obtained from EPA's Air Toxics Database (EPA 2002).

Long-term exposure to HAPs emitted by the Proposed Action will be compared to Reference Concentrations for Chronic Inhalation (RfCs). An RfC is defined by EPA as the daily inhalation concentration at which no long-term adverse health effects are expected. RfCs exist for both non-carcinogenic and carcinogenic effects on human health (EPA 2002). Annual modeled HAP concentrations for all HAPs emitted will be compared directly to the non-carcinogenic RfCs shown in Table 3.3.

RfCs for suspected carcinogens benzene and formaldehyde are expressed as risk factors, shown in Table 3.4. Accepted methods for risk assessment will be used to evaluate the incremental cancer risk for these pollutants.

Annual modeled concentrations will be multiplied by EPA's unit risk factors (URF) (based on 70-year exposure) for those pollutants, and then the product will be multiplied by an adjustment factor which represents the ratio of projected exposure time to 70 years. The adjustment factors represent two scenarios: a most likely exposure (MLE) scenario and one reflective of the maximally exposed individual (MEI).

Table 3.2 Acute RELs.

HAP	REL (mg/m <sup>3</sup> )
Benzene	1.3 <sup>1</sup>
Toluene	37 <sup>1</sup>
Ethylbenzene	35 <sup>2</sup>
Xylene	22 <sup>1</sup>
n-Hexane	39 <sup>2</sup>
Formaldehyde	0.094 <sup>1</sup>

<sup>1</sup> EPA Air Toxics Database, Table 2 (EPA 2002).

<sup>2</sup> No REL available for these HAPs. Values shown are from Immediately Dangerous to Life or Health (IDLH/10), EPA Air Toxics Database, Table 2 (EPA 2002).

Table 3.3 Non-Carcinogenic HAP RfCs.

HAP	Non-Carcinogenic RfC <sup>1</sup> (µg/m <sup>3</sup> )
Benzene	30
Toluene	400
Ethylbenzene	1,000
Xylenes	430
n-Hexane	200
Formaldehyde	9.8

<sup>1</sup> EPA Air Toxics Database, Table 1 (EPA 2002).

Table 3.4 Carcinogenic HAP RfCs and Exposure Adjustment Factors.

Analysis <sup>1</sup>	HAP Constituent	Carcinogenic RfC (Risk Factor) <sup>2</sup>	
		1/(µg/m <sup>3</sup> )	Exposure Adjustment Factor
MLE	Benzene	7.8 x 10 <sup>-6</sup>	0.0949
MLE	Formaldehyde	1.3 x 10 <sup>-5</sup>	0.0949
MEI	Benzene	7.8 x 10 <sup>-6</sup>	0.71
MEI	Formaldehyde	1.3 x 10 <sup>-5</sup>	0.71

<sup>1</sup> MLE = most likely exposure; MEI = maximally exposed individual.

<sup>2</sup> EPA Air Toxics Database, Table 1 (EPA 2002).

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The MLE duration will be assumed to be 9 years, which corresponds to the mean duration that a family remains at a residence (EPA 1993). This duration corresponds to an adjustment factor of  $9/70 = 0.13$ . The duration of exposure for the MEI is assumed to be 50 years (i.e., the LOP), corresponding to an adjustment factor of  $50/70 = 0.71$ .

A second adjustment will be made for time spent at home versus time spent elsewhere. For the MLE scenario, the at-home time fraction is 0.64 (EPA 1993), and it will be assumed that during the rest of the day the individual would remain in an area where annual HAP concentrations would be one quarter as large as the maximum annual average concentration. Therefore, the MLE adjustment factor will be  $(0.13) \times [(0.64 \times 1.0) + (0.36 \times 0.25)] = 0.0949$ . The MEI scenario assumes that the individual is at home 100% of the time, for a final adjustment factor of  $(0.71 \times 1.0) = 0.71$ . EPA unit risk factors and adjustment factors are shown in Table 3.4.

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## 4.0 FAR-FIELD ANALYSIS

### 4.1 METHODOLOGY

The purpose of the far-field analysis is to quantify the impacts on Class I and other sensitive areas from air pollutant emissions expected to result from the development of the Project. Ambient air quality impacts beyond the immediate Project area and throughout the study area will be analyzed. Cumulative impacts also will be quantified by including in the analysis other documented sources of air pollutant emissions within the study area. To achieve these goals, the most current long-range modeling analysis tools will be used in conjunction with the most recent guidance for their utilization.

As requested by BLM and generally accepted for long-range modeling analyses, the CALMET/CALPUFF modeling system (Earth Tech 2003) will be used in this analysis. The study will be performed in accordance with the following recent and major guidance sources:

- direct guidance provided by representatives of the BLM, the National Park Service, and the U.S.D.A. Forest Service;
- *Guideline on Air Quality Models*, 40 Code of Federal Regulations (C.F.R.), Part 51, Appendix W;
- *Interagency Work Group on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts*, EPA-454/R-98-019, Office of Air Quality Planning and Standards, December 1998 (IWAQM 1998); and
- *Federal Land Managers - Air Quality Related Values Workgroup (FLAG), Phase I Report*, December 2000 (FLAG 2000).

Air emissions of NO<sub>x</sub>, SO<sub>2</sub>, PM<sub>10</sub>, and PM<sub>2.5</sub>, from 1) 1,250 wells, 2) 3,100 wells, and 3) cumulative emissions, including all currently operating, proposed, and RFD emissions sources within the modeling domain, will be modeled. A description of the emissions inventory

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procedures to be implemented is included in Section 2.0 of this Protocol. The idealization of these emissions sources for input to the CALPUFF model is described in Section 4.2.

The proposed modeling domain for this analysis includes the domain developed for SWWYTAF and used for Pinedale Anticline EIS, but extends approximately 50 km farther to the north. The extent of the domain, along with other regional features, is shown in Map 2.1. The CALPUFF dispersion model will be run with CALMET wind field data, developed for year 1995, to predict the transport and dispersion of pollutants. The CALPUFF model accounts for changes in the wind field, variability in surface conditions, terrain influences, chemical transformation, wet removal from precipitation, and dry deposition, and calculates concentration and deposition at receptors input to the model.

CALPUFF output will be post-processed with POSTUTIL and CALPOST to derive concentrations for comparison to ambient standards, significance thresholds, and Class I and II Increments; deposition rates for comparison to sulfur (S) and nitrogen (N) deposition thresholds and to calculate acid neutralizing capacity (ANC) for sensitive water bodies; and light extinction for comparison to visibility impact thresholds in Class I and other sensitive areas. A discussion of the post-processing methodology to be used is provided in Section 4.3 of this Protocol.

## **4.2 MODEL INPUT**

### **4.2.1 Model Selection and Settings**

The recently released regulatory version of the CALMET/CALPUFF modeling system (CALMET Version 5.5 dated March 4, 2002, CALPUFF Version 5.7 dated March 4, 2002) will be used to develop wind fields and calculate both ambient concentrations and AQRV impacts. The SWWYTAF CALMET methodology is proposed for use in combination with meteorological data updated for use in the Pinedale Anticline EIS. This approach ensures consistency with the well-accepted SWWYTAF study while incorporating improved data quality



resulting from extensive quality assurance/quality control (QA/QC) procedures performed on data used in the Pinedale Anticline EIS (BLM 1999a).

The CALMET wind fields utilized in the Pinedale Anticline EIS study were based upon wind fields developed by Earth Tech for the SWWYTAF study (Earth Tech 2001). As part of the Pinedale Anticline EIS, Air Sciences performed extensive review and QA/QC of surface station and precipitation data used in SWWYTAF and corrections were made. These surface data will be used in this analysis, along with additional available surface meteorological data sites within the newly extended northern portion of the domain. Table 4.1 lists the additional sites that will be added to the analysis.

Precipitation data for the stations used in the SWWYTAF study will be used for this analysis, since they include stations throughout the proposed Jonah Infill modeling domain. The Pinedale Anticline modeling analysis identified problems with the original SWWYTAF precipitation data files, specifically, that the data for the month of December were missing. The precipitation data proposed for use in this analysis have been corrected.

Table 4.1 Additional Surface Meteorological Data Sites.

Site	Data Source
Craters of the Moon, Idaho	National Park Service (NPS)
Yellowstone, Wyoming	NPS
Cody, Wyoming	National Weather Service (NWS)
Idaho Falls, Idaho	NWS
Salmon, Idaho	NWS
Sheridan, Wyoming	NWS
Meeteetse, Wyoming	Wyoming Department of Transportation (WYDOT)
Interstate 25 (I-25) Divide	WYDOT

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Other differences between the SWWYTAF study and the Pinedale Anticline EIS study include: 1) upper air observations were not used in the Pinedale Anticline EIS and 2) changes were made to CALMET input settings in the Pinedale Anticline EIS from those originally used in SWWYTAF. A detailed description of the modeling methodology used in the Pinedale Anticline EIS can be found in the supporting air quality technical document (BLM 1999b).

This analysis proposes to utilize the SWWYTAF CALMET methodology, the regional mesoscale meteorological (MM5) data subgrid processed to 20-km spacing, surface and precipitation data updated for use in the Pinedale Anticline EIS as discussed above and including data from 75 surface meteorological stations and 155 precipitation stations, and four upper air meteorological stations to supplement MM5 upper air estimates, in accordance with current NPS recommendations.

The uniform horizontal grid is processed to 4-km resolution, based on a Lambert Conformal Projection defined with a central longitude/latitude at (-108.55°, 42.55°) and first and second latitude parallels at 30° and 60°. The modeling domain consists of 116 x 112, 4-km grid cells, and covers the project area and Class I and other sensitive areas with a sufficient buffer zone to allow for potential recirculation or flow reversal effects to be evaluated. The total area of the modeling domain is 464 x 448 km. Ten vertical layers exist at heights of 20, 40, 100, 140, 320, 580, 1,020, 1,480, 2,220, and 2,980 m. The extents of the horizontal grid, which form the extents of the cumulative study area, are shown in Map 2.1.

The CALPUFF model will be run using the IWAQM-recommended default switch settings for all parameters. Chemical transformation will be based on the MESOPUFF II chemistry for conversion of SO<sub>2</sub> to sulfate (SO<sub>4</sub>) and NO<sub>x</sub> to nitric acid (HNO<sub>3</sub>) and nitrate (NO<sub>3</sub>). Each of these pollutant species will be included in the CALPUFF model run. NO<sub>x</sub>, HNO<sub>3</sub>, and SO<sub>2</sub> will be modeled with gaseous deposition and SO<sub>4</sub>, NO<sub>3</sub>, PM<sub>10</sub>, and PM<sub>2.5</sub> will be modeled using particle deposition. Electronic copies of CALMET, CALPUFF, and CALPOST input files will be included with the Technical Support Document.

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## **4.2.2 Emissions**

### **4.2.2.1 Project Emissions**

Pollutant emission rates estimated as described in Section 2.0 will be input to CALPUFF to predict air quality impacts from the Project. Emissions from both the construction phase and well production (field operation) phase will be modeled. Emissions from construction activities and production activities over the LOP will be examined to determine an annual period representing a maximum combination of production and construction.

Hourly emission-rate adjustment factors will be applied to emissions that occur only during specific diurnal periods, such as travel on unpaved roads. Seasonal adjustment factors will be applied to compensate for increased gas well-heater use in the winter months. Well locations will be modeled as area sources within the specific area of the JIDPA they are projected to be located in, on a rectangular grid not exceeding 4 x 4 km spacing and possessing a total area not exceeding the total area of the JIDPA.

The analysis for both 1,250 and 3,100 wells will include future regional compression requirements projected by the pipeline companies working in the Jonah and Pinedale Anticline fields. Compressor-engine emissions will be input as point sources with actual expected stack parameters at their anticipated locations.

### **4.2.2.2 Cumulative Source Emissions**

Cumulative sources, including permitted sources, RFD, and RFFA inventoried following the methodology described in Section 2.2, will be input to the CALPUFF model as point sources or area sources. As part of the emissions inventory, source location and exit parameter data will be obtained. Permitted and proposed sources will be modeled both alone and with RFD and RFFA sources to provide a clear analysis of the impacts attributable to each.

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Pollutant emissions from stacks will be modeled as point sources in the CALPUFF model. EIS development project emissions will be assessed to determine worst-case emission levels (i.e., full production vs. interim production level + drilling). Multiple stacks within single facilities will be combined into a single, worst-case stack to reduce model run-time. This procedure was followed in the Pinedale Anticline EIS and other EIS cumulative source inventories. Worst-case stack parameters will be selected based on the potential for the greatest long-range impacts (i.e., greater stack height, greater exhaust flow rate). For already aggregated facilities that have undergone modifications, sources will be de-aggregated and re-examined for source parameters before combining into a single source.

Fugitive emissions will be aggregated into area sources in the model, either source location-specific or regional depending upon the nature of the fugitive emissions sources. The locations of area sources input to the model will be disclosed in the technical support document. Because regional paved and unpaved roadway travel not associated with any specific regional well development field and biogenic sources are considered to be included in the ambient air background concentrations described in this Protocol, those fugitive sources will not be modeled.

### **4.2.3 Receptors**

Model receptors will be input to CALPUFF, at which concentration, deposition, and other impacts will be calculated. A gridded Cartesian receptor grid will be created at the computational grid resolution of 4 km throughout the modeling domain to calculate domain-wide cumulative impacts. Receptors will be placed along the boundaries of all Class I and sensitive areas at 2-km spacing, and within the boundaries of those areas at 4-km resolution.

Prevention of Significant Deterioration (PSD) Class I and other sensitive areas located within the modeling domain and the distance of each from the JIDPA are shown in Map 2.1. Federal Class I areas to be evaluated are:

- Bridger Wilderness Area,
- Fitzpatrick Wilderness Area,
- Teton Wilderness Area,
- Washakie Wilderness Area,

- 
- Grand Teton National Park, and
  - Yellowstone National Park.

Because the southern portion of Yellowstone National Park is along the boundary of the modeling domain, the wind patterns surrounding those receptors may not be accurately modeled by CALMET and treatment of receptors at boundary locations may be suspect. A discussion of the uncertainty of modeling results for Yellowstone will be included in the TSD.

Several PSD Class II areas are located within the modeling domain for which ambient air and AQRV impacts assessments are not mandatory but have been requested. These Class II sensitive areas are:

- Popo Agie Wilderness Area (Federal Class II), and
- Wind River Roadless Area (Federal Class II).

In addition, discrete receptors will be placed at the following sensitive lakes identified as the most sensitive to acid deposition:

- Black Joe Lake, Bridger Wilderness Area,
- Deep Lake, Bridger Wilderness Area,
- Hobbs Lake, Bridger Wilderness Area,
- Lazy Boy Lake, Bridger Wilderness Area,
- Upper Frozen Lake, Bridger Wilderness Area,
- Ross Lake, Fitzpatrick Wilderness Area, and
- Lower Saddlebag Lake, Popo Agie Wilderness Area.

#### **4.2.4 Background Data**

##### **4.2.4.1 Criteria Pollutants**

Ambient air concentration data collected at monitoring sites in the region provide a measure of background conditions in existence during the most recent available time period. Regional monitoring-based background values for criteria pollutants (PM<sub>10</sub>, PM<sub>2.5</sub>, CO, NO<sub>x</sub>, and SO<sub>2</sub>)

were collected at monitoring sites in Wyoming and northwestern Colorado, and are summarized in Table 4.2. These ambient air background concentrations will be added to modeled pollutant concentrations (expressed in micrograms per cubic meter [ $\mu\text{g}/\text{m}^3$ ]) to arrive at total ambient air quality impacts for comparison to National Ambient Air Quality Standards (NAAQS), Wyoming Ambient Air Quality Standards (WAAQS), Colorado Ambient Air Quality Standards (CAAQS), Utah Ambient Air Quality Standards (UAAQS), and Idaho Ambient Air Quality Standards (IAAQS), as discussed in Section 5.0.

#### 4.2.4.2 Chemical Species

The CALPUFF chemistry algorithms require hourly estimates of background ammonia and ozone concentrations for the conversion of  $\text{SO}_2$  and  $\text{NO}/\text{NO}_2$  to sulfates and nitrates,

Table 4.2 Far-Field Analysis Background Ambient Air Quality Concentrations ( $\mu\text{g}/\text{m}^3$ ).

Pollutant	Averaging Period	Measured Background Concentration
Carbon monoxide ( $\text{CO}$ ) <sup>1</sup>	1-hour	3,336
	8-hour	1,381
Nitrogen dioxide ( $\text{NO}_2$ ) <sup>2</sup>	Annual	3.4
Ozone ( $\text{O}_3$ ) <sup>3</sup>	1-hour	169
	8-hour	147
$\text{PM}_{10}$ <sup>4</sup>	24-hour	47
	Annual	16
$\text{PM}_{2.5}$ <sup>4</sup>	24-hour	15
	Annual	5
Sulfur dioxide ( $\text{SO}_2$ ) <sup>5</sup>	3-hour	132
	24-hour	43
	Annual	9

<sup>1</sup> Data collected by Amoco at Ryckman Creek for an 8-month period during 1978-1979, summarized in the Riley Ridge EIS (BLM 1983).

<sup>2</sup> Data collected at Green River Basin Visibility Study site, Green River, Wyoming during period January-December 2001 (ARS 2002).

<sup>3</sup> Data collected at Green River Basin Visibility Study site, Green River, Wyoming during period June 10, 1998, through December 31, 2001 (ARS 2002).

<sup>4</sup> Data collected by WDEQ-AQD at Emerson Building, Cheyenne, Wyoming, Year 2002.

<sup>5</sup> Data collected at LaBarge Study Area at the Northwest Pipeline Craven Creek Site 1982-1983.

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respectively. While ammonia concentrations are thought to be fairly uniform spatially, ozone concentrations vary greatly over time and space. A review of background ozone data indicates that six ozone stations are available in the region for year 1995. 1995 ozone data is used because it is concurrent with the CALMET windfields, which were created using 1995 surface and MM5 datasets. Ozone stations proposed for use are as follows:

- Pinedale, Wyoming,
- Centennial, Wyoming,
- Yellowstone National Park, Wyoming,
- Craters of the Moon National Park, Idaho,
- Highland, Utah, and
- Mount Zirkel Visibility Study, Hayden, Colorado.

Hourly ozone data from these stations will be included in the CALPUFF modeling, with a default value of 44.7 parts per billion (ppb) (7 a.m.-7 p.m. mean, used for SWWYTAF) used for missing hours. A background ammonia concentration of 1.0 ppb as suggested in the IWAQM Phase 2 guidance (for arid lands) will be used.

#### 4.2.4.3 Visibility

The proposed analysis differs from previous Wyoming NEPA cumulative air quality analyses in its update of visibility background to include the most current data available at the time of this Protocol. Monitored visibility background data that have undergone QA/QC are currently available through December 31, 2001. This analysis proposes to utilize IMPROVE visibility data for the period of record 1989 through 2001 and 2001 NO<sub>x</sub> background data collected in the final year of the Green River Basin Visibility Study, and to revise the period of regional emissions inventory to reflect industrial activity occurring during and since that updated background to represent the most appropriate combination of measured background and modeled impacts. If 2002 IMPROVE visibility data are available by the time the analysis is conducted, that data will be utilized.

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WDEQ-AQD has prepared an annual report on Wyoming's long-term strategy for visibility protection in Class I areas (WDEQ 2003). An assessment of visibility monitoring data is presented as Appendix F of that report, including an analysis of trends in visibility monitored at Wyoming IMPROVE and Wyoming Visibility Monitoring Network sites. Bridger Wilderness and Yellowstone National Park IMPROVE sites are the closest monitoring sites to the Project area, and data reported from these sites extends from January 1989 through December 2001. As a result, visibility trends at these sites are of particular interest. These visibility trends are well-illustrated by two graphs in WDEQ-AQD's report, Graph 3 and Graph 6, presented in Appendix B of this Protocol. A detailed description of the data and assumptions behind these graphs is not presented here; rather, the reader is referred to the WDEQ-AQD report (WDEQ 2003).

As the graphs indicate, visibility conditions at Bridger Wilderness have not decreased since 1989, and an improvement in monitored visibility conditions has occurred at Yellowstone National Park since 1989 (Appendix B). It is important to note the significant fluctuations in monitored visibility during the period from 1995 through 1997 and that previous Wyoming NEPA cumulative air quality analyses utilized visibility background data monitored through 1997. Updating background visibility will improve the quality of the analysis by providing a longer period of record and resulting in a better estimate of long-term visibility conditions in the region.

CALPOST will be used to estimate change in light extinction from CALPUFF model concentration results. At the request of the BLM and following the most current agency recommendations, two separate methods are proposed for this analysis: FLAG and WDEQ.

The FLAG method uses seasonal natural background visibility conditions and relative humidity factors at Class I areas. This method is highly conservative since values of estimated natural background are generally less than measured background, and a calculated light extinction value will therefore comprise a greater percentage of the total light extinction (background + calculated). For the FLAG method proposed for this analysis, estimated natural background visibility values as provided in Appendix 2.B of FLAG (2000), and monthly relative humidity



factors as provided in the *Draft Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule* (EPA 2001) will be used. Because natural background data are provided for Federal Class I areas only, data from the nearest Federal Class I area will be used for other areas analyzed but not classified as Federal Class I areas. The natural background visibility data that will be used with the FLAG visibility analysis for each area analyzed are shown in Table 4.3.

Table 4.3 FLAG Report Background Extinction Values.<sup>1</sup>

Site	Season	Hygroscopic (Mm <sup>-1</sup> )	Non-hygroscopic (Mm <sup>-1</sup> )
Bridger Wilderness Area (will also be used for Popo Agie Wilderness Area and Wind River Roadless Area)	Winter	0.6	4.5
	Spring	0.6	4.5
	Summer	0.6	4.5
	Fall	0.6	4.5
Fitzpatrick Wilderness Area	Winter	0.6	4.5
	Spring	0.6	4.5
	Summer	0.6	4.5
	Fall	0.6	4.5
Teton Wilderness Area	Winter	0.6	4.5
	Spring	0.6	4.5
	Summer	0.6	4.5
	Fall	0.6	4.5
Washakie Wilderness Area	Winter	0.6	4.5
	Spring	0.6	4.5
	Summer	0.6	4.5
	Fall	0.6	4.5
Grand Teton National Park	Winter	0.6	4.5
	Spring	0.6	4.5
	Summer	0.6	4.5
	Fall	0.6	4.5
Yellowstone National Park	Winter	0.6	4.5
	Spring	0.6	4.5
	Summer	0.6	4.5
	Fall	0.6	4.5

<sup>1</sup> FLAG (2000).

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The WDEQ method uses reconstructed IMPROVE aerosol total extinction data. Background visibility data will be based on the seasonal mean of the 20% cleanest days measured at the Bridger Wilderness Area and Yellowstone National Park IMPROVE sites. The WDEQ method will also utilize monthly relative humidity factors as provided in the *Draft Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule*. The seasonal mean of the 20% cleanest days visibility data will be determined using data from the historical record through December 2001 or through December 2002 if available at the time of the analysis.

Seasonal visibility data from the Bridger Wilderness Area IMPROVE site will be used for the Bridger, Fitzpatrick, and Popo Agie Wilderness Areas and for the Wind River Roadless Area, and visibility data from the Yellowstone National Park IMPROVE site will be used for the Teton and Washakie Wilderness Areas and for Grand Teton and Yellowstone National Parks. Monthly relative humidity data are available for the Bridger, Fitzpatrick, Teton, and Washakie Wilderness Areas, and for Grand Teton and Yellowstone National Parks. Relative humidity data for the Bridger Wilderness Area will also be used for the Popo Agie Wilderness Area and for the Wind River Roadless Area analyses.

#### 4.2.4.4 Lake Chemistry

The most recent lake chemistry background ANC data have been obtained from the FLMS for each sensitive lake listed in Section 4.2.4. The 10th percentile lowest ANC values were calculated for each lake following procedures provided from the U.S.D.A. Forest Service. The ANC values proposed for use in this analysis and the number of samples used in the calculation of the 10<sup>th</sup> percentile lowest ANC values are provided in Table 4.4.

Table 4.4 Background ANC Values for Acid Sensitive Lakes.

Wilderness Area	Lake	Latitude (Deg-Min-Sec)	Longitude (Deg-Min-Sec)	10th Percentile Lowest ANC Value (µeq/l)	Number of Samples
Bridger	Black Joe	42°44'22"	109°10'16"	65.8	55
Bridger	Deep	42°43'10"	109°10'15"	60.6	47
Bridger	Hobbs	43°02'08"	109°40'20"	70.3	54
Bridger	Lazy Boy	43°19'57"	109°43'47"	18.8	1
Bridger	Upper Frozen	42°41'08"	109°09'38"	3.0	3
Fitzpatrick	Ross	43°22'41"	109°39'30"	60.4	33
Popo Agie	Lower Saddlebag	42°37'24"	108°59'38"	54.2	32

### 4.3 POST-PROCESSING

#### 4.3.1 Concentration

CALPOST will be used to process the CALPUFF concentration output file to compute maximum concentration values for SO<sub>2</sub> (3-hour, 24-hour, and annual average), PM<sub>2.5</sub> (24-hour and annual average), PM<sub>10</sub> (24-hour and annual average) and NO<sub>2</sub> (annual average).

#### 4.3.2 Visibility

As discussed in Section 4.2.4.3, visibility impacts (measured as change in light extinction) will be calculated using two separate methods, which differ by the background data used to derive the percent change in visibility. Changes in light extinction will be estimated for both Project emissions and cumulative source emissions at receptor locations outlined in Section 4.2.3 of this Protocol.

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CALPOST will first be run using the FLAG method recommended screening mode (MVISBK = 6), to calculate the change in light extinction from natural background conditions. This procedure computes light extinction changes from seasonal estimates of natural background aerosol concentrations and monthly relative humidity factors, and CALPUFF-predicted particle species concentrations. Seasonal background extinction values used for the FLAG method are shown in Table 4.3. Those values will be input to CALPOST as variables BKSO<sub>4</sub> (dry hygroscopic) and BKSOIL (non-hygroscopic). Using these parameters, CALPOST will compute the change in daily (24-hour) visibility, with the results reported in percent change in light extinction and change in deciview (dv). The FLAG method conservatively assumes that the seasonal natural visibility conditions occur on every day during the entire season.

CALPOST will then be run using the WDEQ method to calculate the change in light extinction using the seasonal mean of the 20% cleanest days particle mass data as background conditions. Seasonal speciated aerosol data for the 20% cleanest days, measured at the Bridger Wilderness Area and Yellowstone National Park IMPROVE sites will be used. This method uses the seasonal background aerosol concentrations and monthly averaged relative humidity factors to estimate the change in light extinction. The CALPOST switch 'MVISBK' is set to 6 for this method. Similar to the FLAG method, the WDEQ method also conservatively assumes that the cleanest seasonal visibility conditions occur on every day during the entire season.

### **4.3.3 Deposition**

The POSTUTIL utility provided with the CALPUFF modeling system will be used to estimate total S and N fluxes from CALPUFF-predicted wet and dry fluxes of SO<sub>2</sub>, SO<sub>4</sub>, NO<sub>x</sub>, NO<sub>3</sub>, HNO<sub>3</sub>, PM<sub>10</sub>, and PM<sub>2.5</sub>. CALPOST will be used to summarize the annual S and N deposition values from the POSTUTIL program.

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## 5.0 ASSESSMENT OF AIR QUALITY IMPACTS

### 5.1 NEAR-FIELD

Pollutant significance levels are set forth in Wyoming Air Quality Standards and Regulations (WAQSR). Under the New Source Review (NSR) process, an emission source which models pollutant concentrations (from its operations alone) that are below these significance levels is typically exempt from additional modeling analyses for the insignificant pollutant. In this near-field modeling analysis, significance levels will be compared to Project concentrations predicted by AERMOD as an indicator of the magnitude of impact from the Project alone. Another demonstration of project-only impacts will be made by comparison of Project concentrations to Class II PSD Increments. This demonstration is for information only and is not a regulatory PSD Increment consumption analysis, which would be completed as necessary during the WDEQ-AQD permitting process.

In addition, the WDEQ-AQD has been authorized by EPA to enforce ambient air quality standards set forth in the *Clean Air Act* through approval of the Wyoming State Implementation Plan. The NAAQS and ambient standards adopted by state regulatory agencies set absolute upper limits for specific air pollutant concentrations (expressed in  $\mu\text{g}/\text{m}^3$ ) at all locations where the public has access. Modeled concentrations occurring from construction and production operations will be added to the existing ambient air quality background concentrations shown in Table 3.1, and the total concentrations will be compared to corresponding NAAQS and state ambient air quality standards (i.e., WAAQS, CAAQS, UAAQS, IAAQS) shown in Table 5.1.

Ambient air quality standards, significance levels, and PSD Class II Increments are shown in Table 5.1.

Table 5.1 Ambient Standards, Class II PSD Increments, and Significance Levels For Comparison to Near-Field Analysis Results ( $\mu\text{g}/\text{m}^3$ ).<sup>1</sup>

Pollutant/Averaging Time	Ambient Air Quality Standards				PSD Class II Increment	Class II Significance Level
	National	Wyoming	Colorado	Utah and Idaho		
<b>Carbon monoxide (CO)</b>						
1-hour <sup>1</sup>	40,000	40,000	40,000	40,000	--	2,000
8-hour <sup>1</sup>	10,000	10,000	10,000	10,000	--	500
<b>Nitrogen dioxide (NO<sub>2</sub>)</b>						
Annual <sup>2</sup>	100	100	100	100	25	1
<b>Ozone (O<sub>3</sub>)</b>						
1-hour	235	235	235	235	--	--
8-hour <sup>3</sup>	157	157	--	157	--	--
<b>PM<sub>10</sub></b>						
24-hour <sup>1</sup>	150	150	150	150	30	5
Annual <sup>2</sup>	50	50	50	50	17	1
<b>PM<sub>2.5</sub></b>						
24-hour <sup>4</sup>	65	65	--	65	NA	--
Annual <sup>4</sup>	15	15	--	15	NA	--
<b>Sulfur dioxide (SO<sub>2</sub>)</b>						
3-hour <sup>1</sup>	1,300	1,300	700 <sup>5</sup>	1,300	512	25
24-hour <sup>1</sup>	365	260	100 <sup>5</sup>	365	91	5
Annual <sup>2</sup>	80	60	15 <sup>5</sup>	80	20	1

<sup>1</sup> No more than one exceedance per year.

<sup>2</sup> Annual arithmetic mean.

<sup>3</sup> Average of annual fourth-highest daily maximum 8-hour average.

<sup>4</sup> Proposed.

<sup>5</sup> Category III Incremental standards (increase over established baseline).

## 5.2 FAR-FIELD

### 5.2.1 Class I and Class II Increments

Under federal and state PSD regulations, increases in ambient air concentrations in Class I areas are limited by PSD Class I Increments. Specifically, emissions associated with a particular development may increase ambient concentrations above baseline levels only within those specific increments developed for SO<sub>2</sub>, PM<sub>10</sub>, and NO<sub>2</sub>. PSD Class I Increments are set forth in federal and state PSD regulations and are shown in Table 5.2. EPA has also proposed modeled

significance levels for Class I areas which would eliminate further analysis under the NSR program if ambient concentrations were shown to be below significance levels, which are also shown in Table 5.2. PSD Class II Increments are applicable in Class II areas and are shown in Table 5.1

Modeled concentrations predicted in Federal PSD Class I areas from the Project alone will be compared to Class I significance levels and Class I Increments, and cumulative modeling results predicted within Federal PSD Class I areas will be compared to Class I Increments. Project and cumulative impacts predicted at sensitive areas designated as PSD Class II areas will be compared to Class II Increments.

These demonstrations are for information only and are not regulatory PSD Increment consumption analyses, which would be completed as necessary during WDEQ-AQD permitting processes.

### **5.2.2 Visibility**

Atmospheric light extinction relative to background conditions is used to measure regional haze. Analysis thresholds for atmospheric light extinction are set forth in FLAG (2000). The thresholds are defined as 5% and 10% of the reference background visibility (or 0.5 and 1.0 dv) for projects sources alone and cumulative source impacts, respectively. In general, if impacts are

Table 5.2 PSD Class I Increments and Significance Level Concentrations ( $\mu\text{g}/\text{m}^3$ ).

Pollutant	Averaging Period	Class I Increment	Significance Level <sup>1</sup>
SO <sub>2</sub>	Annual	2	0.1
	24-hour	5	0.2
	3-hour	25	1.0
PM <sub>10</sub>	Annual	4	0.2
	24-hour	8	0.3
NO <sub>2</sub>	Annual	2.5	0.1

<sup>1</sup> Proposed Class I significance levels, *Federal Register*/Vol. 61, No. 142, pg. 38292, July 23, 1996.

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greater than these thresholds, FLMs may consider conditions (magnitude, frequency, duration, etc.) of the impact on a case by case basis. These thresholds and the FLAG guidelines were developed for NSR applications where an AQRV analysis is required as part of a PSD permit application.

### **5.2.3 Deposition**

CALPUFF will be used to predict the total wet and dry fluxes of SO<sub>2</sub>, SO<sub>4</sub>, NO<sub>x</sub>, NO<sub>3</sub>, and HNO<sub>3</sub> at the sensitive receptor areas. The modeled deposition flux of each oxide of S or N will then be adjusted for the difference of the molecular weight of their oxide and then summed to yield a total deposition flux of S or N. The total S deposition and N deposition from Project emissions will be calculated and presented in kilograms/hectare/year (kg/ha/yr). These values will be compared to the 0.005 kg/ha/yr deposition analysis thresholds defined by NPS for total N and total S in the western U.S. (NPS 2001). Estimated total deposition fluxes of S and N from cumulative source impacts at sensitive areas will be compared with threshold values for terrestrial ecosystems presented by the U.S.D.A. Forest Service in its screening procedure to evaluate effects of air pollution in eastern region wildernesses cited as Class I air quality areas (Fox et al. 1989). These threshold values are 5 and 3 kg/ha/yr for total S and N deposition fluxes, respectively.

### **5.2.4 ANC**

The CALPUFF-predicted annual deposition fluxes of S and N at sensitive lake receptors listed in Section 4.2.3 will be used to estimate the change in ANC. The change in ANC will be calculated following the January 2000, USFS Rocky Mountain Region's *Screening Methodology for Calculating ANC Change to High Elevation Lakes, User's Guide* (U.S.D.A. Forest Service 2000). The predicted changes in ANC will be compared with the U.S.D.A. Forest Service's Level of Acceptable Change (LAC) thresholds of 10% for lakes with ANC values greater than 25 microequivalents per liter (ieq/l) and 1 ieq/l for lakes with background ANC values of 25 ieq/l and less. Lake impacts will be assessed with consideration of limited data points available for several analyzed lakes. ANC calculations will be performed for both Project emissions and for cumulative source emissions.



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**APPENDIX A:**  
EPA OZONE SCREENING METHODOLOGY

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## VOC/NO<sub>x</sub> POINT SOURCE SCREENING TABLES

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September, 1988

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Office of Air Quality Planning and Standards  
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## 1.0 INTRODUCTION

This document provide a simple screening procedure presented in tabular form to calculate the ozone increment due to a VOC dominated (i.e, VOC mass emissions greater than NOx emissions) point source. [Throughout this document, ozone increment refers to a calculated increase in ozone above an assumed ambient value due to the effect of a single point source.] The tables are based on a series of applications of the Reactive Plume Model-II (RPM-II), a Lagrangian based photochemical model. Anticipated applications would include evaluation of the impact on ambient ozone due to new or modified point sources emitting more than 25 tons/year NMOC (nonmethane hydrocarbons). The screening technique is presented as two separate tables intended for appilcation in urban and rural areas, respectively.

The user is directed to Section 3 of this report for appilcation procedures needed to conduct an ozone increment screening analysis. Required inputs for determining an ozone increment are limited to estimates of NMOC and NOx mass emissions rates. As a screening technique the procedure has been designed be both robust and simple to use, while maintaining several inherent assumptions which lead to conservative (high ozone) ozone increment predictlons. The user is not required to characterize ambient meteorology or source emission and ambient speciation profiles. This technique is not intended to to substituted for a realistic photochemical modeling analysis; rather it is to be used only in the context of a firt-step proecdure which potentially can preclude further resource intensive analyses. The ozone increment estimates produced from this analysis should be interpreted as conservative predictions which would exceed ozono formation produced by actual episodic events.

A description of the protocol and asumptions used in developlng the screening tables is given in Appendix A.

## 2.0 BACKGROUND

Estimations of impacts of point sources emitting ozone precursors (NO<sub>x</sub> and/or VOC emissions) on ambient ozone provide regulatory agencies with data to address air quality issues involving proposed new or modified sources. In theory many issues can be resolved by applying a photochemical air quality model. However, two questions regarding model application must be resolved: (1) what is the most appropriate model for a particular application, and (2) how could that model be applied (i.e., how are model inputs developed and output interpreted)?

The Guideline on Air Quality Models (1986) recommends application of two photochemical models for addressing ozone air quality issues, the Urban Airshed Model (UAM) or EKMA. The EKMA model is not designed to handle point sources, as point source emissions are immediately spread into a broadly based urban mix and the individual contribution of a single point source is quenched by such broad spatial dilution. Although the UAM explicitly handles spatial resolution of point sources through spatially gridded cells, the degree of resolution typically offered by such gridding (4-5 km) is still insufficient to account for near-source behaviour. Also, the resources and input data required by the UAM are very extensive; consequently, it is an inefficient means for evaluating effects of individual sources.

The Reactive Plume Model-II (RPM-II) is an alternative air quality model which was developed in the late 1970's to address photochemically reactive plumes. The model's inherent flexibility accommodates recently developed chemical mechanisms; this work was based on use of the Carbon Bond Mechanism-Version IV (CBM-IV), which is consistent with other, current EPA photochemical models (ROM, EXMA).

The RPM-II is an appropriate choice for case by case refined (i.e., not an initial screening estimate) modelling applications. However, the prospective model user faces the possibility of conducting an exhaustive compilation of meteorological and emissions source data. Consequently, use of photochemical models to assess individual point sources has been limited. The development of a screening analysis may eliminate, in certain applications, the need for a more intensive refined modeling analysis. Current modeling guidelines do not offer recommendations for screening of individual source impacts on ozone. The tables presented herein are intended to serve as a means for screening effects on ozone from individual point sources so that subsequent, more refined analyses can be focused on sources where it is warranted.





### 3.0 SCREENING TABLES

The interpretation or definition of a "rural" or "urban" area within the framework of this technique is intended to be rather broad and flexible. The rationale for having rural and urban tables stems from the need to account for the coupled effect of point source emissions and background chemistry on ozone formation. Background chemistry in the context of this procedure refers to a characterization of the ambient atmospheric chemistry into which a point source emits. The underlying model runs used to develop the rural table (Table 1) were performed with spatially invariant background chemistry representative of "clean" continental U.S. areas. Model runs used to develop the urban table (Table 2) are based on background chemistry incorporating daily temporal fluctuations of NO<sub>x</sub> and hydrocarbons associated with a typical urban atmosphere (refer to Appendix A for details regarding background chemistry). Background chemistry is an important factor in estimating ozone formation; however, characterization of background chemistry is perhaps the most difficult aspect of reactive plume modeling because of data scarcity and the level of resources required to measure or model (temporally and spatially) the components necessary to characterize the ambient atmosphere along the trajectory of a point source plume.

Recognizing the conflicting needs of using simple characterizations of background chemistries and applying this screening technique in situations where sources are located in or impact on areas which can not be simply categorized, the following steps should be used to choose an appropriate table:

- (1) If the source location and downwind impact area can be described as rural and where ozone exceedances have never been reported, choose the rural area table.
- (2) If the source location and downwind impact area are of urban character, choose the urban area table.
- (3) If an urban based source potentially can impact a downwind rural area, or a rural based source can potentially impact a downwind urban area, use the highest value obtained from applying both tables.

The VOC point source screening tables (Tables 1 and 2) provided ozone increments as a function of NMOC (nonmethane organic carbon) mass emissions rates and NMOC/NO<sub>x</sub> emissions ratios. To determine an ozone impact the user is required to apply best estimates of maximum daily NMOC emissions rate, and estimated annual mass emissions rates of NMOC and NO<sub>x</sub> which are used to determine NMOC/NO<sub>x</sub> ratio for ascribing the applicable

column in Table 1 or 2. The reasons for basing application on daily maximum NMOC emissions rates are (1) to avoid underestimates resulting from discontinuous operations and (2) the underlying modeling simulations are based on single day episodes. The NMOC emissions rates in Tables 1 and 2 are given on an annual basis; consequently the user must project daily maximum to annual emissions rates illustrated in the example application given below. One purpose of the technique is to provide a simple, non-resource intensive tool; therefore, annual NMOC/NOx emissions ratios are used because consideration of daily fluctuations would require a screening application applied to each day.

Parameters describing background chemistry, episodic meteorology, and source emissions speciation affect actual ozone impact produced by a point source. However, as a screening methodology the application should be simple, robust and yield conservative (high ozone) values. Thus, only NMOC and Nox emissions rates are required as input to Tables 1 and 2.

#### Rural Example Application

A manufacturing company intends to construct a facility in an isolated rural location where ozone exceedances have never been observed. The pollution control agency requires that the company submit an analysis showing that operation of the proposed facility will not result in an ozone increment greater than X ppm in order to permit operation. The estimated daily maximum NMOC emissions rate is 9000 lbs/day. The annual estimated emissions rates for NMOC and NOx are 1000 tons/yr and 80 tons/yr, respectively. The company's strategy is to provide a screening analysis using the rural area table to prove future compliance. If the screening result exceeds X ppm, the company will initiate a detailed modeling analysis requiring characterization of source emissions speciation, ambient chemistry, and episodic meteorology.

Screening Estimate:

- 1 - Determine which column of Table (1) is applicable:

The NMOC/NOx ratio is based on annual estimates; thus,  $1000/80 = 12.5$  and middle column values are applied.

- 2 - Calculate annual NMOC emissions rates in tons/yr from maximum daily rate:

$$(9000 \text{ lbs/day}) (1 \text{ ton}/2000 \text{ lbs}) (365 \text{ days/yr}) = 1643 \text{ ton~/yr}$$

- 3 - Interpolate linearly between 1500 tons/yr and 2000 tons/yr to produce an interpolated column 2 ozone increment:

$$(1643-1500) (3.84-3.05) / (2000-1500) + 3.04 = 3.27 \text{ pphm}$$

$$3.27 \text{ pphm} (1 \text{ ppm}/100 \text{ pphm}) = \underline{0.0327 \text{ ppm}}$$

If 0.0327 ppm is below the criterion value (X ppm), no further modeling analysis required and operation may be permitted. Otherwise, the company will proceed with an additional case-specific modeling analysis.

Table 1. Rural based ozone increment (pphm) as a function of NMOC emissions and NMOC/NOx ratios.

NMOC EMISSIONS (TONS/YR)	NMOC/NOx TONS NMOC/TONS NOx (PPMC/PPM)		
	> 20.7 (>20)	5.2-20.7 (5-20)	< 5.2 (< 5)
50	0.4	0.4	1.1
75	0.4	0.4	1.2
100	0.4	0.5	1.4
300	0.8	1.0	1.7
500	1.1	1.4	1.9
750	1.6	1.9	2.3
1000	2.0	2.4	2.7
1500	2.7	3.0	3.3
2000	3.4	3.8	3.7
3000	4.8	5.2	4.3
5000	7.0	7.5	4.8
7500	9.8	10.1	5.1
10000	12.2	12.9	5.4

- multiply pphm by 0.01 to obtain ppm

***DRAFT***

Table 2. Urban based ozone increment (pphm) as a function of NMOC emissions and NMOC/NOx ratios.

NMOC EMISSIONS (TONS/YR)	NMOC/NOx TONS NMOC/TONS NOx (PPMC/PPM)		
	> 20.7 (>20)	5.2-20.7 (5-20)	< 5.2 (< 5)
50	1.1	1.1	1.0
75	1.2	1.1	1.1
100	1.3	1.2	1.1
300	1.8	1.6	1.9
500	2.2	2.0	2.8
750	3.3	2.6	3.9
1000	4.1	3.2	4.7
1500	5.8	4.2	4.9
2000	7.1	5.4	4.9
3000	9.5	7.8	6.5
5000	13.3	12.0	9.3
7500	17.3	16.7	12.5
10000	21.1	20.8	15.5

- multiply pphm by 0.01 to obtain ppm

**DRAFT**

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## APPENDIX A

### DEVELOPMENT OF SCREENING TABLES

#### RPM-II DESCRIPTION

Screening tables presented in this report were derived using the Reactive Plume Model-II (RPM-II). RPM-II was originally developed by Systems Applications, Incorporated (SAI) under contract to EPA in the late 1970's. RPM-II is a Lagrangian based model which describes the downwind transport and chemical behaviour of a plume emitted from a point source. Plume concentrations are a function of meteorological source emission and ambient air quality inputs. Downwind plume dimensions are either calculated through Gaussian dispersion formulae using Pasquill-Gifford stability classes, or dimensions are manually set. The plume is resolved into several well-mixed columns aligned transversely with the mean wind flow. Mass transfer of reactive species occurs across cell boundaries. As the plume expands it entrains background air which then is incorporated within the reactive plume mix. A thorough description of the model formulation can be found in the RPM-II User's Guide (SAI, 1980). Listed below are general categories of model inputs used during RPM-II applications for developing the screening tables.

#### Model Inputs:

The following summary of model inputs addresses the major input data requirements used in developing the screening tables; a comprehensive list of required modeling inputs is found in the User's Guide. The RPM-II source code addresses a single input which includes following:

Meteorological Considerations - Required meteorological inputs include time-dependent values of wind speed and either stability class to determine horizontal and/or vertical plume dimensions or values reflecting user-determined plume depths and/or horizontal plume widths. The program has been modified to accept ambient temperature to adjust temperature dependent reaction rate constants.

Chemistry Considerations - The RPM-II was designed to accept different chemical mechanisms; a particular mechanism is entered as input data. The original RPM-II and subsequent variations have used an older mechanism, Carbon Bond 2 (CB2). The source code was modified to accept an array of eleven time-dependent photolysis rate constants so that the most recent version of the Carbon Bond-4 mechanism, which is also used in EKMA/OZIPM4 (EPA,



1988), could be applied. Additional code was installed to accept activation energies to determine temperature dependent reaction rates. These code modifications and the operation of CB4 within RPM-II were evaluated by comparing RPM-II predictions with EKMA/OZIPM4. Both models were run in batch reactor mode with identical sunlight, temperature and initial conditions over the course of a ten-hour run, both models produced nearly identical time profiles for all species.

Air Quality Considerations - The model requires initialization of all CB4 surrogate and explicit species concentrations, and concentrations of background air. Time-variant concentrations of background air can be input manually, or the model will calculate temporal profiles of all species based on a user-supplied initial mix and diurnal variation in photolytic reaction rates.

Emissions Estimates - Principal emissions inputs are emissions rate of organic and inorganic species. Although any species included in the CB4 mechanism can be declared as an emissions input, typical inputs include NO; NO<sub>2</sub>; CO; CB4 surrogate organic groups - paraffins (PAR), olefins (OLE), higher aldehydes (ALD2) and explicit organic groups - formaldehyde (FORM), ethylene (ETH), toluene (TOL) and xylene (XYL).

#### DERIVATION OF SCREENING TABLE

The concept of a screening procedure for ozone precursors is immediate with an immediate contradiction: A screening tool must be simple to apply and robust, but the inclusion of photochemical phenomena in a modeling analysis typically is complicated and case specific. A major difficulty in applying a model such as RPM-II is specifying background concentrations because the model is particularly sensitive to ambient air quality. Hydrocarbon and NO<sub>x</sub> composition vary spatially and temporally throughout any region. A thorough refined modeling exercise would require temporal profiles of all dominant inorganic and organic species in the CB4 mechanism. Such data are scarce for even a single location. The problem is handled explicitly in grid modeling (e.g., UAM application) by assimilating appropriate emissions inventories and generating ambient air quality estimates (in combination with invoking reasonable assumptions regarding initial and boundary conditions). Similarly, it is feasible to generate ambient air quality data with a trajectory model like RPM-II, with appropriate placement of emissions sources. However, that approach is cumbersome within the model framework as well as application specific and, consequently, not amenable to developing a robust screening tool. To overcome this difficulty, simplifying assumptions regarding background

chemistry quality must be invoked. Such assumptions should yield conservative answers (i.e., high ozone generation) and, as a consequence of building in "conservatism" via air quality assumptions, the need for case-specific representativeness diminishes. Accordingly, these screening tables are based on "prototypical", assumed characterizations of background chemistries, representing rural and urban locations. The following discussions outline the procedures used to develop base case meteorological and chemical inputs so that conservative estimates of ozone formation would be produced from model runs performed with the various source emissions scenarios incorporated in the screening tables.

## DEVELOPMENT OF REASONABLE WORST-CASE MODEL INPUTS (RURAL)

### Background Air Chemistry

Ambient concentrations of all CB4 species (Table A1) assumed for rural background air are identical to those utilized in rural ozone modeling studies (PEI, 1988) performed with EPA's Regional Oxidant Model (ROM). Those concentrations were generated by applying the CBM-RR chemical mechanism (a more detailed version of the carbon bond mechanism) in a batch reactor mode under sequential 12-hour alternating periods of full sunlight and darkness until a relatively aged, steady state mixture was produced. Initial concentrations of NO<sub>x</sub>, CO, and NMOC were derived by EPA's Atmospheric Science and Research Laboratory (Schere, 1988).

The ambient NO<sub>x</sub> and hydrocarbon concentrations in Table A1 reflect generally low ozone precursor concentrations which might suggest a minimum of ozone forming potential, relative to a more concentrated urban mix. Although somewhat counter-intuitive results derived from running various emissions mixes (VOC don\$dated) with rural or urban background concentrations showed a greater ozone increment with rural background air, under equivalent emission rates. This might simply be explained by considering that ozone forming potential already exists in urban air due to a large mass of pollutants implied in urban background concentrations. In contrast, ozone forming potential in rural air may be lacking key ingredients (NO<sub>x</sub>, reactive VOC) which when supplied results in a larger increment. Also, low NO concentrations in rural air probably results in less ozone scavenging through direct titration.

### Meteorological and Source Speciation Inputs

A prospective user of the screening tables would select an appropriate mass emission rate and NMOC/NO<sub>x</sub> emissions ratio to

determine the ozone increments due to individual VOC/NO<sub>x</sub> sources. The tables have no provisions for specifying values of meteorological variables (such rigidity is common for most screening analyses). Furthermore, adjustment of the mix of emitted hydrocarbon fractions is not permitted, again keeping within reasonable restrictions imposed by a screening technique.

A base-case input file incorporating a single set of base-case values for meteorological parameters and one emissions reactivity mix was developed with the intention of providing conservative (worst case) ozone formation estimates. The screening tables represent runs based on those meteorological parameters with selected adjustments in emissions rates.

The set of meteorological parameters were chosen by running the model over a range of discrete values for one variable, while holding all other variables constant. A true factorial analysis of all possible combinations of wind speed plume dimensions, starting time and temperature was not performed because of the range, continuous nature and number of variables involved.

The procedures used to determine base-case meteorological inputs are listed below and followed by a discussion of the results from that analysis. For clarity, throughout the discussion "standard value" refers to the value which each variable is maintained while other variables are varied; the "standard value" should not be confused with "base-case" value, the determination of which was the object of this exercise.

Background Air - Concentrations of CB4 species representative of rural, continental U.S. locations as presented in Table A1 were held constant throughout each modeling run.

Emissions - A continuous mass emission rate of 10,000 tons/year NMOC was used for all runs designed to produce base-case values for meteorological variables. The NMOC/NOx; NOx/NO; CO/NMOC and hydrocarbon speciation partitioning were based on EKMA default values (EPA, 1988):

PPM CO/PPMC NMOC - 1.2  
PPMC NMOC/PPM NOx - 10  
PPM NOx/PPM NO - 4

CB4 group fraction on PPMC basis

ETH 0.037  
OLE 0.035  
ALD2 0.052  
FORM 0.021  
TOL 0.089  
XYL 0.117  
PAR 0.564  
NR 0.085

Additional related issues involving emissions scenarios are discussed below within the context of reactivity.

Location - In terms of model inputs, location only translates to diurnal variation of solar zenith angle. The EKMA default location of Los Angeles, California (Lat. 34.058; Long. 138.256; 6/21/75) was used in all runs, virtually no sensitivity resulted from varying latitude.

Starting Time - Starting times (i.e., plume emergence were incremented hourly from 0600 to 1200 LST (0800 standard start).

Wind Speed - Wind speeds were incremented by 1 m/s over a range from 1 m/s to 4 m/s. The standard wind speed for all runs was 4 m/s.

Plume Width - Spatially variant downwind plume widths were generated by specifying standard Pasquill-Gifford stability classes 1-5 with class 3 used as the standard stability class.

Plume Depth - Plume depths were incremented 200 m over a range from 300 m to 1500 m (500m standard depth).

Temperature - Temperatures were incremented 8 K over a range from 287 K to 311 K (303 K was standard).

Emissions NMOC Mix - In addition to the standard EKMA mix with a NMOC/NO<sub>x</sub> of 10, runs were performed with single-component NMOC emissions representing each CB4 class (except isoprene) and different NMOC/NO<sub>x</sub> ratios. To overcome numerical problems requiring excessive computational time for olefins, a mix of 70% olefins and 30% paraffins was used in place of pure olefins.

These single-component emissions were run with mass emissions rates of CO and NO<sub>x</sub> that were identical to those applied for the standard EKMA emissions mix. Consequently, NMOC/NO<sub>x</sub> (PPMC/PPM basis) ratios varied somewhat due to differences in effective molecular weights among the emissions scenarios. All NMOC emissions were based on the standard mass emission rate of 10,000 tons/year. Also, additional NMOC/NO<sub>x</sub> ratios of 5 and 2 (based on standard EKMA mix) were applied for all emissions mixes.

## RESULTS AND DISCUSSION

### Meteorology:

Sensitivities of maximum ozone increments within a point source plume due to independent variation of several meteorological parameters are presented in Figures 1-5. Based on 13 these results and consideration of consistency among meteorological variables, the following values based on the subsequent analysis were chosen for base-case meteorological inputs to provide conservative ozone increment estimates:

wind speed - 1 m/s  
horizontal stability - class C  
plume depth - 700 m  
ambient temperature - 311 K  
start time - 1000 LST (NMOC/NO<sub>x</sub> > 5)  
                  - 0700 LST (5 > NMOC/NO<sub>x</sub> > 1)  
                  - 0600 LST (NMOC/NO<sub>x</sub> < 1)

Starting Time - Only minor sensitivity was attributed to varying starting time from 0600 to 1200 LST for standard mix with NMOC/NO<sub>x</sub> = 10 (Figure 1). Sensitivity to starting time increased as NMOC/NO<sub>x</sub> ratio decreased; at lower NMOC/NO<sub>x</sub> ratios earlier starting times produced larger ozone increments (Figures 2-3).

Sensitivity to starting time is strongly coupled to optimizing both NO to NO<sub>2</sub> conversion and providing adequate reactive VOC. At high NMOC/NO<sub>x</sub>, NO titration of ozone is not dominant and exposure of high incident radiation to concentrated NMOC (short time after start-up) produces large ozone increments. In contrast, at low NMOC/NO<sub>x</sub> ratios NO titration is a problem and the plume requires extended time to reach optimum ozone forming potential. Accordingly, an earlier start time which provides intense incident radiation upon segments sufficiently downwind such that a substantial percentage of NO has been converted (as well as diluted).

Wind Speed - Wind speed variations impart the greatest degree of sensitivity on maximum ozone increments (Figure 4). Successively smaller decreases in ozone impacts occur as wind speed increases from 1 to 5 m/s; a reasonable response since, in effect, a 2-fold increase in wind speed represents a 50% decrease in the effective emissions rate injected into a plume segment. In addition, a dilution effect due to increased dispersion near the source accompanies elevated wind speeds.

Stability Class (Horizontal dispersion) - Ozone formation increased as stability classes were changed from Class A(1) to

Class E(5) (Figure 5), an expected response related to successively less downwind dilution when proceeding through higher stability categories. In the context of this analysis Class D and E stabilities yield large ozone increments; but these classes are clearly inconsistent with other optimal ozone forming conditions (full sunlight, light winds). In following a conservative approach consistent with any screening protocol selection of Class C stability is appropriate. Actually, the selection of a more stable dispersion scenario is consistent with the notion of plume meander whereby plume dispersion calculated from standard dispersion parameters encompasses a complete crosswind profile due to plume meander, yet the effective crosswind plume dimension (where reactions occur) is governed by an instantaneous crosswind dimension. While plume meander certainly increases areal exposure to a particular plume, reactivity is dependent on actual crosswind dimensions at a point in time.

Plume depth - The ozone formation response to plume depth (held constant throughout time) is similar to that for wind speed (Figure 6), an apparent dilution phenomenon. The selection of 700 m maximum plume depth is, admittedly, somewhat arbitrary. Certainly an upper bound must be imposed to account for low mixing heights, otherwise a plume would grow indefinitely, and rather rapidly, over time. While the existence of 700 m mixing heights is not uncommon, the occurrence of such a low mixing height under optimal ozone forming conditions is not likely in many locations. Nevertheless, an upper bound must be imposed and, as illustrated in Figure 6, the difference in maximum ozone increments between 700 m and 900 m is about 15 %. Furthermore, observed summertime, afternoon measurements of plume depths taken from the Tennessee Plume Study (Ludwig et al., 1981) show plume depths typically ranging from 500 m to 700 m.

Temperature - Ozone formation increased with increased temperature (Figure 7), a result consistent with observed correlations among high temperature and high ozone levels. The selection of 311 K (100 F) is not unreasonably high.

#### VOC Emissions Reactive Mix

The apportioning of emissions by CB4 classes would typically be set by a particular source profile for a refined modeling application. Since screening tables are designed to provide a simple and robust screening procedure, out of necessity the emissions mix becomes a variable which must be addressed when developing a worst-case baseline input file. A robust method conceivably should bracket the limitless variety of VOC mixes, a rather encompassing objective. To that end a crude attempt at bracketing a range of all possible VOC point

source emissions was developed by running the RPM-II with single-component NMOC emissions for each CB4 category.

Results of this analysis are shown in Figures 8-10 for three different NMOC/NOx ratios. All VOC emissions rates were held at 10,000 tons/year, and NMOC/NOx and NMOC/CO ratios were based on the standard EKMA mix. The large NMOC emissions rate of 10,000 tons/year was not intended to be representative; the rate was used to better identify trends which otherwise might have been lost in numerical noise. The ratios varied slightly among the different mixes because of differences in VOC molecular weights. To provide consistency all mass rates for NOx (at a given NMOC/NOx ratio) and CO were identical for different mixes (the NMOC/NOx ratio is volume based). Consequently, different NMOC molar emissions rates existed among mixes, with higher molar emission rates for lower weight classes (e.g. paraffins). The decision to base this analysis on mass emissions is based on the expectation that the anticipated users of this screening technique will address permitting issues based on mass emission rates.

As shown in Figures 8-10, variation in ozone increments predicted for different CB4 components range up to about 1.5 times the ozone increment obtained with a standard EKMA urban mix. Accordingly, the EKMA mix is retained for all screening analyses and application will require a scale-up factor of 1.5. It should be noted that a 70 % olefin mix is unrealistic as most olefin-named compounds are composed of chains dominated by paraffin bonds. At first glance the magnitude of differences among various mixes is surprising within the context of k-OH values for the various CB4 groups (listed below) - this topic is pursued further in a later section regarding urban table development.



CB4 Class	k-OH (min <sup>-1</sup> )
ETH	5824
OLE	20422
ALD2	11833
FORM	15000
TOL	1284
XYL	4497
PAR	1203
EKMA MIX	3180

### Rural Area Screening Tables

Results from a matrix of runs covering a range of VOC emission rates and NMOC/NOx emissions ratios are presented in Table A2. In order to maintain a consistent basis for data evaluation, all Table A2 results are based on a 1000 LST start time. Several trends exist among the data in Table A2:

- \* At NMOC ratios greater than 3, any increase in NMOC loading leads to an increased ozone maximum
- \* As VOC loading rate increases an optimal NMOC/NOx emissions ratio exists, and this ratio shifts to lower values as NMOC source size increases.
- \* At NMOC/NOx emissions ratios less than 3, VOC loading increases can lead to relative decreases in ozone maximums as well as oxone deficits during one solar day.

A simplified version of Table A2 is presented as the rural area screening table in section 3.0 (Table 1). The effects of NMOC/NOx ratios have been attenuated somewhat by presenting three broad NMOC/NOx ratios. The results under each range reflects a scale-up factor of 1.5 and are based on the most conservative (maximum ozone producing) NMOC/NOx ratio each range > 20 (NMOC/NOx = 20); 5-20 (12 - see Figure 11); < 5 (5). In addition the results in Table 1 are based on optimal starting times for different NMOC/NOx ratios and adjusted by using a reactivity scale-up factor of 1.5.

### DEVELOPMENT OF REASONABLE WORST-CASE MODEL INPUTS (URBAN)

Unless listed below, all model inputs used to develop urban screening tables were identical to those used for rural tables.

Specifically, these similar inputs include plume geometry, wind speed and ambient temperature.

### Background Air Chemistry

A diurnal concentration and composition profile for background air chemistry was prepared by conducting 8 A.M.-6 P.M. simulations using the ambient mode option (batch reactor) in RPM-II followed by a plume simulation using a 10,000 ton/yr VOC emissions source with composition described above in the rural table development section. The ambient mode simulation develops background profiles for all CB4 species (inorganics, intermediates, precursors and sinks). In turn, the background air developed by the ambient simulation can become entrained (and available for reaction) within the source emissions plume during the subsequent plume simulation.

A rather crude attempt at determining a "reasonable worst-case" background profile consisted of running various simulations using different precursor levels to identify a set of precursors which produces 1) a relative maximum ozone increment during the plume simulation and 2) a background profile characteristic, in a broad sense, of urban air quality. Initial concentrations of precursors used to drive the ambient simulation were based on starting with OZIPM4 default values (listed below) for NMOC, NO<sub>x</sub> and CO composition and concentration, and scaling those values downward and across-the-board (i.e., reducing total precursor concentration yet retaining default composition) such that conditions 1) and 2) were achieved. The downward scaling is required because the ambient mode option in RPM-II has no provision for adjusting mixing height; consequently, a set of precursors which might produce a realistic profile with typical diurnal dilution yields highly concentrated, unrealistic concentrations with a constant reactor volume constraint.

#### OZIPM4 DEFAULT PRECURSOR INPUTS

NMOC Total	1.0	ppmc	OLE 0.0175	ppm
Nox Total	0.1	ppm	ETH 0.0185	ppm
NO2	0.025	ppm	FORM 0.021	ppm
NO	0.075	ppm	TOL 0.0127	ppm
CO	1.2	ppm	ALD2 0.026	ppm
PAR	0.564	ppm	NR 0.085	ppm
XYL	0.146	ppm	H2O 20,000	ppm

The results of several simulations are presented in Figure 12. The OZIPM4 default set of precursors without reduction produces an excessively high peak background ozone concentration of 46.4 pphm. subsequent simulations with across-the-board precursor reductions resulted in successively larger ozone increments and lower peak ambient ozone concentrations. The set of precursor inputs corresponding to 16 % of default values produced the largest ozone increment while achieving ambient ozone above 12 pphm. Accordingly, that set of precursors were used for developing the urban screening tables (unadjusted - Table A3, adjusted - Table 2, main text).

#### Starting Time

The precursor concentrations reflect 6-9 A.M. values. Thus, to provide consistency with precursor composition, all simulations started at 8 A.M. LST.

#### VOC Emissions Reactive Mix

Results of modal runs conducted with single-component CB4 mixes at different NMOC/NOx ratios show substantial differences on formation of ozone increments (Figure 12). These results contrast sharply with the analogous set of rural based simulations (Figures 8-10). The urban based ozone increment due to olefins is more than five times that of the EKMA mix at an NMOX/NOx ratio of 10, whereas only a 50 % increase occurred in the rural analysis. Differences among the more reactive urban mixes and the EKMA mix diverge further at lower XMOC/NOx ratios. Also, a large dependence on NOx which produces a shift from reactive to much less reactive (high to low NMOC/NOx ratio)

occurs with formaldehyde.

For the purpose of preparing a "single" urban screening table, a scale-up factor of 3 was applied to the results in Table

A3 (urban area increments as a function of VOC emissions rates and NMOC/NOx emissions ratios) to derive the urban screening table (Table 2). The value of 3 is not entirely arbitrary. Based on the results in Figure 13, a scale-up factor of 5 might be more appropriate. However, because so much conservatism is built in to the meteorological and, to a certain degree, the background chemistry inputs, collecting the most reactive mixes for scale-up would probably result in a screening out of nearly all VOC point sources. The factor 3 was determined by surveying the weighted k-OH values of VOC species profiles in the Air Emissions Speciation Manual (EPA, 1988). The weighted k-OH of the 90th percentile (about 9000 min<sup>-1</sup>) was nearly three times that of the standard EKMA mix used in formulating Table A3 (Baugues, 1988). Considering that the highest weighted k-OH values for the VOC species profiles exceeded 20,000 min<sup>-1</sup>, scaling by 3 might be viewed as a less drastic approach.

#### CONCLUDING REMARKS

These reactivity-sensitivity simulations suggest that background chemistry is a limiting factor in determining ozone increments due to ozone precursor emissions - hardly a surprising outcome. Such dependency on source composition, especially within urban atmospheres, infers that a single scale-up factor, as used for the rural table, is not adequate. One can always resort to more refined source specific analyses. Ideally, a thorough refined analysis would formulate background chemistry with the best available modeling techniques and let a source plume entrain those concentrations - the basic concept of the PARIS model which imbeds RPM-II within the Urban Airshed Model (UAM), which can utilize available meteorological, air quality and emissions (all categories) information to formulate background chemistry profiles. Such an exercise is highly resource intensive, and thus a motivation for developing a usable screening approach. \_

Clearly, a need exists for accommodating variations in point source VOC speciation within the context of a screening analysis. It is suggested that the concept of an extended screening approach which allows source specific emissions speciation inputs be pursued. a possible approach could utilize the apparent, conservative meteorological inputs developed for these tables (and/or from additional efforts) as default inputs to RPM-II in combination with best estimates of the composition of a specified source. This approach would eliminate the major

difficulties in operating a model such as RMP-II -  
characterization of meteorology and background chemistry.

**Table A1. Background species concentrations (ppm) taken to be representative of "clean" atmospheric conditions**

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ALD2	9.005E-5	NO	5.054E-5
H2O2	1.084E-3	OH	2.947E-7
MGLY	1.529E-6	PHO	4.124E-9
O	1.496E-10	XYL	1.296E-9
PAR	3.224E-3	ETH	1.681E-5
XO2	1.171E-5	HO2	2.496E-5
C2O3	7.389E-7	NO2	1.491E-4
N2O5	1.723E-9	OLE	4.676E-9
O3	3.193E-2	FORM	1.148E-3
PHEN	4.286E-5	ISOP	0.000E+0
XO2N	1.417E-6	NO3	2.041E-8
CO	9.873E-2	PAN	5.167E-5
HNO3	1.646E-3	TOL	1.219E-5

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from (PEI, 1988)

Table A2. Rural based ozone increment (pppm) as a function of NMOC emissions and NMOC/NOx emissions ratios.

NMOC EMISSIONS (TONS/YR)	ALL VOC	NMOC/NOx (PPMC/PPM)							
		30	20	15	12	10	5	3	1
50	0.21	0.23	0.24	0.25	0.25	0.27	0.35	0.42	0.70
75	0.21	0.24	0.25	0.27	0.29	0.32	0.42	0.53	0.83
100	0.20	0.27	0.28	0.31	0.34	0.36	0.49	0.63	0.92
300	0.19	0.44	0.53	0.60	0.69	0.72	0.94	1.09	1.14
500	0.18	0.63	0.76	0.88	0.96	1.02	1.25	1.36	0.87
750	0.16	0.85	1.05	1.17	1.29	1.32	1.55	1.55	0.39
1000	0.15	1.08	1.33	1.46	1.57	1.59	1.80	1.68	0.12
1500	0.15	1.47	1.82	2.01	2.03	2.15	2.20	1.70	-
2000	0.15	1.86	2.24	2.48	2.56	2.65	2.44	1.61	-
3000	0.15	2.63	3.20	3.39	3.46	3.54	2.87	1.29	-
5000	0.15	3.93	4.65	4.88	5.00	4.97	3.22	0.90	-
7500	0.14	5.49	6.52	6.63	6.73	6.63	3.40	0.75	-
10000	0.13	6.83	8.11	8.22	8.57	8.06	3.62	0.65	-

- indicates no discernible ozone enhancement

Table A3. Urban based ozone increment (pphm) as a function of NMOC emissions and NMOC/NOX ratios.

NMOC EMISSIONS (TONS/YR)	ALL VOC	NMOC/NOx (PPMC/PPM)						
		30	20	15	10	5	3	1
50	0.38	0.27	0.36	0.36	0.36	0.34	0.32	0.21
75	0.39	0.39	0.38	0.38	0.38	0.35	0.32	0.20
100	0.42	0.40	0.40	0.40	0.39	0.35	0.32	0.22
300	0.59	0.57	0.54	0.52	0.51	0.42	0.34	0.62
500	0.74	0.71	0.68	0.68	0.62	0.46	0.48	0.93
750	1.09	0.90	0.87	0.85	0.78	0.61	0.65	1.31
1000	1.38	1.08	1.07	1.02	0.91	0.74	0.89	1.56
1500	1.93	1.61	1.41	1.36	1.21	1.02	1.27	1.64
2000	2.35	2.07	1.80	1.68	1.48	1.33	1.63	1.24
3000	3.16	2.81	2.59	2.28	2.00	1.95	2.17	0.14
5000	4.43	4.31	4.01	3.43	3.11	2.99	3.09	-
7500	5.34	5.76	5.56	4.92	4.37	4.17	3.64	-
10000	5.90	7.03	6.93	6.31	5.49	5.17	3.55	-

- indicates no discernible ozone enhancement



Figure 1. Starting Time

NMOC/NOx = 10

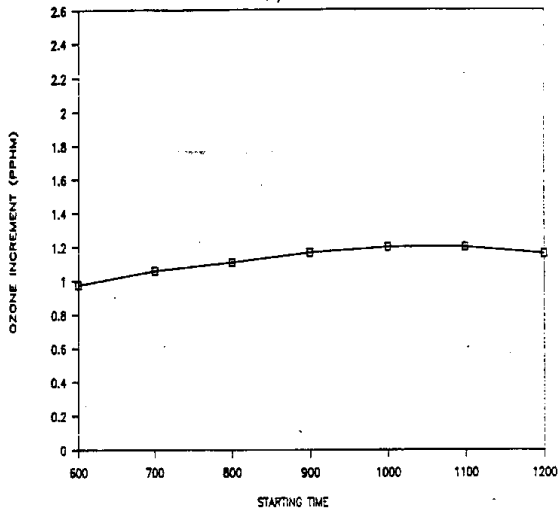


Figure 2. Starting Time

NMOC/NOx = 5

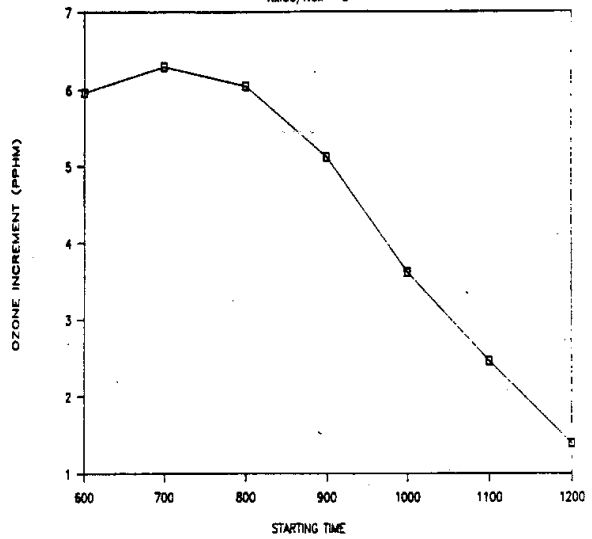


Figure 3. Starting Time

NMOC/NOx = 1

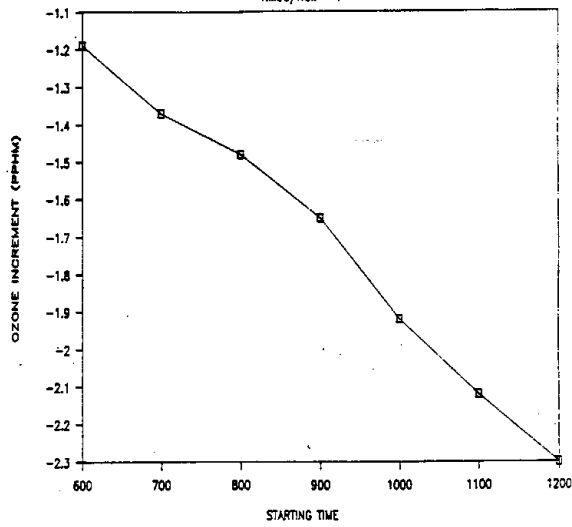


Figure 4. Wind Speed

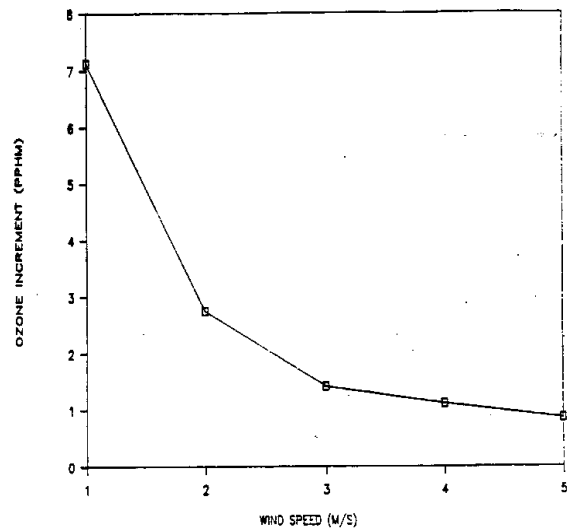


Figure 5. Stability Class

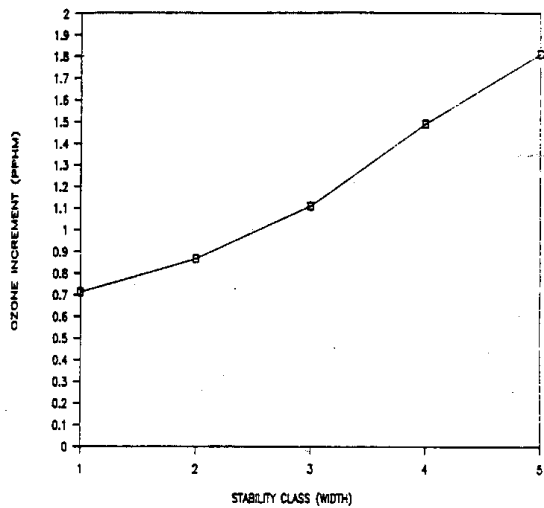


Figure 6. Plume Depth

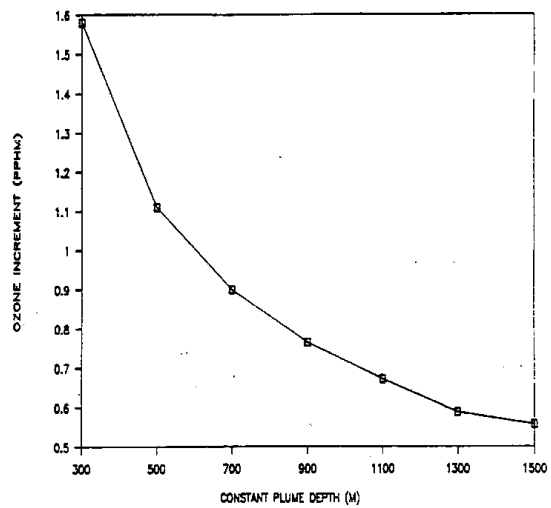


Figure 7. Temperature

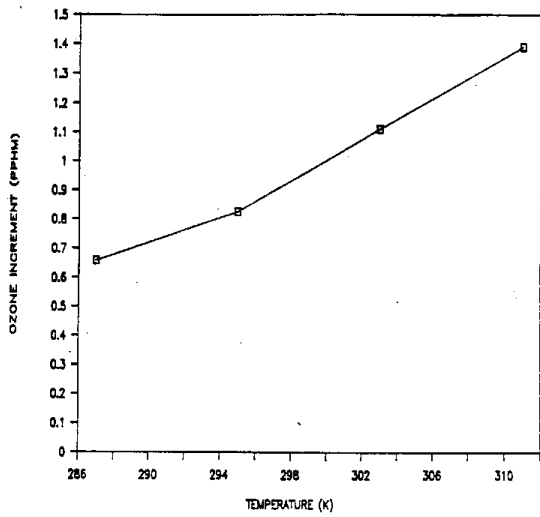


Figure 8. Single component CB4 emissions

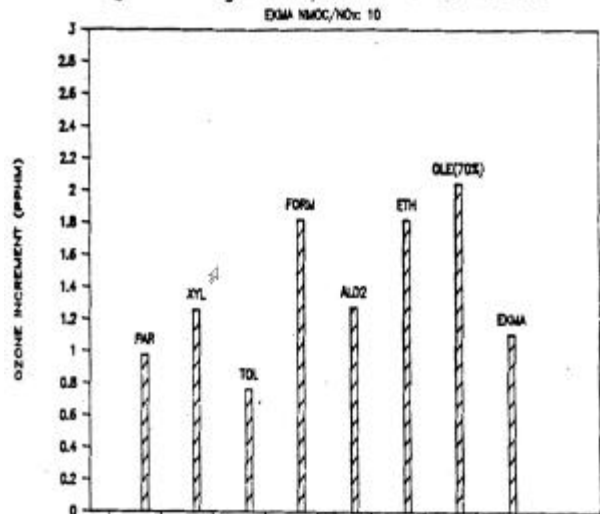


Figure 9. Single component CB4 emissions

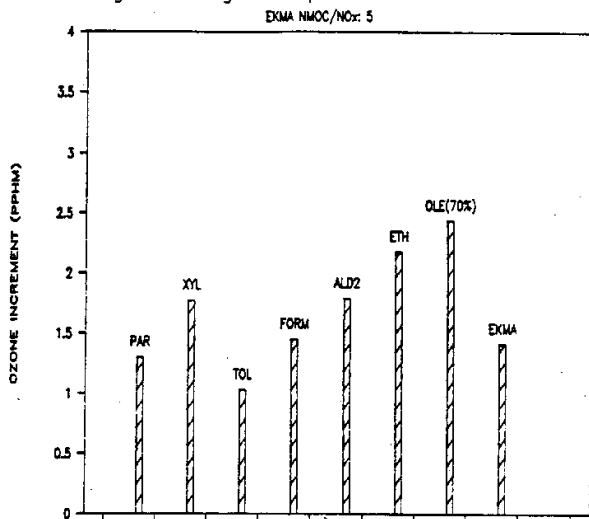


Fig. 10. Single component CB4 emissions

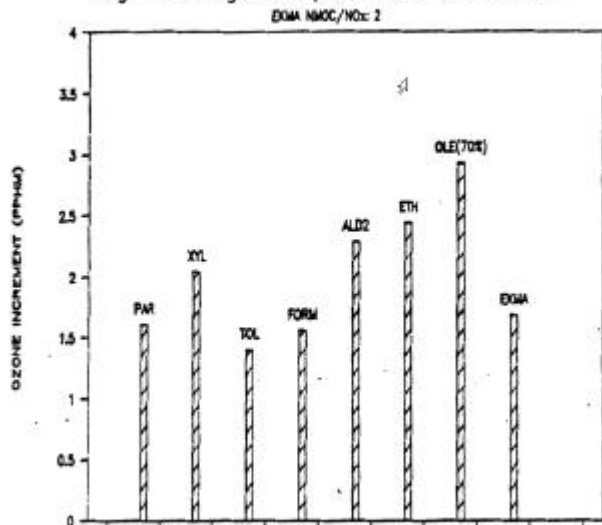


Figure 11. NMOC/NOx effect on ozone

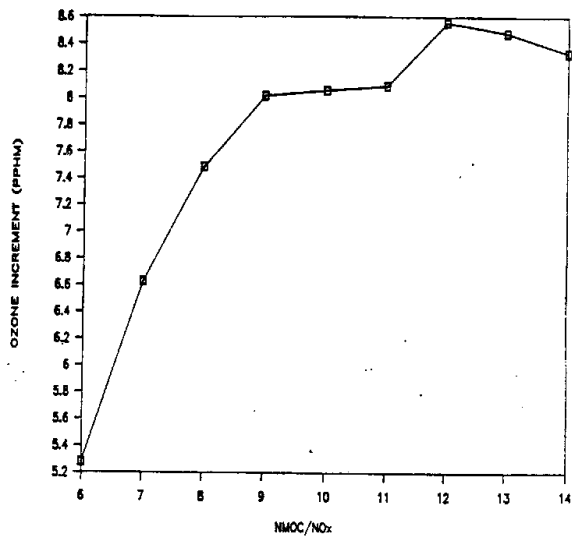


Figure 12. Effect of Urban Precursor Levels on Ozone Increment

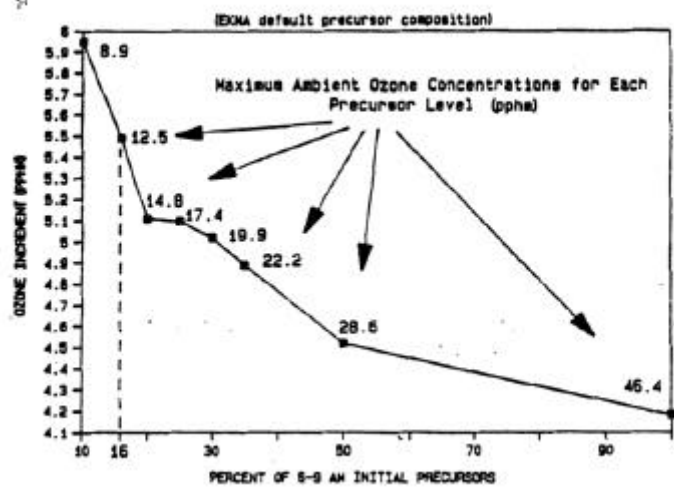
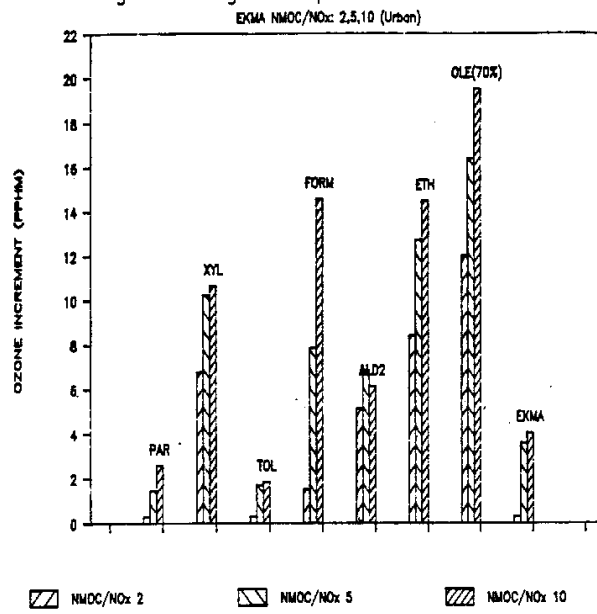


Fig. 13. Single Component CB4 Emissions



**APPENDIX B:**  
SOUTHWEST WYOMING VISIBILITY TRENDS

**Graph 3: Reconstructed Total Extinction at IMPROVE Sites in Wyoming**  
 IMPROVE Aerosol Data

