Environment

Submitted to:
Bureau of Land Management
High Plains District Office and
Wyoming State Office

Submitted by:
AECOM
Fort Collins, Colorado
February 2014

Task 1A Report for the Powder River Basin Coal Review Current Air Quality Conditions

Executive Summary

This Task 1A Report for the Powder River Basin (PRB) Coal Review describes the existing air quality conditions in the PRB study area and at regional assessment areas based on modeling results for the base year 2008. Existing conditions for water resources, socioeconomics, and other environmental resources for the base year (2008) are presented in separate Task 1 Reports. The past and present actions are summarized in the Task 2 Report for the PRB Coal Review.

For purposes of the air quality component of the study, the Wyoming PRB study area comprises all of Campbell County, all of Sheridan and Johnson counties outside of the Bighorn National Forest lands to the west of the PRB, and the northern portion of Converse County. It includes all of the area administered by the Bureau of Land Management (BLM) Buffalo Field Office, a portion of the area administered by the BLM Casper Field Office, and a portion of the Thunder Basin National Grasslands, which is administered by the U.S. Forest Service. The Montana portion of the PRB study area comprises portions of Rosebud, Custer, Powder River, Big Horn, and Treasure counties. It encompasses the area administered by the BLM Miles City Field Office and the Billings Field Office. State and private lands also are included in the study area.

ES.1 Technical Approach

The air quality model for the PRB Coal Review was developed for the intended purpose of modeling base year (2008) and projected future year cumulative air quality impacts for this study. The model is not intended for use in evaluating project-specific impacts. The requirements for future project-specific modeling to facilitate site-specific analyses of potential impacts relative to National Ambient Air Quality Standards (NAAQS) and other applicable state standards would be determined in response to state or other regulatory requirements at that time.

The Weather Research and Forecasting (WRF) meteorological model, the Sparse Matrix Operator Kernel Emissions (SMOKE) emissions processing system and the Comprehensive Air Quality Model with Extensions (CAMx) photochemical grid model comprise the CAMx modeling system used for this study. The CAMx modeling system was selected in coordination with the BLM for use in assessing base year (2008) conditions and projected future cumulative air quality impacts for 2020 and 2030. It was used to address all components of the cumulative air quality impact analysis, including air quality conditions for criteria pollutants, as well as air quality-related values (AQRVs) such as changes to visibility, atmospheric deposition, and sensitive lake acid neutralizing capacity (ANC). Base year conditions and projected future cumulative air quality impacts were addressed at the assessment areas identified in the PRB Coal Review Air Quality Assessment Protocol (AECOM 2010) including Class I and sensitive Class II areas and sensitive lakes within the 12- and 4-kilometer (km) model domains.

For the CAMx modeling system, three horizontal nested domains were developed surrounding the PRB study area: a large domain with coarse 36-km grid resolution, a smaller domain with 12-km grid resolution, and a focused domain with 4-km grid resolution. The 4-km model domain was developed with careful consideration of the PRB study area, Class I areas, and sensitive Class II areas. The model's vertical grid was composed of 34 layers from the surface to the top of the model at 100 millibars (mb), or approximately 14 km above the earth's surface. A 38-layer vertical structure was adopted in the winter months of December, January, and February to better resolve the planetary boundary layer near the earth's surface. The planetary boundary layer is the lowest part of the atmosphere where the physical properties of the air are directly influenced by its contact with the ground surface.

The WRF model was used to develop a gridded meteorological dataset appropriate for use in modeling the base year (2008) and future (2020 and 2030) cumulative air quality impacts associated with ongoing

energy-related development in the PRB study area. A meteorological Model Performance Evaluation (MPE), including qualitative and quantitative analyses, was performed to determine whether the created meteorological fields were sufficiently accurate for the air quality model to properly characterize the transport, chemistry, and removal processes (AECOM 2011a). Based on the meteorological MPE results, the PRB WRF modeling simulation demonstrated acceptable performance and was determined to be suitable for use in air quality modeling for the PRB Coal Review.

The SMOKE emissions processing system was configured for this study to generate two-dimensional and elevated emissions files in a format compatible with CAMx. Several different types of emissions were processed for the study by SMOKE, including point, non-point, non-road, on-road mobile, fire, and biogenic emissions. SMOKE was run with the temporal, spatial, chemical speciation profiles, and cross-reference data from a variety of sources, including data currently available from the U.S. Environmental Protection Agency (USEPA) and data collected specifically for this study. Special care was taken in developing the emissions data from activities related to coal mining, coal bed natural gas (CBNG) wells, conventional oil wells, conventional gas wells, pipelines, railroads, power plants, and other mines in the PRB study area.

The base year (2008) CAMx modeling was performed to evaluate the performance of the air quality model for modeling current air quality conditions and to provide a basis for comparison of the model-simulated impacts for future years 2020 and 2030. Based on the air quality MPE (AECOM 2013a), the model is considered suitable for assessing metrics for which the model is intended. According to the USEPA, these metrics include ozone, particulate matter with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$), particulate matter with an aerodynamic diameter of 10 microns or less (PM_{10}), and regional haze (visibility). The model performance for these metrics typically was within the USEPA-recommended criteria at Class I and sensitive Class II areas. While the model under-predicted concentrations of other gas-phase criteria pollutants and wet deposition, this is consistent with other studies and is recognized as a limitation of the model.

ES.2 Description of Current Conditions

The PRB study area is characterized by windy conditions with prevailing westerly winds and is noted for little rainfall. This region has a wide range of daily temperatures, a strong seasonal pattern of temperature and precipitation, and a seasonal pattern of strong storms moving across the area. However, climatic conditions vary considerably due to the variation in elevation and topography throughout the study area.

Climatological conditions generally favor strong atmospheric dispersion in the region. However, there are occasional periods of stable air and light winds, usually with clear nighttime conditions that reduce pollutant mixing and transport, leading to higher pollutant impacts. The meteorological wind pattern and the topographic features tend to lead to higher impacts toward the east of the PRB, specifically within the area of the Black Hills.

The current air quality conditions in the region are good. Limited data show that generally the region is in compliance with the ambient air quality standards for criteria pollutants, which include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone, and particulate matter (PM). Occasional exceedences of the ambient air quality standards for NO_2 (1-hour) (in Rosebud County, Montana) and SO_2 (1-hour) (in Rosebud County, Montana, and Campbell County, Wyoming) have been observed based on reported data from the USEPA (USEPA 2013a).

Under the Clean Air Act, visibility has been established as a critical resource for mandatory Class I areas. Visibility values derived from 2008 Interagency Monitoring of Protected Visual Environments (IMPROVE) data indicate that the Class I and sensitive Class II areas to the northwest, west, and southwest of the PRB study area experienced the worst visibility conditions.

Emissions of nitrogen- and sulfur-containing compounds can lead to increasing acidification of sensitive soils and lakes. Representative nitrogen and sulfur deposition data in the vicinity of the eight sensitive lakes included in this analysis indicate that the region generally experiences low levels of deposition. However, sensitive lakes in the region may experience decreases in ANC due to even small increases in atmospheric deposition.

ES.3 Modeled Base Year Cumulative Impacts

Table ES.3-1 presents a summary of the modeled base year cumulative impacts for the key components of the analysis (air quality, atmospheric deposition, visibility). Note that this study does not directly evaluate Prevention of Significant Deterioration (PSD) increment consumption, because it does not separate PSD increment-consuming sources from non-increment-consuming sources. In general, the modeled cumulative air quality impacts for base year 2008 show some exceedences of the NAAQS for criteria pollutants, especially for carbon monoxide (CO). The summer of 2008 was a very active fire season, and various wildfires reflected in the model emissions inventory had an impact on criteria pollutants at different times and assessment areas. Modeled impacts of NO_2 and SO_2 (with one exception) are well below the NAAQS.

Table ES.3-1 Summary of Modeled Air Quality Impacts

Air Quality Component		Base Year 2008
Concentrations	Criteria	Primarily below NAAQS and state AAQS, except CO, ozone, and PM_{10} at five Class I areas and four sensitive Class II areas during wildfire episodes.
Visibility	Far-field	The largest visibility impacts occurred at the Class I Lostwood WA and Class II Fort Laramie National Historic Site, with extinction values of 50.9 inverse megameters (Mm^{-1}) (16.3 deciviews [dv]).
Atmospheric Deposition: Nitrogen	LOC	The largest nitrogen deposition in a Class I area occurred at North Absaroka WA (9.89 kilograms nitrogen per hectare per year kg [N/ha/yr]), while the smallest occurred at UL Bend WA (1.43 kg N/ha/yr).
Atmospheric Deposition: Sulfur	LOC	The largest sulfur deposition in a Class I area occurred at the Fitzpatrick WA (1.46 kilograms sulfur per hectare per year [kg S/ha/yr]), while the smallest occurred a UL Bend WA (0.23 kg S/ha/yr).
Atmospheric Deposition: Lake Chemistry	ANC	The largest ANC percent change occurred at Upper Frozen Lake, Bridger WA (304.7 percent), while the smallest occurred at Emerald Lake, Cloud Peak WA (41.5 percent).

Note: LOC = level of concern.

For the base year (2008), the modeled worst visibility days were at the Class I Lostwood WA and Class II Fort Laramie National Historic Site, with extinction values of 50.9 Mm^{-1} (or 16.3 dv). The modeled best visibility days were observed at the Class I Mount Zirkel WA and Class II High Uinta WA (Wasatch National Forest portion), with extinction values of 15.2 Mm^{-1} (4.2 dv).

Nitrogen and sulfur deposition resulting from emissions of NO_x and SO_2 can lead to increasing acidification of sensitive soils and lakes. Based on modeling results, the largest nitrogen deposition in a

Class I area occurred at North Absaroka WA (9.89 kg N/ha/yr), while the smallest occurred at UL Bend WA (1.43 kg N/ha/yr). For sulfur deposition, the largest value in a Class I area occurred at Fitzpatrick WA (1.46 kg S/ha/yr), while the smallest occurred at UL Bend WA (0.23 kg S/ha/yr). Of the analyzed sensitive lakes, the largest ANC percent change occurred at Upper Frozen Lake in Bridger WA (304.7 percent), while the smallest percent change occurred at Emerald Lake in Cloud Peak WA (41.5 percent).

List of Acronyms

°F	degrees Fahrenheit
µeq/l	micro-equivalents per liter
$\mu g/m^3$	micrograms per cubic meter
AAQS	ambient air quality standards
amsl	above mean sea level
ANC	acid neutralizing capacity
AAQS	Ambient Air Quality Standards
AQS	Air Quality System
AQRVS	air quality-related values
BEIS3	Biogenic Emissions Landuse Database, version 3
b_{ext}	extinction coefficient for visibility
BLM	Bureau of Land Management
CAA	Clean Air Act
CALPUFF	model used to generate long range impact
CAMx	Comprehensive Air Quality Model with Extensions
CASTNET	Clean Air Status and Trends Network
CBNG	coal bed natural gas
CB05	Carbon Bond version 2005
CB06	Carbon Bond version 2006
CM	carbon mass
CO	carbon monoxide
dv	deciview
EA	environmental assessment
EC	elemental carbon
EGU	electric generating unit
EIS	environmental impact statement
$eq/m^2/yr$	equivalence per square meter per year
FLAG	Federal Land Manager's Air Quality Guidance
HNO_3	nitric acid
IMPROVE	Interagency Monitoring of Protected Visual Environment
IOA	Index of Agreement
IR	Indian Reservation
kg N/ha/yr	kilograms nitrogen per hectare per year
kg S/ha/yr	kilograms sulfur per hectare per year
km	kilometer
LBA	lease-by-application
LOC	level of concern
LSM	land surface model

MATS	Modeled Attainment Test Software
mb	millibar
mps	meters per second
Mm^{-1}	Inverse megameter
MOVES	Motor Vehicle Emission Simulator
MPE	Model Performance Evaluation
NADP	National Atmospheric Deposition Program
NAAQS	National Ambient Air Quality Standards
NCEP	National Center for Environmental Protection
NEPA	National Environmental Policy Act
NARR	North American Regional Analysis
NF	national forest
NH_3	ammonia
NH_4	ammonium
NM	national monument
NO	nitrogen oxide
NO_2	nitrogen dioxide
NO_3	nitrate
NO_x	nitrogen oxide
NP	national park
NPS	National Park Service
NTN	National Trends Network
OC	organic compound
PBL	planetary boundary layer
PM	particulate matter
$PM_{2.5}$	particulate matter with an aerodynamic diameter of 2.5 microns or less
PM_{10}	particulate matter with an aerodynamic diameter of 10 microns or less
ppb	parts per billion
ppm	parts per million
PRB	Powder River Basin
PRRCT	Powder River Regional Coal Team
RFD	reasonably foreseeable development
RPO	Regional Planning Organization
SMOKE	Sparse Matrix Operator Kernel Emissions
SOIL	fine soil
SO_2	sulfur dioxide
SO_4	sulfate
TDL	Techniques Development Laboratory
TOG	total organic gas
tpy	tons per year
U.S.	United States

USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound
WA	Wilderness Area
WARMS	Wyoming Air Resource Monitoring System
WDEQ	Wyoming Department of Environmental Quality
WRCC	Western Regional Climate Center
WRF	Weather Research and Forecasting

Contents

Executive Summary **ES-1**

List of Acronyms **A-1**

1.0 Introduction **1-1**

1.1 Study Background 1-1

1.2 Objectives 1-2

1.2.1 Phase I of the Study 1-2

1.2.2 Phase II of the Study 1-2

1.3 Key Issues 1-3

1.4 Agency Outreach, Coordination, and Review 1-3

2.0 Technical Approach **2-1**

2.1 Overview of Assessment Approach 2-1

2.2 Model Domains and Assessment Areas 2-1

2.3 Models Used in the Analysis 2-5

2.3.1 WRF Model 2-6

2.3.2 SMOKE Model 2-9

2.3.3 CAMx Model 2-10

2.4 Modeled 2008 Emissions Inventory 2-12

3.0 Description of Current Conditions **3-1**

3.1 Air Quality Standards 3-1

3.2 Meteorological Conditions 3-2

3.2.1 Topography 3-2

3.2.2 Climate and Meteorology 3-2

3.3 Air Quality Conditions 3-3

3.3.1 Nitrogen Dioxide 3-6

3.3.2 Sulfur Dioxide 3-6

3.3.3 Ozone 3-6

3.3.4 Particulate Matter 3-6

3.4 Visibility 3-6

3.5 Atmospheric Deposition 3-8

3.5.1 Deposition 3-8

3.5.2 Sensitive Lake Acid Neutralizing Capacity 3-9

4.0 Modeled Base Year Cumulative Impacts 4-1

4.1 Summary of Cumulative Impacts 4-1

4.2 Cumulative Impacts on Ambient Air Quality 4-1

4.3 Cumulative Impacts on Visibility 4-8

4.4 Cumulative Impacts on Atmospheric Deposition 4-10

4.4.1 Deposition 4-10

4.4.2 Cumulative Impacts on Sensitive Lake Acid Neutralizing Capacity 4-12

5.0 References 5-1

List of Tables

Table 2-1 Statistical Benchmarks and Model Performance for the WRF 4-km Domain 2-8
Table 2-2 Annual Base Year 2008 Emissions by Domain 2-13
Table 2-3 Annual Emissions by Sector in the 4-km Domain 2-13
Table 3-1 Applicable Ambient Air Quality Standards 3-1
Table 3-2 Monthly Climate Summary for Sheridan, Wyoming 3-2
Table 3-3 Ambient Air Quality Conditions in the PRB Study Area 3-3
Table 3-4 Visibility Values Estimated from Monitored Data by MATS for Class I and Sensitive Class II Areas – Base Year 2008 3-7
Table 3-5 Background Atmospheric Nitrogen and Sulfur Deposition Data 3-9
Table 3-6 Background ANC Values for Sensitive Lakes 3-10
Table 4-1 Summary of Modeled Air Quality Impacts 4-1
Table 4-2 Modeled Base Year 2008 Concentrations of Criteria Pollutants 4-3
Table 4-3 Modeled Visibility Values for Class I and Sensitive Class II Areas – Base Year 2008 4-8
Table 4-4 Modeled Base Year 2008 Deposition for Nitrogen and Sulfur 4-10
Table 4-5 Modeled Base Year 2008 Impacts on ANC of Sensitive Lakes 4-13

List of Figures

Figure 1-1 Montana and Wyoming PRB Study Area 1-4
Figure 2-1 WRF and CAMx 36-, 12-, and 4-km Domains 2-2
Figure 2-2 Assessment Areas in the 12-km and 4-km CAMx Domains 2-3
Figure 4-1 Base Year 2008 Model-predicted Hourly Average NO_2 and CO from July 29 through July 31 4-5
Figure 4-2 Base Year 2008 Model-predicted Hourly Average SO_2 and Ozone from July 29 through July 31 4-6
Figure 4-3 Base Year 2008 Model-predicted Daily Average $PM_{2.5}$ and PM_{10} from July 29 through July 31 4-7

1.0 Introduction

The Powder River Basin (PRB) Coal Review is a regional technical study for assessing the existing conditions and the projected future cumulative impacts associated with energy-related past, present, and reasonably foreseeable development (RFD) in the Wyoming PRB and, for specific resources, the Montana PRB. This study is being conducted by AECOM, Inc., dba AECOM Environment (AECOM), under the direction of the Bureau of Land Management (BLM) High Plains District Office and Wyoming State Office.

1.1 Study Background

The PRB of Wyoming is a major energy development area with diverse resource and environmental values. Energy development has been occurring in the PRB for well over a century. The first coal mine in the basin was developed near Glenrock, in Converse County, in 1883 (Foulke et al. 2002). While coal can be found in several areas of Wyoming, the extensive surface-accessible coal resource is what sets the PRB apart from other energy-producing areas of the state and country. The Wyoming portion of the PRB is the largest coal-producing region in the United States (U.S.); PRB coal is used to generate electricity within and outside of the region. The PRB also has produced large amounts of oil and gas resources. Over the last two decades, this region has experienced nationally significant development of natural gas from coal seams (coal bed natural gas [CBNG]).

Federal coal leasing is a high profile activity as over 90 percent of the PRB's coal is federally owned. The BLM is required to complete a National Environmental Policy Act (NEPA) analysis (environmental impact statement [EIS] or environmental assessment [EA]) for each coal lease-by-application (LBA) as part of the leasing process. In the coal leasing EAs and EISs that have been prepared since the Powder River Regional Coal Team decertified the region in early 1990 (thereby allowing the BLM to use the coal LBA process), cumulative impacts have been addressed in a separate section of the NEPA analyses to highlight the distinction between site-specific and cumulative impacts. With coal leasing continuing into the foreseeable future, and with impacts related to oil and gas development increasing since the late 1990s due to development of CBNG in the PRB, the BLM initiated studies and analyses to provide a consistent basis for evaluation of cumulative impacts in the coal leasing EISs. These studies and analyses included the PRB Coal Development Status Check (BLM 1996), Wyodak EIS (BLM 1999), PRB Oil and Gas EIS (BLM 2003), Montgomery Watson Harza (2003) study of PRB coal demand through 2020, and most recently, the PRB Coal Review.

Initiated in 2003, Phase I of the PRB Coal Review included the identification of current conditions (Task 1 reports); identification of RFD and future coal production scenarios for 2010, 2015, and 2020 (Task 2 report); and predicted future cumulative impacts (Task 3 reports) in the PRB. Phase II of the PRB Coal Review was initiated in January 2010 to update the Phase I analyses. Under Phase II, base year information will be updated through 2008, new RFD and future coal production scenarios will be developed, and projected cumulative impacts will be analyzed for 2020 and 2030.

The PRB Coal Review provides data, models, and projections to facilitate cumulative analyses for BLM's future land use planning efforts and for the cumulative impact sections of future project-specific impact assessments for project development in compliance with NEPA. It should be noted that the PRB Coal Review itself is <u>not</u> a NEPA document. It also is <u>not</u> a policy study, analysis of regulatory actions, or an analysis of the impacts of project-specific development.

This report summarizes Task 1A of the PRB Coal Review, which documents the regional cumulative air quality impacts during base year 2008. The analysis of cumulative base year impacts is based on the modeling of 2008 actual emissions from sources in the PRB study area in northeastern Wyoming and southeastern Montana (**Figure 1-1**). Impacts are assessed in the PRB study area and at sensitive areas surrounding the region. Assessment areas for the air quality model were selected as part of the protocol

review process (AECOM 2010) to include all regional Class I areas, as identified in the Clean Air Act (CAA) Amendments of 1977, and other environmentally sensitive Class II areas (e.g., national parks [NPs] and national monuments [NMs], wilderness areas [WAs], etc.). The PRB Coal Review Task 1 descriptions for water resources, socioeconomics, and other environmental resources are presented in separate stand-alone reports.

1.2 Objectives

1.2.1 Phase I of the Study

Phase I of the PRB Coal Review was developed as a regional technical study to determine the base year conditions and assess potential future cumulative effects of projected energy-related development activities in the PRB for the years 2010, 2015, and 2020. The Task 1A report (ENSR 2005a) for the PRB Coal Review documented the cumulative air quality impacts during the base year (2002) as obtained from modeling 2002 actual emissions with the CALPUFF model. The base year analysis evaluated impacts on air quality and air quality-related values (AQRVs) both in the near-field and at selected sensitive areas surrounding the region. The analysis specifically looked at impacts of coal and coal-related activities (including power plants) in the PRB of Wyoming and Montana, oil and gas (including conventional oil and gas and CBNG) and related development, and other development-related activities in the Wyoming PRB. Results were provided for both Wyoming and Montana source groups and receptors, including a near-field receptor grid and a set of receptors at the identified sensitive areas.

The Task 2 report (AECOM 2009b; ENSR 2005b) defined the past and present development actions in the Wyoming and Montana PRB study area, as well as the projected RFD scenarios in the study area, for years 2010, 2015, and 2020. The RFD scenarios presented in the Task 2 report provided the basis for the analysis of potential cumulative impacts (Task 3 reports).

Based on the Task 2 RFD scenarios, three separate cumulative air quality impact assessments were performed for future years 2010, 2015, and 2020 as documented in the Task 3A reports (AECOM 2009a; ENSR 2008, 2006). The modeled future cumulative air quality impacts specifically identified changes from the base year (2002) conditions.

The study also included the evaluation of base year conditions (Task 1) and projected cumulative impacts (Task 3) for water resources, socioeconomics, and other environmental resources. The results of these analyses were presented in separate stand-alone reports.

1.2.2 Phase II of the Study

Similar to Phase I, Phase II of the PRB Coal Review is a regional technical study to determine the base year (2008) conditions and assess potential future (2020 and 2030) cumulative effects of projected energy-related development activities in the PRB. Phase II of the study was initiated due to the ongoing energy-related development in the PRB, the elapsed time since initiation of Phase I of the study, and the BLM's need to maintain up-to-date development projections and related projected future cumulative impact analyses for use in the agency LBA EISs and EAs. Under Phase II, the existing and projected future energy-related development activities have been updated (Task 2) based on more recent information, with the air quality, water resources, socioeconomic, and other environmental resources base year analyses (Task 1) and projected cumulative impact analyses (Task 3) correspondingly updated.

Specific to the Phase II air quality component, the Comprehensive Air Quality Model with Extensions (CAMx) was selected in coordination with the BLM in conjunction with a meteorological model (Weather Research and Forecasting [WRF] model) and an emissions processor system (Sparse Matrix Operator Kernel Emissions [SMOKE]) (collectively referred to hereafter as the CAMx modeling system), for use in assessing base year (2008) conditions and projected future cumulative air quality impacts for 2020 and 2030. Base year conditions and projected future cumulative air quality impacts address the assessment

areas identified in the Phase II Protocol (AECOM 2010) including Class I and sensitive Class II areas, as well as sensitive lakes, within the 12- and 4-km model domains. The assessment areas closest to the PRB study area are within the 4-km grid to provide enhanced resolution of regional impacts due to ongoing energy-related development in the PRB. As in Phase I, the analysis evaluates air quality conditions for criteria pollutants and AQRVs, such as changes to visibility, atmospheric deposition, and acid neutralizing capacity (ANC) of sensitive lakes. In addition, ozone modeling for base year 2008 and the future years (2020 and 2030) has been added to the Phase II air quality analysis based on the elevated ozone concentrations observed in southwestern Wyoming and the lowering of the ambient ozone standard by the U.S. Environmental Protection Agency (USEPA) in May 2008. Also, greenhouse gas emissions have been projected for the future years (2020 and 2030) for Phase II.

This Task 1A report documents the modeled base year (2008) regional cumulative air quality impacts in the PRB study area and at regional assessment areas. Similarly, the Task 3A report will document the modeled regional cumulative air quality impacts for 2020 and 2030, with the focus on the change in cumulative impacts resulting from the projected Task 2 (AECOM 2011b) RFD scenarios.

Model selection and the methodology for the modeling of base year (2008) conditions and projected future cumulative air quality impacts for 2020 and 2030 are described in the Air Quality Assessment Protocol (AECOM 2010). Other supporting documents for the air quality component of the study include the Meteorological Model and Performance Evaluation (AECOM 2011a), the Air Quality Model Performance Evaluation (MPE) (AECOM 2013a), and the Air Quality Technical Support Document (AECOM 2013b in progress).

1.3 Key Issues

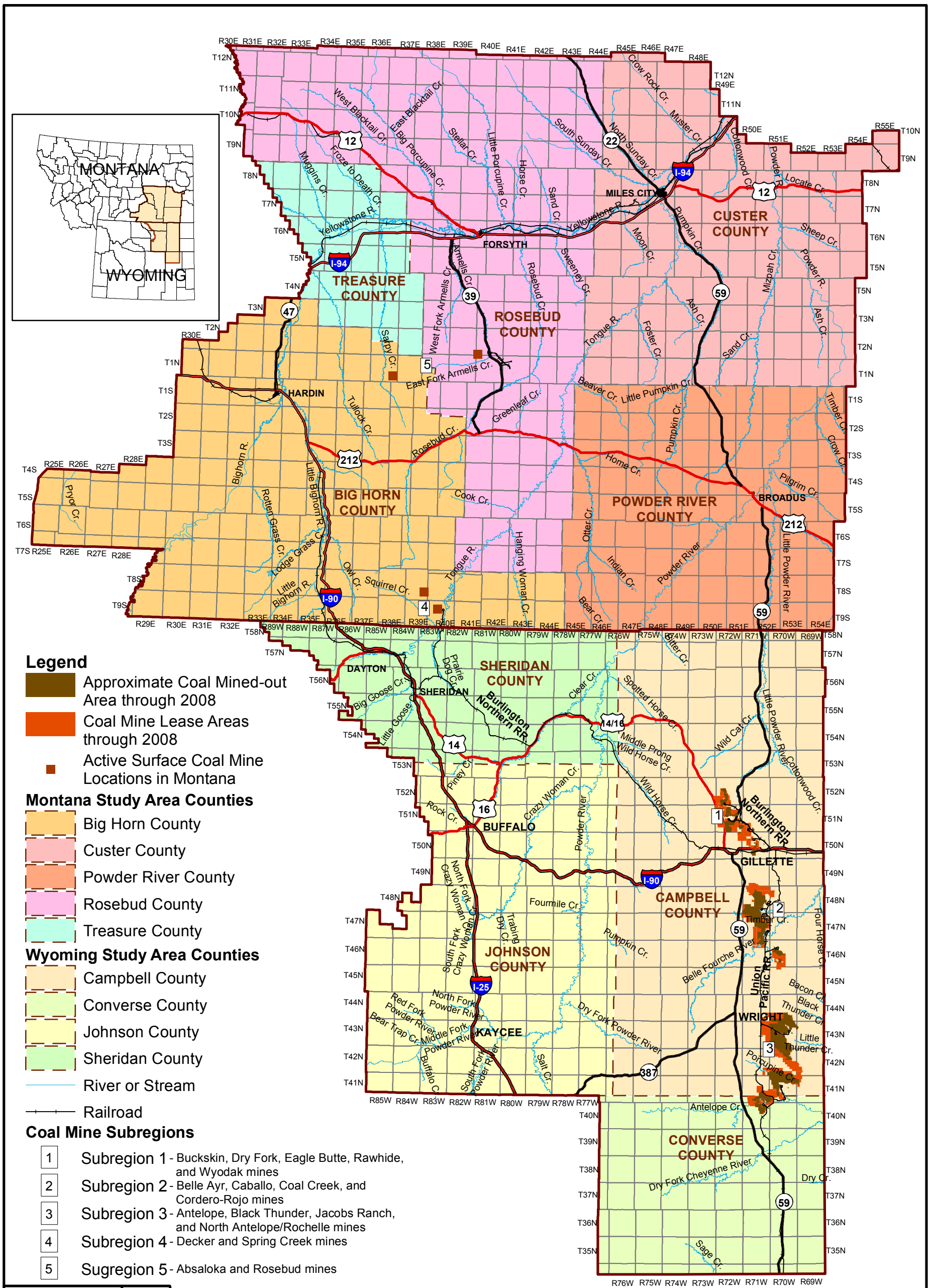
The key air quality issues identified for the PRB Coal Review include:

- Existing (base year 2008) cumulative nitrogen dioxide (NO_2), particulate matter with an aerodynamic diameter equal or less than 2.5 microns ($PM_{2.5}$), and particulate matter with an aerodynamic diameter equal or less than10 microns (PM_{10}) impacts in the PRB study area and changes in visibility, nitrogen and sulfur deposition, and ANC at surrounding assessment areas.
- Projected future (2020 and 2030) cumulative impacts in the PRB study area and at surrounding assessment areas due to energy-related RFD in the study area, including: coal mining and coal-related activities (including power plants) in the PRB of Wyoming and Montana, oil and gas (including conventional oil and gas and CBNG) and related development, and other development-related activities in the Wyoming PRB.

1.4 Agency Outreach, Coordination, and Review

The BLM directed the preparation of this PRB Coal Review. In order to ensure the technical credibility of the data, projections, interpretations, and conclusions of the study and to ensure the study's usefulness for other agencies, the BLM initiated contact with other federal, state, and local agencies early in the Phase I portion of the study. This same approach has been carried forward into Phase II of the study.

As part of this agency outreach and technical oversight, the BLM organized technical advisory groups for each of the key resources (air quality, water resources, and socioeconomics). These groups were composed of agency representatives and stakeholders with technical expertise in the applicable resources. Key participating agencies in the Phase II Air Quality Protocol Group include the BLM, USEPA, U.S. Forest Service (USFS), National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), and Wyoming Department of Environmental Quality (WDEQ).



Note: Approximate coal mined-out areas were not available for the Montana mine sites.

Sources: BLM 2010, 2003.

Powder River Basin Coal Review

Figure 1-1

Montana and Wyoming Study Area

X:\0Projects\BLM_PRB_Phase_II_60143410\Figures\DOC\620_Task_1A_Report\Figure_1-1_StudyArea_20130906.mxd

9/6/2013

2.0 Technical Approach

2.1 Overview of Assessment Approach

The air quality model for the PRB Coal Review was developed for the intended purpose of modeling base year (2008) and projected future year cumulative air quality impacts for this study. The model is not intended for use in evaluating project-specific impacts. The requirements for future project-specific modeling to facilitate site-specific analyses of potential impacts relative to National Ambient Air Quality Standards (NAAQS) and other applicable state standards would be determined in response to state or other regulatory requirements at that time.

The CAMx model, in conjunction with a meteorological model (WRF) and an emissions processor system (SMOKE), comprise the CAMx modeling system used for this study. The CAMx modeling system was used to address all components of the cumulative air quality impact analysis, including air quality conditions for criteria pollutants and ozone, as well as AQRVs, such as changes to visibility, atmospheric deposition, and ANC of sensitive lakes.

The CAMx modeling system was used to estimate potential cumulative air quality impacts on Class I and sensitive Class II areas, as well as sensitive lakes, that would result from base year (2008) emissions (as presented in this report) and projected future year (2020 and 2030) emissions (as presented in the Task 3A report). Model-predicted concentrations of NO_2, sulfur dioxide (SO_2), PM_{10}, $PM_{2.5}$, and ozone, as well as visibility impairment (aerosol light extinction) and nitrogen and sulfur deposition were evaluated at selected assessment areas. The modeled hourly values of applicable pollutant concentrations were processed to compute 3-hour, 8-hour, 24-hour, and annual average concentrations for comparison to appropriate standards and criteria. Visibility estimates were produced for daily intervals, while total sulfur and nitrogen deposition fluxes were computed as cumulative deposition from the entire annual model simulation.

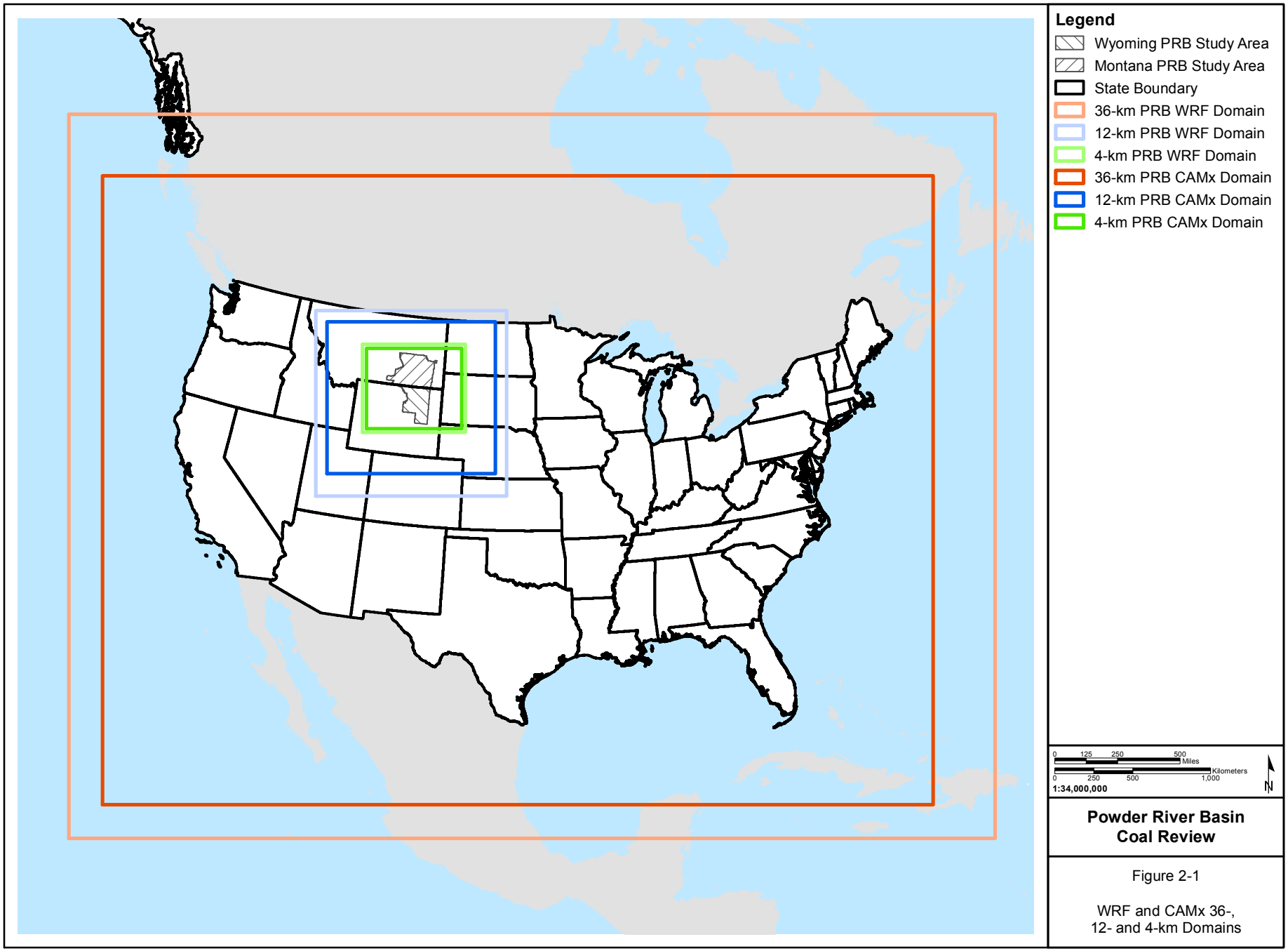
Model results were compared to the following standards and criteria:

- Comparison of the modeled base year (2008) conditions and projected future (2020 and 2030) cumulative air quality impacts to the applicable state Ambient Air Quality Standards (AAQS) and applicable NAAQS; and
- Evaluation of the modeled change in cumulative air quality conditions and AQRVs resulting from the projected upper development scenarios for 2020 and 2030.

The AQRVs evaluated include visibility and atmospheric deposition. Visibility impacts were assessed at the assessment areas by using the new Interagency Monitoring of Protected Visual Environment (IMPROVE) equation (Hand and Malm 2006). Atmospheric deposition impacts were assessed for both soils and lakes. Atmospheric deposition to soils was assessed in terms of total terrestrial deposition loading (Fox et al. 1989). Atmospheric deposition impacts were assessed at the levels of concern suggested in Baron (2006) for nitrogen deposition and in Fox et al. (1989) for sulfur deposition. Atmospheric deposition to lakes was assessed in terms of ANC by comparing predicted annual total atmospheric deposition of nitrogen and sulfur to current ANC based on the USFS data (USFS 2000).

2.2 Model Domains and Assessment Areas

The PRB air quality modeling domains include a coarse domain focused on the continental U.S., with a 36-km horizontal grid resolution and two more refined domains with 12- and 4-km grid resolutions. **Figure 2-1** shows the nested horizontal domains for the CAMx model relative to the horizontal domains of the WRF meteorological model. These domains use the map projection from the Regional Planning Organization (RPO) unified grid. The domains are the same for all modeling performed for the PRB Coal Review. The locations of the Class I and sensitive Class II areas within the 12-km and 4-km modeling domains are shown in **Figure 2-2**. Model results for all assessment areas are reported in this document from either the 12-km or the 4-km domain, depending on their location relative to each of these domains.



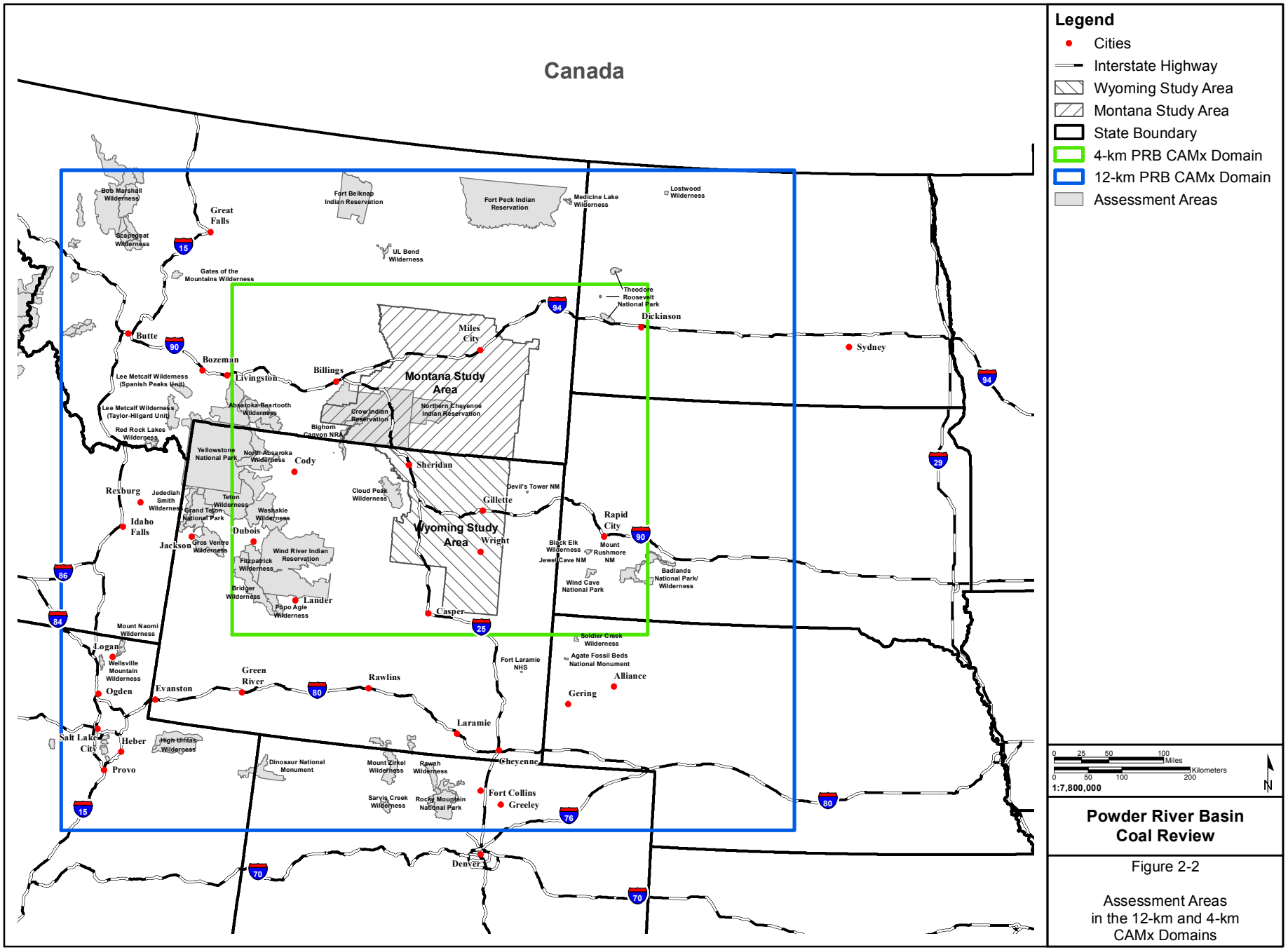
Powder River Basin Coal Review

Figure 2-1

WRF and CAMx 36-, 12- and 4-km Domains

X:\0Projects\BLM_PRB_Phase_II_60143410\Figures\DOC\620_Task_1A_Report\Figure_2-1_WRF_CAMx_Domains_20130906.mxd

9/10/2013



Powder River Basin Coal Review

Figure 2-2

Assessment Areas in the 12-km and 4-km CAMx Domains

X:\0Projects\BLM_PRB_Phase_II_60143410\Figures\DOC\620_Task_1A_Report\Figure_2-2_Domains_SensitiveAreas_20130917.mxd

9/17/2013

The model's vertical grid is composed of 34 layers from the surface to the top of the model at 100 millibars (mb) (approximately 14 km above the surface), with thinner (more) layers in the planetary boundary layer (PBL) to better capture the boundary layer characteristics important for air quality modeling. The PBL is the lowest part of the atmosphere where the physical properties of the air are directly influenced by its contact with the ground surface. To better resolve the surface layer for winter months (January, February, and December) when the PBL may be lowest, the first four vertical layers were replaced by eight vertical layers. This resulted in a total of 38 vertical layers for modeling the winter months.

The Class I and sensitive Class II areas analyzed for all air quality metrics (except ANC) are identified below and shown in **Figure 2-2**. The refined 4-km model grid was developed with careful consideration of the Class I and sensitive Class II areas surrounding the PRB study area.

- Badlands National Park (NP) (Class I, NPS)
- Badlands WA (Class I, NPS)
- Bob Marshall WA (Class I, USFS)
- Bridger WA (Class I, USFS)
- Fitzpatrick WA (Class I, USFS)
- Fort Peck Indian Reservation (IR) (Class I, Fort Peck Tribal Council)
- Gates of the Mountain WA (Class I, USFS)
- Grand Teton NP (Class I, NPS)
- Lostwood WA (Class I, USFWS)
- Medicine Lake WA (Class I, USFWS)
- Mount Zirkel WA (Class I, USFS)
- North Absaroka WA (Class I, USFS)
- Northern Cheyenne IR (Class I, Northern Cheyenne Tribal Council)
- Rawah WA (Class I, USFS)
- Red Rocks Lakes WA (Class I, USFWS)
- Rocky Mountain NP (Class I, NPS)
- Scapegoat WA (Class I, USFS)
- Theodore Roosevelt NP (Class I, NPS)
- UL Bend WA (Class I, USFWS)
- Washakie WA (Class I, USFS)
- Wind Cave NP (Class I, NPS)
- Yellowstone NP (Class I, NPS)
- Absaroka-Beartooth WA (Class II, USFS)
- Agate Fossil Beds NM (Class II, NPS)
- Bighorn Canyon National Recreation Area (Class II, NPS)
- Black Elk WA (Class II, USFS)
- Cloud Peak WA (Class II, USFS)
- Crow IR (Class II, Crow Tribal Council)

- Devils Tower NM (Class II, NPS)
- Dinosaur NM (Class II, NPS)
- Fort Belknap IR (Class II, Fort Belknap Indian Community Council)
- Fort Laramie National Historic Site (Class II, NPS)
- High Uintas WA (Class II, USFS)
- Jewel Cave NM (Class II, NPS)
- Jedediah Smith WA (Class II, USFS)
- Lee Metcalf WA (Class II, USFS)
- Mount Naomi WA (Class II, USFS)
- Mount Rushmore National Memorial (Class II, NPS)
- Popo Agie WA (Class II, USFS)
- Sarvis Creek WA (Class II, USFS)
- Soldier Creek WA (Class II, USFS)
- Teton WA (Class II, USFS)
- Wellsville Mountain WA (Class II, USFS)
- Wind River IR (Class II, Shoshone and Arapaho Joint Tribal Business Council)

Model-predicted annual and total (wet plus dry) deposition fluxes of total nitrogen and sulfur compounds were used to estimate the ANC (based on total nitrogen and sulfur deposition) at the following sensitive lakes:

- Black Joe Lake, Class I Bridger WA
- Deep Lake, Class I Bridger WA
- Hobbs Lake, Class I Bridger WA
- Upper Frozen Lake, Class I Bridger WA
- Ross Lake, Class I Fitzpatrick WA
- Emerald Lake, Class II Cloud Peak WA
- Florence Lake, Class II Cloud Peak WA
- Lower Saddlebag Lake, Class II Popo Agie WA

2.3 Models Used in the Analysis

The following models were selected in coordination with the BLM for use in assessing base year (2008) conditions and projecting future cumulative air quality impacts (2020 and 2030) for this study. Collectively, these models are referred to in this report as the CAMx modeling system.

- The WRF model is a state-of-science mesoscale numerical weather prediction system capable of supporting urban- and regional-scale photochemical, fine particulate, and regional haze regulatory modeling studies. The Advanced Research WRF (ARW) dynamic core (version 3.2.1), was used for this study.
- The SMOKE modeling system (version 2.7) is an emissions modeling system that generates hourly, gridded, and speciated emissions inputs of mobile, non-road, area, point, fire, and biogenic emissions sources for photochemical grid models.

- The CAMx model (version 5.4) is a state-of-science 'One-Atmosphere' photochemical grid model capable of addressing ozone and other criteria pollutants, visibility, and atmospheric deposition at the regional and urban scale.

2.3.1 WRF Model

Meteorological data are required in order to simulate air quality conditions using atmospheric models such as CAMx. Because observed data were not available for the full gridded model domain for this study, a numerical meteorological model was required to provide these inputs.

Development of the meteorological fields for this study using the WRF model included the following steps: 1) obtain the necessary input data for the WRF model and generate the meteorological input files for three domains (36-, 12-, and 4-km); 2) perform an annual model simulation for each of the three domains; and 3) evaluate the WRF model performance. The data sources and evaluation of model performance were documented in the PRB Coal Review – Meteorological Model Performance Evaluation (meteorological MPE) (AECOM 2011a). The evaluation of model performance is summarized in this section.

The goal of the WRF modeling was to develop a gridded meteorological dataset appropriate for use in modeling current conditions (as of base year 2008) and projected future cumulative air quality impacts associated with ongoing energy-related development in the PRB. The overall goal of the meteorological MPE was to determine whether the created meteorological fields were sufficiently accurate for the air quality model to properly characterize the transport, chemistry, and removal processes. Therefore, model performance was assessed based on the accuracy and bias of the resulting meteorological fields for the different model configurations as discussed in detail in the meteorological MPE (AECOM 2011a). An initial WRF configuration was defined during the model protocol development based on other WRF modeling studies conducted in the western U.S. Details regarding the WRF modeling approach and air quality analysis techniques for this study are presented in the PRB Coal Review Air Quality Assessment Protocol (AECOM 2010).

The model domains and vertical layers for the WRF model are discussed in Section 2.2. Sensitivity tests were conducted to optimize the WRF model configuration for this study. The sensitivity studies included the use of: 1) one-way nesting versus two-way nesting; 2) two different initialization datasets; 3) three combinations of land surface model (LSM) and PBL algorithms; and 4) 38 or 34 vertical layers during spring and fall transition seasons (tested for the month of March).

The WRF model was run in sequential 5-day periods and was re-initialized at the beginning of each period to reduce error propagation through the simulation. The 2008 base year simulation included the final 2 weeks of December 2007 to allow for sufficient spin-up time. Fixed time steps of 60 seconds in winter months and 120 seconds in all other months were used to keep the model numerically stable. Based on the results of the sensitivity tests, the final WRF configuration used two-way nesting, was initialized with the 32-km National Center for Environmental Protection (NCEP) North American Regional Reanalysis (NARR) (ds608.0) dataset, used the Noah LSM with the Mellor-Yamada-Janjic PBL algorithm, and had 38 vertical layers for December, January, and February, and 34 vertical layers for all other months. Key WRF configuration options for the study are presented in the meteorological MPE (AECOM 2011a).

Both qualitative and quantitative (statistical) analyses were used to examine the WRF model performance. For quantitative analyses, the WRF simulation results were compared with two observational datasets: the Techniques Development Laboratory (TDL) U.S. and Canada surface hourly observations and the Wyoming Air Resource Monitoring System (WARMS) dataset. These results were presented for annual and seasonal periods, as well as varying spatial extents. The domain-wide results were presented for all three model domains. The WRF performance also was analyzed for different topographic regions to determine if the model performed better for the PRB study area, and qualitative comparisons were conducted for select days by comparing spatial and vertical plots of model results with

synoptic conditions, precipitation fields, and upper air soundings. After the model results were compared with observational data, the performance of the WRF simulation was compared with the 2008 WRF simulation performed by the USEPA.

For all quantitative evaluations, statistics were computed and compared against a set of statistical benchmarks derived by Tesche et al. (2002). These benchmarks were developed from the evaluation of approximately 30 meteorological simulations in support of air quality applications performed over a 5- to 10-year period. Since the WRF model was not operational at the time, it was not used in any of the meteorological simulations used to develop the benchmarks, and new benchmarks for the WRF model have not yet been developed. Statistical benchmarks were not used as an acceptance and/or rejection criteria of the WRF model simulation. Rather, they put the WRF model performance for each model domain into perspective relative to other meteorological model simulations performed in the U.S.

The WRF model performance statistics were computed relative to the observed TDL data for sites within the 4-km domain, and the performance was compared with the statistical benchmarks (**Table 2-1**). In general, the WRF configuration performed slightly better for the 4-km domain than the 36- and 12-km domains (not shown). This likely is due, in part, to the use of the TDL data for observation nudging in the 4-km domain. The improved performance in the 4-km domain was not supported when the WRF model was evaluated with the WARMS data, which were not used during observation nudging. The model performance was best for water vapor mixing ratio and generally performed adequately for temperature, while it had more difficulty reproducing wind speed and direction.

- The WRF configuration showed a tendency to under-predict wind speed relative to the TDL data; however, this bias was not exhibited relative to WARMS monitoring stations.
- The model-predicted wind direction was biased approximately 10 degrees counterclockwise from TDL observations in the 36- and 12-km domains, while this bias was not exhibited in comparison to the WARMS monitoring stations.
- Based on both the WARMS and TDL datasets, the model exhibited a seasonal temperature bias, whereby temperature was biased cold in winter and warm in summer.
- Errors for wind speed, wind direction, and temperature were outside of the recommended range of the benchmarks when model results were compared with both the TDL and WARMS datasets.

In general, the statistics and time series plots showed good agreement between the WRF simulation and WARMS observed data and generally had better agreement than when the WRF model results were compared with the TDL observed data. This was particularly true for wind speed and wind direction bias. However, the model appeared to have notable errors in wind speed and direction, both annually and seasonally.

Because the reported model error is weighted more heavily by large values, the reported model errors must be considered relative to topographical features. An analysis of topographical regions indicated that the model errors were largest in areas with steeper terrain. The PRB 12- and 4-km model domains were divided into five different topographic regions based on terrain and elevation.

The five topographic regions were defined as interior plains, hills, mountain basins, mountain valleys, and mountains. In general, WRF performs in order from best to worst for interior plains, hills, mountain basins, mountain valleys, and mountains. Because the PRB study area mainly falls within areas classified as interior plains and hills, the WRF model performed better within the PRB study area than for the aggregate values reported for the 4-km domain as a whole.

Table 2-1 Statistical Benchmarks and Model Performance for the WRF 4-km Domain

Parameter	Statistic	Statistical Benchmark	Average Values				
			Annual	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Wind speed (meters per second [mps])	Root mean square error	≤ 2	**2.03**	**2.15**	**2.03**	1.85	**2.08**
	Bias	±0.5	**-0.54**	-0.48	**-0.57**	**-0.55**	**-0.55**
	Index of Agreement (IOA)	≥ 0.6	0.79	0.82	0.78	0.75	0.82
Wind direction (degrees from true north)	Bias	±10	-1.92	-1.66	-3.31	-0.58	-2.14
	Gross Error	≤ 30	**31.43**	**30.22**	**31.91**	**34.97**	28.61
Temperature (degrees Kelvin)	Bias	±0.5	0.20	**-0.87**	**0.65**	**1.29**	-0.28
	Gross Error	≤ 2	**2.60**	**3.08**	**2.31**	**2.33**	**2.67**
	IOA	≥ 0.8	0.89	0.86	0.92	0.93	0.86
Mixing ratio (grams per kilogram)	Bias	±1	-0.04	0.24	0.00	-0.50	0.10
	Gross Error	≤ 2	0.76	0.49	0.85	1.22	0.50
	IOA	≥ 0.6	0.73	0.74	0.71	0.73	0.74

Values in **bold** indicate values outside of the benchmark's recommended range.

In addition to these statistical evaluations, qualitative assessments of the WRF model performance were conducted for select days with elevated ozone levels measured near the PRB study area in 2008. The months of March and June 2008, were selected for qualitative analysis in order to review both summer and winter conditions. The dates of March 3 and June 30, 2008, were selected for analysis. The days selected for assessment were based on elevated measured ozone levels in the PRB study area. On March 3, 2008, the monitored 1-hour ozone concentration reached 69 parts per billion (ppb). On June 30, 2008, the monitored 1-hour ozone concentration reached 65 ppb. The highest 1-hour ozone concentration in 2008 was 82 ppb, which occurred on July 27, 2008. Spatial and vertical plots of model results were compared with observed data to assess the model's ability to reproduce important synoptic features, spatial variability of precipitation and precipitation amounts, and vertical profiles of wind speed, wind direction, temperature, and mixing ratio. In general, the daily weather plots from the 2 selected days demonstrated that the WRF simulation was capable of reproducing the observed synoptic and precipitation patterns.

Vertical profiles of model-predicted parameters were compared with the upper air soundings at Riverton, Wyoming, and Rapid City, South Dakota, for March 3 and June 30, 2008. These are the closest cities to the PRB study area that conduct upper air measurements. In general, for both days and locations, the temperature profile performed better than the dew point temperature profile. The WRF model had difficulty capturing sharp vertical water vapor mixing ratio changes associated with the dew point temperature profile. It generally was able to simulate the vertical variability in wind speed and direction and was capable of reproducing the inversion layers; however, the model was better able to simulate the late afternoon convective boundary layer than the early morning nocturnal boundary layer.

After comparing the model results to the observational data, the performance of the WRF simulation was compared with the 2008 WRF simulation performed by the USEPA (2010). In general, the USEPA simulation performed similarly to the PRB WRF simulation for the 4-km domain, with some parameters performing better and some not as well; however, the USEPA simulation performed consistently better than the PRB WRF simulation for the 12-km domain. Specifically, wind performance in the PRB WRF

4-km simulation was better than the USEPA simulation in the 4-km domain; however, the PRB WRF 12-km simulation did not perform as well as the USEPA simulation in the 12-km domain. For temperature, the PRB WRF 4-km simulation did not perform as well as the USEPA simulation. The mixing ratio performance showed a mixed performance between the PRB 4-km and USEPA 12-km simulations. Although the USEPA simulation performed better than the PRB WRF simulation for some parameters, the performance was not consistently better. In addition, meteorological data at the 4-km resolution, which are required for the air quality model, are not available from the USEPA simulation.

Based on the MPE results, the WRF modeling simulation demonstrated acceptable performance and was determined to be suitable for use in air quality modeling for the PRB Coal Review. The WRF simulation was capable of reproducing the observed synoptic and precipitation patterns. The accuracy and bias of the meteorological fields demonstrated that the simulated meteorological fields were reasonable and consistent, and they agreed adequately with available observations in time and space.

2.3.2 SMOKE Model

The SMOKE emissions processing system (Coats 1995; Houyoux and Vukovich 1999) has continued to be developed through the University of North Carolina Environmental Program. SMOKE was configured for this study to generate emissions files in a format that is compatible with CAMx. There are several different types of emissions that were processed for the study by SMOKE, including point, area, non-road, on-road, fire, and biogenic emissions. These source types were processed separately in order to prepare emission inventories for modeling with a photochemical grid model.

The emissions files generated by SMOKE for the 2008 base year and future years (2020 and 2030) annual simulations included:

- Area sources;
- Non-road sources;
- Stationary point sources;
- Continuous emissions monitoring data;
- Wildfire emissions;
- On-road motor vehicle miles travelled and activity data; and
- Mobile source emissions using Motor Vehicle Emission Simulator (MOVES) 2010 input parameters.

SMOKE also requires data files to temporally allocate, spatially allocate, and speciate emissions that are reported as one group (e.g., volatile organic compounds [VOCs]). SMOKE was run with the temporal, spatial, chemical speciation profiles, and cross-reference data currently provided by the USEPA. With the exception of biogenic and highway mobile source emissions that were generated using the Biogenic Emissions Landuse Database, version 3 (BEIS3) and MOVES 2010 models, pre-computed annual emissions were processed using the month, day, and hour-specific temporal profiles of the SMOKE model.

- Spatial Allocation. The spatial resolution of the emissions must match the CAMx grid cells for each domain. Initial non-point, on-road, and non-road emission inventories were spatially resolved at the county level. The spatial area of counties is too coarse for the PRB Coal Review CAMx grid resolution. Therefore, county-level emissions were further allocated to the grid cells within each county based on spatial surrogates (e.g., population, land use categories, and industrial development). The default spatial surrogates developed by the USEPA were used for spatially allocating most emissions sources, except oil and gas non-point source emissions and coal mine emissions, which were spatially allocated based on data collected for this study (AECOM 2011b; BLM 2012).

- Temporal Allocation. Initial emissions data were provided for different averaging periods depending on each source type. Source types with annual or short-term emission rates were adjusted to seasonal or monthly profiles accounting for day-of-week and hour-of-day differences. Non-point sources, including non-road and dust emissions, were allocated by monthly, daily, and hourly profiles provided by the USEPA. Biogenic and on-road emissions were modeled using hourly meteorological data. Point sources, including continuous emissions monitoring and fire emissions, were modeled with available day-specific, or hour-specific emissions and meteorology.
- Chemical Speciation. Emission inventories do not routinely include estimates of every chemical species emitted, rather total emissions are reported for similar pollutants. Emissions of total VOCs were converted to estimates of carbon bond types as required by the Carbon Bond version 2005 (CB05) (Yarwood et al. 2005) chemical mechanism. Total oxides of nitrogen (NO_x) emissions were allocated to nitrogen oxide (NO) and NO_2 components. Particulate matter (PM) was allocated to coarse PM, nitrate (NO_3), NO, sulfate, organic carbon (OC), elemental carbon (EC), and other fine particulates. The default speciation profiles developed by the USEPA were used for most source categories, with the exception of oil and gas VOC emissions. Oil and gas VOC emissions were speciated based on chemical composition analyses for various types of equipment and processes.
- Elevated Sources. All sources are treated by SMOKE as potentially elevated. Wildfire emissions are handled as point sources. Large, elevated point sources were modeled with plume-in-grid treatment.
- Quality Assurance. SMOKE includes quality assurance and reporting features to keep track of the adjustments at each processing stage and ensure that data integrity is not compromised. The quality assurance tools from SMOKE were used.

2.3.3 CAMx Model

The air quality component of the PRB Coal Review focuses on the cumulative effects of energy-related development activities in the PRB of Wyoming and Montana, primarily as related to coal mining and oil and gas (including CBNG) activities. The CAMx modeling approach and configuration as discussed in the PRB Coal Review Air Quality Assessment Protocol (AECOM 2010) are summarized below. Also presented below are the results of the CAMx modeling simulation for base year 2008 and the associated air quality MPE that are discussed in detail in the PRB Coal Review Air Quality MPE (AECOM 2013a). The goal of the CAMx base year (2008) modeling was two-fold: 1) to evaluate the performance of the air quality model for modeling current air quality conditions; and 2) to provide a basis for comparison of the model-simulated impacts for future years 2020 and 2030. The overall goal of the air quality MPE was to determine whether the air quality modeling system was sufficiently accurate to characterize current air quality conditions at assessment areas in the 12- and 4-km model domains, and therefore, sufficiently accurate to evaluate projected future year cumulative air quality impacts as a result of ongoing energy-related development in the Wyoming and Montana PRB study area. Model performance was assessed based on a comparison of the model results to measured ambient air quality data for base year 2008. The model domains and vertical layers for the CAMx model are discussed in Section 2.2.

The Carbon Bond version 6 (CB06) gas-phase photochemical mechanism was implemented in CAMx for this study. The CB6 gas-phase photochemical mechanism contains 218 reactions involving 77 chemical species. VOC species were treated using a lumped bond approach in which actual VOC species are represented by model species that are designed to represent certain carbon bond types. This approach was used to reduce the total number of VOC species represented in the photochemical model. The CAMx model was configured to run the 36-km domain first. These results were used as boundary conditions for the two-way nested 12- and 4-km domains.

CAMx results were compared with ambient monitoring data collected during 2008 from multiple networks in the 36-, 12-, and 4-km domains. The available monitoring data did not include speciated or total VOCs

nor did it include reduced nitrogen measurements in the 4-km domain, making it difficult to assess some aspects of the model performance. Multiple methods were used to examine the CAMx model performance relative to the available ambient measurements, including statistical summaries of performance over various spatial and temporal scales, time series comparisons, review of spatial plots, scatter plots, and bugle plots. Results were compared with benchmarks from the USEPA, when appropriate.

In general, the model under-predicted concentrations of almost all gas-phase criteria pollutants. These results are consistent with the intended use of photochemical grid models. Results from other studies are available from a recent synthesis (Simon et al. 2012) for comparison. The USEPA (2007) considers regional photochemical grid models to be the most appropriate tool for ozone, $PM_{2.5}$, and regional haze (visibility) attainment demonstrations. In addition, photochemical grid models are suitable for estimating cumulative impacts from all sources by estimating pollutant concentrations and deposition of both inert and chemically reactive pollutants over large spatial scales (USEPA 2007). (Note: Use of gridded models for other purposes should be performed with caution. Compliance with other federal and state AAQS (i.e., assessment of maximum impacts] should be conducted with an approved near-field dispersion model [40 Code of Federal Regulations Part 51, Appendix W]).

The concentrations of NO_x were under-predicted in most locations throughout the year. Given that the model systematically under-predicted the observed peak concentrations but was able to reproduce the observed diurnal cycle as well as expected spatial patterns of emissions sources, the model is appropriate for use in predicting future cumulative NO_x impacts with the understanding that model predictions were approximately 50 percent low on an annual basis.

In general, the model tended to under-predict carbon monoxide (CO) throughout the year, independent of modeling domain; however, the validity of these results is severely limited by the small number of CO monitoring sites in the 4-km modeling domain (e.g., only one CO monitoring site was operating in 2008 in the 4-km domain). Importantly, CO is primarily a pollutant of concern for project-specific compliance with NAAQS and state standards. Given the uncertainty surrounding the model performance for CO, model-predicted concentrations of cumulative CO are not considered to be representative of maximum values.

In general, the model tended to under-predict SO_2; however, the model biases varied by season. The model tended to be biased low relative to monitoring sites near industrial activities (e.g., the Air Quality System [AQS] monitors), but biased low in winter and high in summer relative to other background or rural monitors. Similar to NO_x performance, model-predicted short-term cumulative SO_2 values are not considered to be representative of maximum values.

In general, the model performance for ozone was acceptable and generally within the USEPA-recommended bias and error limits for the 4-km domain during all seasons except for winter, when the values were typically low in the PRB study area. Modeled ozone concentrations captured the peak ozone values as well as the diurnal variation during analyzed events; however, the model over-predicted values in the range of 0 to 20 ppb throughout the year and under-predicted the frequency of elevated winter values. The model results are considered suitable for assessing cumulative ozone impacts for this study.

In general, the model performed fairly well for total $PM_{2.5}$ concentrations in most locations and seasons and tended to under-predict total PM_{10} concentrations in the PRB study area. The model tended to be biased high in rural areas and low in urban/industrial areas for both $PM_{2.5}$ and PM_{10}. The model performance for total $PM_{2.5}$ was within the USEPA-established performance criteria for almost all months and modeling domains. Given the good model performance for $PM_{2.5}$ relative to USEPA performance criteria, the model is considered suitable for assessing cumulative $PM_{2.5}$ impacts for this study. The PM_{10} model performance is within the USEPA-established performance criteria relative to rural IMPROVE monitors for all months and modeling domains; however, relative to the AQS monitors, the model

performance for PM_{10} frequently exceeds the USEPA-established performance criteria independent of modeling domain. Therefore, the model is considered suitable for the intended purpose of assessing cumulative $PM_{2.5}$ impacts at Class I and Class II areas.

The overall performance for $PM_{2.5}$ and PM_{10} is related to the performance of the primary chemical constituents that make up $PM_{2.5}$ and PM_{10}. There is variability in the model performance of these PM components, notably the model was biased high for SO_4, ammonium (NH_4), and fine soil (SOIL) and biased low for NO_3, OC, and carbon mass (CM) in the 4-km domain.

In general, the model performed well for visibility (measured as light extinction coefficient [b_{ext}]) for both the 12- and 4-km domains. Similar to $PM_{2.5}$ and PM_{10}, model performance of individual contributors to visibility can vary; however, total b_{ext} showed good agreement with monitoring sites upwind, downwind, and within the PRB study area. Although the maximum model-predicted b_{ext} did not always occur at the same time or location as monitored events, the model-predicted maximum b_{ext} was frequently similar in magnitude. The influence of smoke from wildfires was identified as the primary factor for substantial differences between the monitored and modeled $b_{ext.}$ The model is considered suitable for assessing cumulative visibility impacts for this study.

In general, the model under-predicted the wet deposition of SO_4, NO_3, and NH_4 for all three domains. However, within the 4-km domain, the model tends to over-predict wet deposition in mountainous areas and under-predict wet deposition in the plains. This bias may be due to under-estimates of precipitation from the meteorological model. The annual modeled wet deposition of SO_4, NO_3, and NH_4 has very similar spatial patterns. This indicates that the wet deposition results are more strongly influenced by the precipitation fields than the locations of emissions, which is further supported by the fact that these compounds are all in the aerosol phase and are subject to the same wet removal processes. Furthermore, the model results indicate that annual wet deposition has negative biases for all species analyzed, while the biases in the ambient concentrations may be either positive or negative. For instance, SO_4 ambient concentrations tend to have positive biases, while NO_3 has negative biases only in the summer and spring. The most likely explanation for the systematic wet deposition negative bias is the negative bias in the precipitation fields used by the model for wet removal processes.

In summary, the model is considered suitable for assessing metrics (ozone, $PM_{2.5}$, PM_{10}, and regional haze [visibility]) for which the model is intended. The model performance for these metrics typically was within the USEPA-recommended criteria at Class I and sensitive Class II areas. While the model under-predicted concentrations of other gas-phase criteria pollutants and wet deposition, this is consistent with other studies and recognizes limitations of the model.

2.4 Modeled 2008 Emissions Inventory

After a qualitative analysis of the individual sources, all sources, by domain, were merged. The final emissions inputs were converted into two types of model-ready emissions input files required to run CAMx:

- Two-dimensional emissions file for all sources except elevated point sources; and
- Elevated-point source emissions file.

A complete emissions inventory for photochemical modeling includes all sources of emissions from both anthropogenic sources (e.g., power plants, agricultural activities) and natural sources (e.g., biogenic, wildfires). Emissions are grouped into categories depending on the source type (e.g., coal mines, oil and gas industry, windblown dust). Often the emissions within a category are split into sub-categories for processing.

Table 2-2 shows the final base year 2008 emissions totals for each modeling domain. **Table 2-3** shows the annual values for each sector in the 4-km domain. The oil and gas point source sector include

compressor stations, associated equipment, and drilling and completion emissions. The oil and gas area source sector include well pad activities and equipment such as tanks, engines, flaring, venting, and dehydrators for conventional oil and gas and CBNG. The emissions activities associated with coal mining point source sector include: mine construction, non-road engines that process and transport the coal, and intra-facility railroad hauling. Operational fugitive dust (which includes windblown dust associated with storage piles) was processed under the coal mine fugitive dust source sector. The point source sectors represent both electric generating unit (EGU) and non-EGU stationary point sources. The non-point source sector emissions include non-point source airport, locomotive, and marine emissions. Mobile emissions were from the MOVES model. The MOVES model provides emissions rates per distance, per vehicle, and per profile. The resulting emissions rates were combined with local activity data and meteorological information and processed through SMOKE. The non-road source sector includes all non-road engines except those emissions that are quantified elsewhere (e.g., mining equipment, construction equipment for mining, drill rig engines). The fugitive dust source sector includes unpaved and paved road dust, commercial and residential construction, agricultural tilling, agricultural planting, and livestock operations. The agricultural source sector contains ammonia (NH_3) emissions from agricultural and anthropogenic activities (e.g., fertilizer application, feedlots, soil). The fire and biogenic emissions were obtained from the SMARTFIRE and MEGAN models, respectively.

Table 2-2 Annual Base Year 2008 Emissions by Domain

Model Domain	NO_X (tons per year [tpy])	TOG[1] (tpy)	CO (tpy)	SO_2 (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
36-km	22,810,770	103,899,344	114,981,536	14,681,067	15,728,982	6,524,190	5,477,247
12-km	1,079,472	5,923,514	5,236,468	377,545	537,335	286,593	294,392
4-km	240,632	1,892,887	2,262,285	78,177	249,808	162,104	58,990

[1] TOG = Total organic gases; includes VOCs as well as additional organic compounds such as methane and ethane.

Table 2-3 Annual Emissions by Sector in the 4-km Domain

Source Sector	NO_X (tpy)	TOG (tpy)	CO (tpy)	SO_2 (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	NH_3 (tpy)
Oil and Gas Point	16,788	18,827	11,486	7,894	3,428	2,487	4
Oil and Gas Area	23,535	64,034	10,131	1,214	789	772	0
Coal Mine Point	4,549	104	3,561	152	2,663	520	2
Coal Mine Fugitive Dust	0	0	0	0	8,752	6,158	0
Point	55,344	8,779	11,877	58,511	8,928	4,926	138
Non-Point	30,659	13,248	17,915	547	3,291	3,108	486
Mobile	65,598	35,939	376,902	474	3,925	3,761	1,077
Non-road	8,851	13,584	57,677	176	1,011	966	10
Fugitive Dust	0	0	0	0	65,394	10,907	0
Agricultural	0	0	0	0	0	0	31,774
Fire	13,026	383,454	1,563,451	9,209	151,629	128,499	25,499
Biogenic	22,283	1,354,919	209,285	0	0	0	0
Total	**240,633**	**1,892,888**	**2,262,285**	**78,177**	**249,810**	**162,104**	**58,990**

3.0 Description of Current Conditions

3.1 Air Quality Standards

The NAAQS, state AAQS for Montana and Wyoming, and PSD increments for Class I and sensitive Class II areas are summarized in **Table 3-1**.

Table 3-1 Applicable Ambient Air Quality Standards

Pollutant (units)	Averaging Period	NAAQS[2]	State AAQS[1]		PSD Increments[18]	
			Wyoming[3]	Montana[4]	Class I	Class II
NO_2 (ppb)	1-hour	100[12]	100[12]	300	--	--
	Annual[5]	53	53	50	1.3	13.3
CO (parts per million [ppm])	1-hour[6]	35	35	23	--	--
	8-hour[6]	9	9	9	--	--
SO_2 (ppb)	1-hour	75[13]	75[13]	500[14]	--	--
	3-hour[6]	500	500	--	9.5	195.5
	24-hour	--[7]	--	100	1.9[6]	34.8[6]
	Annual	--[7]	--	20	0.76[5]	7.6[5]
Ozone (ppm)	1-hour[8]	--	--	0.1	--	--
	8-hour[9]	0.075	0.075	--	--	--
$PM_{2.5}$ (micrograms per cubic meter [$\mu g/m^3$])	24-hour[10]	35	35	--	2[6]	9[6]
	Annual[5]	12[15]	15	--	1	4
	Annual[5]	15[16]	--	--	1	4
PM_{10} ($\mu g/m^3$)	24-hour[11]	150	150	150	8[6]	30[6]
	Annual[5]	--[17]	50	50	4	17

1 Due to the lack of an identified regional issue for lead, it was not analyzed as part of this study.
2 Source: http://www.epa.gov/air/criteria.html#3.
3 Source: http://soswy.state.wy.us/Rules/RULES/8887.pdf.
4 Source: http://www.deq.mt.gov/AirQuality/Planning/AirStandards/AirStandards.pdf.
5 Not to be exceeded.
6 Not to be exceeded more than once per year.
7 Final rule signed June 2, 2010. The 24-hour and annual SO_2 standards from 1971 were revoked in that same rulemaking. However, these standards remain in effect until 1 year after an area is designated for the 2010 standard, except in areas designated nonattainment for the 1971 standards, where the 1971 standards remain in effect until implementation plans to attain or maintain the 2010 standard are approved.
8 The USEPA revoked the 1-hour ozone standard in all areas, although some areas have continuing obligations under that standard. The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is less than or equal to 1.
9 To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm. A new 8-hour ozone standard is anticipated to be finalized by the USEPA in 2013.
10 24-hour average of the 98th percentile concentrations (effective December 17, 2006).
11 Not to be exceeded more than once per year on average over 3 years.
12 The 3-year average of the 98th percentile of the daily maximum 1-hour average is not to exceed this standard.
13 The 3-year average of the 99th percentile of the daily maximum 1-hour average is not to exceed this standard.
14 Not to be exceeded more than 18 times in any 12 consecutive months.
15 Primary standard, annual mean, averaged over 3 years.
16 Secondary standard, annual mean, averaged over 3 years.
17 The annual PM_{10} NAAQS of 50 $\mu g/m^3$ was revoked by the USEPA on September 21, 2006; see Federal Register, volume 71, number 200, 10/17/06.
18 Source: 40 Code of Federal Regulations Part 52, Section 21, as amended by the Final Rule in Federal Register, volume 70, number 59582 (10/12/05) and Federal Register, volume 75, number 64863 (10/20/10).

3.2 Meteorological Conditions

The PRB study area, spanning northeast Wyoming and southeast Montana (**Figure 1-1**), is characterized as high plains and noted for windy conditions and little rainfall. The windy conditions are indicative of the westerly wind prevalence over the region that is typical of sites in the PRB. However, climatic conditions vary considerably due to the variation in elevation and topography throughout the study area.

3.2.1 Topography

The study area focuses on the Wyoming and Montana PRB of the northwestern Great Plains Steppe. The topography of the study area varies from foothills and canyons in the west, to rolling plains and tablelands of moderate relief with occasional valleys, canyons, and buttes throughout the PRB. Elevations generally range from approximately 3,000 to 6,000 feet above mean sea level (amsl), with mountain peaks rising to over 10,000 feet west of the study area. The PRB study area generally slopes toward the east, with the clear features of the Big Horn Mountain Range to the west of the study area and the Black Hills to the east. Although these features may influence the upper level flow, the higher terrain could show slightly higher impacts from distant sources, due to potential plume impaction on those features. The Black Hills may be more susceptible because the prevailing wind tends to advect emissions from the PRB to the east.

3.2.2 Climate and Meteorology

Most of the PRB study area is classified as a semi-arid cool steppe, where evapotranspiration far exceeds precipitation, with relatively short, warm summers and longer, cold winters. **Table 3-2** summarizes the typical climate conditions for Sheridan, Wyoming, for the period of record from 1920 to 2013. These data are reasonably representative of the PRB study area. On the plains, wintertime average daily temperatures typically range from lows of 5 to 10 degrees Fahrenheit (°F) to daily highs of 30 to 35 °F. Typical mid-summer daily averages range between 50 to 60 °F (low) and 85 to 90 °F (high). The frost-free period generally occurs for 120 days between late May and mid-September. The annual average total precipitation ranges between 12 and 16 inches, with 36 to 60 inches of total annual snowfall. Temperatures generally are cooler, frost-free periods shorter, and precipitation and snowfall greater at higher elevations, including the mountains along the western margin of the study area (Western Regional Climate Center [WRCC] 2013).

Nighttime cooling under the frequent clear skies enhances the formation of stable air, or temperature inversions, during the late night and early morning. The stable air promotes light winds and inhibits air pollutant mixing and transport from sources located along the valley drainages. The maximum localized impacts from the low-level sources tend to occur during these periods. Dispersion potential improves along ridges and mountain tops, especially during the winter-spring weather transition periods and summer convective heating periods.

Table 3-2 Monthly Climate Summary for Sheridan, Wyoming

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average Maximum Temperature (˚F)	32.5	36.7	45.1	57.2	67.3	76.7	87.8	86.8	74.9	61.8	45.3	35.5	59.0
Average Minimum Temperature (˚F)	6.3	10.7	19.6	29.7	39.3	47.6	53.5	50.9	40.6	30.4	18.6	9.6	29.7

Table 3-2 Monthly Climate Summary for Sheridan, Wyoming

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average Total Precipitation (inches)	0.5	0.46	0.91	1.77	2.58	2.69	1.24	0.87	1.4	1.28	0.7	0.49	14.9
Average Total Snowfall (inches)	7.3	6.6	9	5	0.8	0.1	0	0	0.3	2.1	5.3	6.4	43
Average Snow Depth (inches)	4	3	1	0	0	0	0	0	0	0	1	2	1

Note: Period of record average: January 1, 1920, to February 28, 2013.

Source: WRCC 2013.

3.3 Air Quality Conditions

General air quality conditions are favorable in the PRB study area. Low air pollutant concentrations result from favorable atmospheric dispersion conditions and limited air pollution emissions sources (few industrial facilities and relatively small residential communities and isolated ranches). However, the potential exists for localized, highly concentrated pockets of NO_2, SO_2, and PM_{10} due to the large number of minor sources in the area. **Table 3-3** summarizes typical ambient air quality conditions in the PRB study area from 2008 to 2012 using data from representative monitoring sites in central Campbell County, Wyoming, and southern Rosebud County, Montana. While lead is regulated by NAAQS, ambient monitoring indicates that is not a pollutant of concern, and therefore, it is not discussed in detail. Although CO monitoring data are not available for this time period, this pollutant has been analyzed for this study.

Table 3-3 Ambient Air Quality Conditions in the PRB Study Area

Pollutant	Averaging Period	Site ID, Monitor Location	Year	Pollutant Level	Number of NAAQS Exceedences
NO_2 (ppb)	1-hour	560050456, Campbell County, Wyoming	2008	33	0
			2009	29	0
			2010	32	0
			2011	33	0
			2012	32	0
		300870761, Rosebud County, Montana	2008[2]	6	0
			2009	59	3
			2010	31	1
			2011	39	3
			2012	56	2
	Annual[1]	CAMP (560050456), Campbell County, Wyoming	2008	3.1	0
			2009	2.6	0
			2010	3.3	0
			2011	2.7	0
			2012	3.0	0

Table 3-3 Ambient Air Quality Conditions in the PRB Study Area

Pollutant	Averaging Period	Site ID, Monitor Location	Year	Pollutant Level	Number of NAAQS Exceedences
SO_2 (ppb)	1-hour	560050857, Campbell County, Wyoming	2008	69	2
			2009	60	0
			2010	52	2
			2011	37	0
			2012	39	0
		300870761, Rosebud County, Montana	2008	85	1
			2009	11	0
			2010	16	0
			2011	14	0
			2012	33	2
	24-hour	560050857, Campbell County, Wyoming	2008	26	0
			2009	24	0
			2010	19	0
			2011	13	0
			2012	12	0
		300870761, Rosebud County, Montana	2008	7	0
			2009	7	0
			2010	9	0
			2011	7	0
			2012	8	0
Ozone (ppm)	1-hour	560050456, Campbell County, Wyoming	2008	0.070	0
			2009	0.069	0
			2010	0.070	0
			2011	0.078	0
			2012	0.082	0
		300870001, Rosebud County, Montana	2008	ND	ND
			2009	ND	ND
			2010	0.065	0
			2011	0.061	0
			2012	0.075	0
	8-hour	560050456, Campbell County, Wyoming	2008	0.064	0
			2009	0.060	0
			2010	0.061	0
			2011	0.062	0
			2012	0.069	0
		300870001, Rosebud County, Montana	2008	ND	ND
			2009	ND	ND
			2010	0.059	0
			2011	0.052	0
			2012	0.059	0

Table 3-3 Ambient Air Quality Conditions in the PRB Study Area

Pollutant	Averaging Period	Site ID, Monitor Location	Year	Pollutant Level	Number of NAAQS Exceedences
$PM_{2.5}$ ($\mu g/m^3$)	24-hour	560050892, Campbell County, Wyoming	2008	15	ND
			2009	12	ND
			2010	18	ND
			2011	20	ND
			2012	55	ND
		300870001, Rosebud County, Montana	2008	ND	ND
			2009	ND	ND
			2010	11	ND
			2011	17	ND
			2012	29	ND
	Annual	560050892, Campbell County, Wyoming	2008	5.8	ND
			2009	5.1	ND
			2010	6.8	ND
			2011	5.5	ND
			2012	7.9	ND
		300870001, Rosebud County, Montana	2008	ND	ND
			2009	ND	ND
			2010	4.1	ND
			2011	4.5	ND
			2012	7.9	ND
PM_{10} ($\mu g/m^3$)	24-hour	560050456, Campbell County, Wyoming	2008	32	0
			2009	36	0
			2010	34	0
			2011	40	0
			2012	55	0
		300870307, Rosebud County, Montana	2008	50	0
			2009	112	0
			2010	86	0
			2011	130	0
			2012	109	0
	Annual[1]	CAMP (560050456), Campbell County, Wyoming	2008	9.6	ND
			2009	12.4	ND
			2010	12.1	ND
			2011	12.1	ND
			2012	16.8	ND

Note: ND = No data. All data were collected from the USEPA AirData Reports (USEPA 2013a) unless otherwise noted. These data include air quality conditions recorded during the occurrence of exceptional events as defined by the USEPA.

[1] Annual arithmetic means calculated from January 1 to December 1 for NO_2 and PM_{10} were taken from WDEQ Annual Air Quality Reports (WDEQ 2013).

[2] Number of observations available less than in other years in time period.

3.3.1 Nitrogen Dioxide

For the monitoring site located south of Gillette in Campbell County, Wyoming (Site ID: 560050456), there is little variation in either the 1-hour or annual NO_2 monitoring data between 2008 and 2012 (**Table 3-3**). Furthermore, no exceedence of the 1-hour or annual NAAQS for NO_2 (**Table 3-1**) occurred during this time. For the monitoring site on Garfield Peak in Rosebud County, Montana (Site ID: 300870761), there is more variation in the 1-hour monitoring data, and one to three NAAQS exceedences occurred each year during this period.

3.3.2 Sulfur Dioxide

NAAQS for SO_2 currently include a primary 1-hour standard and a secondary 3-hour standard (**Table 3-1**). Although 24-hour and annual standards have been revoked by the USEPA, these standards may still be in effect for certain nonattainment areas and in state-regulated air quality standards, including Montana. Sporadic exceedences of the 1-hour SO_2 standard were reported for both the Campbell County, Wyoming (Site ID: 560050857), and Rosebud County, Montana (Site ID: 300870761), monitoring sites between 2008 and 2012 (**Table 3-3**). No exceedence of the 24-hour standard was observed at either site.

3.3.3 Ozone

Currently there is an 8-hour rolling average NAAQS for ozone (**Table 3-1**). Although the 1-hour standard has been revoked by the USEPA, this standard may still be in effect for certain nonattainment areas and in state-regulated air quality standards, including Montana. For the monitoring sites near Garfield Peak in Campbell County, Wyoming (Site ID: 560050456), and near Birney Mountain in Rosebud County, Montana (Site ID: 300870001), no exceedence of the 8-hour ozone standard was reported in the available data between 2008 and 2012 (**Table 3-3**). Furthermore, there is little variation in the ozone data for these monitoring sites during this time period.

3.3.4 Particulate Matter

Both $PM_{2.5}$ and PM_{10} are regulated by annual and 24-hour NAAQS (**Table 3-1**). Although data relative to the number of exceedences of the $PM_{2.5}$ 24-hour and annual standards were not available for either the Campbell County, Wyoming (Site ID: 560050892), or Rosebud County, Montana (Site ID: 300870001), monitoring sites between 2008 and 2012, it is evident that some exceedences occurred at the Campbell County site based on the reported monitoring data (**Table 3-3**). No exceedences of the PM_{10} 24-hour were reported for the representative monitoring sites in either Campbell County (Site ID: 560050456) or Rosebud County (Site ID: 300870307) during this same time period. Based on the available 24-hour and annual monitoring data, average concentrations of both $PM_{2.5}$ and PM_{10} increased between 2008 and 2012.

3.4 Visibility

Visibility may be impacted by a wide range of natural and man-made conditions. Current visibility conditions in the Class I and sensitive Class II areas in the 12- and 4-km model domains have been estimated as shown in **Table 3-4**. The values in **Table 3-4** were generated by the Modeled Attainment Test Software (MATS) (Abt Associates, Inc. 2009) visibility analysis. MATS can calculate baseline visibility levels for the best and worst days for Class I and sensitive Class II areas. These estimates rely on monitoring data from available IMPROVE monitors and were developed using the new IMPROVE visibility equation. The data are provided in both deciviews (dv) and light extinction units of inverse megameters (Mm^{-1}); lower dv values indicate better visibility conditions. Of the Class I and sensitive Class II areas included in the analysis, the areas located to the northwest, west, and southwest of the Wyoming and Montana PRB study area experienced the worst visibility conditions in 2008. A USEPA analysis indicates that visibility on the worst days in locations such as Badlands NP, Bridger WA, and Yellowstone NP historically have been impaired primarily by SO_4 and NO_3. These pollutants

predominantly are from the burning of fossil fuels and industrial activities and account for a combined 45 to 75 percent of the visibility reduction, the majority of which is from SO_4 (USEPA 1997).

Table 3-4 Visibility Values Estimated from Monitored Data by MATS for Class I and Sensitive Class II Areas – Base Year 2008

Assessment Areas	20 Percent Best Visibility (dv)	20 Percent Worst Visibility (dv)	20 Percent Best Visibility (Mm^{-1})	20 Percent Worst Visibility (Mm^{-1})
Class I Areas				
Badlands NP	6.65	16.62	19.4	52.7
Badlands WA	6.65	16.62	19.4	52.7
Bob Marshall WA	2.88	14.74	13.3	43.7
Bridger WA	1.39	10.58	11.5	28.8
Fitzpatrick WA	1.39	10.58	11.5	28.8
Fort Peck IR	6.22	17.89	18.6	59.8
Gates of the Mountains WA	1.08	11.20	11.1	30.6
Grand Teton NP	1.85	11.57	12.0	31.8
Lostwood WA	8.12	19.72	22.5	71.9
Medicine Lake WA	6.30	18.40	18.8	63.0
Mount Zirkel WA	0.95	9.36	11.0	25.5
North Absaroka WA	1.42	11.72	11.5	32.3
Northern Cheyenne IR	3.48	14.21	14.2	41.4
Rawah WA	0.95	9.36	11.0	25.5
Red Rock Lakes WA	1.85	11.57	12.0	31.8
Rocky Mountain NP	1.91	12.04	12.1	33.3
Scapegoat WA	2.88	14.74	13.3	43.7
Theodore Roosevelt NP	6.59	17.88	19.3	59.8
UL Bend WA	4.31	15.01	15.4	44.9
Washakie WA	1.85	11.57	12.0	31.8
Wind Cave NP	4.53	15.42	15.7	46.7
Yellowstone NP	1.85	11.57	12.0	31.8
Class II Areas				
Absaroka-Beartooth WA	1.42	11.72	11.5	32.3
Agate Fossil Beds NM	4.53	15.42	15.7	46.7
Bighorn Canyon National Recreation Area	1.42	11.72	11.5	32.3

Table 3-4 Visibility Values Estimated from Monitored Data by MATS for Class I and Sensitive Class II Areas – Base Year 2008

Assessment Areas	20 Percent Best Visibility (dv)	20 Percent Worst Visibility (dv)	20 Percent Best Visibility (Mm^{-1})	20 Percent Worst Visibility (Mm^{-1})
Black Elk WA	4.53	15.42	15.7	46.7
Cloud Peak WA	1.24	11.36	11.3	31.1
Crow IR	3.48	14.21	14.2	41.4
Devils Tower NM	ND	ND	ND	ND
Dinosaur NM	0.95	9.36	11.0	25.5
Fort Belknap IR	4.31	15.01	15.4	44.9
Fort Laramie National Historic Site	4.53	15.42	15.7	46.7
High Uintas WA	1.39	10.58	11.5	28.8
Jewel Cave NM	4.53	15.42	15.7	46.7
Jedediah Smith WA	1.85	11.57	12.0	31.8
Lee Metcalf WA	1.85	11.57	12.0	31.8
Mount Naomi WA	1.39	10.58	11.5	28.8
Mount Rushmore National Memorial	4.53	15.42	15.7	46.7
Popo Agie WA	1.39	10.58	11.5	28.8
Sarvis Creek WA	0.95	9.36	11.0	25.5
Soldier Creek WA	4.53	15.42	15.7	46.7
Teton WA	1.85	11.57	12.0	31.8
Wellsville Mountain WA	1.39	10.58	11.5	28.8
Wind River IR	1.39	10.58	11.5	28.8

Note: ND = No data.

3.5 Atmospheric Deposition

The atmospheric deposition of nitrogen and sulfur affects the acidification of surface waters. The eight sensitive lakes included in this study, as identified in Section 2.2, are located in Class I and Class II areas at elevations between approximately 9,680 and 11,440 feet amsl. The sensitive lakes are characterized by a generally low level of sulfur deposition and low baseline ANC. Therefore, increases in the wet or dry deposition of atmospheric pollutants, including NO_3, NH_4, nitric acid (HNO_3), dry NO_x, SO_2, and SO_4, may substantially decrease the ANC of the lakes.

3.5.1 Deposition

Background total nitrogen and sulfur deposition data were obtained from the National Atmospheric Deposition Program (NADP) National Trends Network (NTN), for wet deposition and the Clean Air Status

and Trends Network (CASTNET) for dry deposition, for the years 2008 through 2011. **Table 3-5** summarizes the total nitrogen and sulfur deposition data from western Wyoming monitoring sites in the vicinity of the sensitive lakes included in this study. Based on the monitoring data, little annual trend is apparent in either nitrogen or sulfur deposition.

Table 3-5 Background Atmospheric Nitrogen and Sulfur Deposition Data

Site ID, Monitor Location	Year	Total Nitrogen Deposition (kg N/ha/yr)[1]			Total Sulfur Deposition (kg S/ha/yr)[2]		
		Wet[3]	Dry[4]	Wet + Dry	Wet[1]	Dry[4]	Wet + Dry
Pinedale, Sublette County, Wyoming (WY06) (PND165)[5]	2008	0.96	0.40	1.36	0.46	0.18	0.64
	2009	0.92	0.34	1.25	0.46	0.15	0.61
	2010[6]	0.89	0.37	1.27	0.46	0.16	0.61
	2011[6]	1.05	0.34	1.39	0.45	0.14	0.59
Sinks Canyon, Fremont County, Wyoming (WY02)	2008	0.98	ND	ND	0.52	ND	ND
	2009	1.12	ND	ND	0.55	ND	ND
	2010	1.19	ND	ND	0.63	ND	ND
	2011	0.94	ND	ND	0.47	ND	ND
Yellowstone National Park, Teton County, Wyoming (YEL408)	2008	ND	0.25	ND	ND	0.23	ND
	2009	ND	0.17	ND	ND	0.21	ND
	2010	ND	0.18	ND	ND	0.21	ND
	2011	ND	0.22	ND	ND	0.18	ND
Yellowstone National Park – Tower Falls, Park County, Wyoming (WY08)	2008	0.80	ND	ND	0.36	ND	ND
	2009	1.14	ND	ND	0.52	ND	ND
	2010[6]	0.99	ND	ND	0.38	ND	ND
	2011[6]	0.89	ND	ND	0.28	ND	ND

Note: ND = No data.

1 kg N/ha/yr = kilograms nitrogen per hectare per year.

2 kg S/ha/yr = kilograms sulfur per hectare per year.

3 Wet deposition includes nitrogen contributions from NH_4 and NO_3 or sulfur contributions from SO_4 derived from annual NADP/NTN data (NADP 2013).

4 Dry nitrogen deposition includes nitrogen contributions from NO_3, HNO_3, and NH_4 or sulfur contributions from SO_2 and SO_4 derived from annual CASTNET data (USEPA 2013b).

5 The Pinedale site is the only site in the 12-km model domain to measure both wet and dry deposition at the same location.

6 Data do not meet NADP/NTN Completeness Criteria.

3.5.2 Sensitive Lake Acid Neutralizing Capacity

The calculated 10th percentile lowest measured ANC values for the sensitive lakes included in this study are summarized in **Table 3-6**. These ANC values are considered to be a conservative baseline of ANC for calculating future lake impacts from changes in atmospheric deposition of nitrogen and sulfur. Based on the values presented in **Table 3-6**, Upper Frozen Lake falls into a sensitive lake category where ANC

is less than 25 micro-equivalents per liter (µeq/L). Such lakes are vulnerable to changes in atmospheric deposition and seasonal or episodic changes (e.g., snowmelt), that may lower ANC substantially (Sullivan et al. 2012).

Table 3-6 Background ANC Values for Sensitive Lakes

Lake, WA	Latitude (degrees)	Longitude (degrees)	Number of Samples	10th Percentile Lowest ANC Value (µeq/L)
Class I Area Lakes				
Black Joe Lake, Bridger WA	42.7394	-109.1711	72	70.64
Deep Lake, Bridger WA	42.7194	-109.1708	62	61.10
Hobbs Lake, Bridger WA	43.0355	-109.6721	76	69.75
Upper Frozen Lake, Bridger WA	42.6856	-109.1606	3	13.18
Ross Lake, Fitzpatrick WA	43.3781	-109.6583	57	54.00
Class II Area Lakes				
Emerald Lake, Cloud Peak WA	44.4572	-107.3031	40	70.03
Florence Lake, Cloud Peak WA	44.3481	-107.1806	42	34.36
Lower Saddlebag Lake, Popo Agie WA	42.6233	-108.9947	58	55.61

Source: USFS 2011.

4.0 Modeled Base Year Cumulative Impacts

Current air quality conditions for base year 2008 were modeled for this study to provide a comparative basis for evaluation of modeled future year (2020 and 2030) cumulative air quality impacts at the assessment areas. The assessment areas for this study include the Class I and sensitive Class II areas and, for ANC, sensitive lakes located within the 12-km model domain. These assessment areas are identified in Section 2.2 and shown in **Figure 2-2**. The modeled impacts for base year 2008 are summarized this report. The results of the future year cumulative air quality impact modeling/analysis are presented in the Task 3A report.

4.1 Summary of Cumulative Impacts

This section provides a summary of the maximum modeled impacts for the key components of the analysis (air quality, visibility, and atmospheric deposition). **Table 4-1** provides a summary of the results for this study.

In general, the modeled cumulative impacts show some exceedences of the NAAQS for criteria pollutants, especially for CO. The summer of 2008 was a very active fire season, and various wildfires reflected in the model emissions inventory had an impact on criteria pollutants at different times and assessment areas. Modeled impacts of NO_2 and SO_2 (with one exception) are well below the NAAQS and the individual state AAQS.

Table 4-1 Summary of Modeled Air Quality Impacts

Air Quality Component		Base Year 2008
Concentrations	Criteria	Primarily below NAAQS and state AAQS, except CO, ozone, and PM_{10} at five Class I areas and four sensitive Class II areas during wildfire episodes.
Visibility	Far-field	The largest visibility impacts occurred at the Class I Lostwood WA and Class II Fort Laramie National Historic Site, with extinction values of 50.9 Mm^{-1} (16.3 dv).
Atmospheric Deposition: Nitrogen	LOC	The largest nitrogen deposition in a Class I area occurred at North Absaroka WA (9.89 kg N/ha/yr) while the smallest occurred at UL Bend WA (1.43 kg N/ha/yr).
Atmospheric Deposition: Sulfur	LOC	The largest sulfur deposition in a Class I area occurred at Fitzpatrick WA (1.46 kg S/ha/yr) while the smallest occurred at UL Bend WA (0.23 kg S/ha/yr).
Atmospheric Deposition: Lake Chemistry	ANC	The largest ANC percent change occurred at Upper Frozen Lake, Bridger WA (304.7 percent) while the smallest percent change occurred at Emerald Lake, Cloud Peak WA (41.5 percent).

Note: LOC = level of concern.

4.2 Cumulative Impacts on Ambient Air Quality

The modeled cumulative impacts for base year 2008 were calculated for the Class I and sensitive Class II areas included in this study. The modeled results are presented in **Table 4-2**. Results are provided for:

- 1-hour and annual average NO_2 concentrations;
- 1 hour and 8-hour CO concentrations;

- 1-hour and 3-hour SO_2 concentrations;
- 8-hour ozone concentrations;
- 24-hour and annual $PM_{2.5}$ concentrations; and
- 24-hour PM_{10} concentrations.

Note that the analysis does not separate PSD increment consuming sources or emissions from non-PSD increment consuming sources. Therefore, the results cannot be used to develop a pattern of increment consumption for a particular site. The PSD comparisons are for informational purposes only and do not constitute a regulatory PSD increment consumption analysis, which may be required for specific projects by air permitting authorities.

Based on the modeling results for base year 2008 as presented in **Table 4-2**, results for NO_2 at all assessment areas are well below the NAAQS. Modeled concentrations of CO exceed the ambient standards at five Class I areas and three Class II areas, some substantially. These exceedences are mostly due to impacts from wildfires during 2008. For instance, the modeled data for the North Absaroka WA shows exceedences in the month of August for CO, SO_2, ozone, $PM_{2.5}$, and PM_{10}. These exceedences were the consequence of the lightning-caused Gunbarrel fire that started in the North Absaroka Wilderness on July 26, approximately 40 miles west of the town of Cody. In addition to the Gunbarrel fire, other large fires occurred during the summer of 2008, including the Blackhawk and Newt fires in Idaho; New Fork and Cascade fires in Wyoming; Bridal Falls 2 fire in Utah; and the Jordan fire in Colorado. All of these wildfires had a substantial influence in the impacts of the criteria pollutants in different Class I and Class II areas. With the exception of North Absaroka WA, the SO_2 concentrations at the selected assessment areas never exceed the NAAQS. Near the PRB study area, the data for the Northern Cheyenne IR in Montana show no exceedences for any of the criteria pollutants, while the Crow IR in Montana and the Cloud Peak WA in Wyoming show impacts above the standards for CO, ozone, and PM_{10} concentrations, likely related to fires. Figures showing the modeled concentrations during periods with elevated levels of air quality are shown in **Figures 4-1** through **4-3**.

Modeled results are limited by the model's ability to reproduce observed concentrations. Based on the Air Quality MPE (AECOM 2013a) which evaluated the modeled base year 2008 results in relation to reported monitoring data, the model tended to under-predict concentrations of several gas-phase criteria pollutants (i.e., NO_2, CO, and SO_2). As a result, the actual 2008 monitored concentrations of NO_2, CO, and SO_2 as reported in Chapter 3.0 tend to be higher than the modeled concentrations at those monitoring sites. Therefore, it is possible that the modeled values presented in **Table 4-2** also under-estimate the concentrations of NO_2, CO, and SO_2.

The model tended to over-predict ozone concentrations in the summer (when observed values typically are highest near the PRB study area). As a result, the actual 2008 monitored ozone concentrations as reported in Chapter 3.0 tend to be lower than the modeled concentrations at those monitoring sites. Therefore, it is possible that the modeled values presented in **Table 4-2** also over-estimate the concentrations of ozone.

The modeled concentrations of particle-phase criteria pollutants (i.e., $PM_{2.5}$ and PM_{10}) tended to be fairly accurate in rural areas. Therefore, the model performance for most species of PM is within USEPA-established criteria when compared with monitored concentrations in rural areas (AECOM 2013a). However, the model tended to under-predict PM_{10} concentrations within the PRB study area (AECOM 2013a). This indicates that the modeled $PM_{2.5}$ and PM_{10} concentrations presented in **Table 4-2** for assessment areas outside of the PRB study area are likely to be similar to actual concentrations. However, modeled $PM_{2.5}$ and PM_{10} concentrations presented in **Table 4-2** for assessment areas within the PRB study area likely would be lower than actual concentrations.

Table 4-2 Modeled Base Year 2008 Concentrations of Criteria Pollutants

Receptor Site	NO_2 (ppb)		CO (ppm)		SO_2 (ppb)		Ozone (ppm)	$PM_{2.5}$ (µg/m^3)		PM_{10} (µg/m^3)
	1-hour	Annual	1-hour	8-hour	1-hour	3-hour	8-hour	24-hour	Annual	24-hour
Class I Areas										
Badlands NP	1	0	0	0	0	0	0.071	9	3.9	20
Badlands WA	1	0	0	0	0	0	0.071	10	3.9	20
Bob Marshall WA, Flathead National Forest (NF)[1]	1	0	3	2	0	0	0.067	12	3.6	100
Bob Marshall WA, Lolo NF[1]	1	0	1	0	0	0	0.067	11	3.4	30
Bob Marshall WA, Lewis and Clark NF[1]	1	0	1	0	0	0	0.067	11	3.4	20
Bridger WA[2]	1	0	**117**	**86**	1	300	**0.149**	17	6.2	**3,740**
Fitzpatrick WA[2]	1	0	**48**	**29**	1	100	**0.189**	17	4.4	**940**
Fort Peck IR	2	1	3	2	0	0	0.069	10	4.5	100
Gates of the Mountains WA	1	0	1	1	0	0	0.069	12	3.9	30
Grand Teton NP	1	0	3	2	1	0	0.075	14	4.4	90
Lostwood WA	2	1	0	0	1	0	0.061	11	4.9	20
Medicine Lake WA	2	1	0	0	0	0	0.063	10	4.7	20
Mount Zirkel WA	1	0	1	0	0	0	0.074	7	2.9	20
North Absaroka WA[2]	4	1	**639**	**363**	7	**1,300**	**0.270**	**104**	***15.2***	**11,000**
Northern Cheyenne IR	1	0	2	2	1	0	0.070	13	4.0	100
Rawah WA	1	0	1	1	0	0	0.074	7	2.9	30
Red Rock Lakes WA[2]	3	1	**108**	**57**	6	200	**0.182**	**106**	**13.1**	**2,710**
Rocky Mountain NP	4	1	1	1	0	0	**0.085**	7	3.0	30
Scapegoat WA	1	0	1	1	0	0	0.068	11	3.4	30
Theodore Roosevelt NP	3	1	1	0	0	0	0.060	10	4.1	20
UL Bend WA	1	0	3	2	0	0	0.068	11	4.3	80
Washakie WA	1	0	9	4	0	0	**0.082**	11	3.3	**160**
Wind Cave NP	1	0	1	1	0	0	0.071	9	3.6	30
Yellowstone NP[2]	1	0	**61**	**40**	1	200	**0.104**	21	5.5	**1,570**
Class II Areas										
Absaroka-Beartooth WA, Gallatin NF[1,2]	1	0	**71**	**23**	1	100	**0.086**	19	4.4	**680**
Absaroka-Beartooth WA, Custer NF[1,2]	1	0	**137**	**85**	1	300	**0.154**	23	7.4	**3,840**
Agate Fossil Beds NM	2	1	0	0	0	0	0.071	9	3.9	20
Bighorn Canyon National Recreation Area	1	0	7	5	1	0	**0.090**	21	4.4	**250**

Table 4-2 Modeled Base Year 2008 Concentrations of Criteria Pollutants

Receptor Site	NO_2 (ppb)		CO (ppm)		SO_2 (ppb)		Ozone (ppm)	$PM_{2.5}$ ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)
	1-hour	Annual	1-hour	8-hour	1-hour	3-hour	8-hour	24-hour	Annual	24-hour
Black Elk WA	2	1	0	0	0	0	0.071	8	3.4	20
Cloud Peak WA[2]	1	0	**45**	**38**	1	100	0.074	15	3.6	**1,380**
Crow IR[2]	2	0	**43**	**28**	1	100	**0.098**	18	4.3	**1,140**
Devils Tower NM	2	1	0	0	0	0	0.070	9	3.8	20
Dinosaur NM	2	0	3	3	0	0	**0.078**	8	3.7	110
Fort Belknap IR	2	0	1	0	0	0	0.068	10	4.1	20
Fort Laramie National Historic Site	4	2	0	0	0	0	0.072	9	4.1	20
High Uintas WA, Ashley NF[1]	2	0	0	0	0	0	**0.080**	7	2.9	30
High Uintas WA, Wasatch NF[1]	2	0	1	1	0	0	**0.081**	7	2.9	30
Jewel Cave NM	1	0	1	1	0	0	0.070	9	3.4	20
Jedediah Smith WA	2	0	2	1	1	0	0.073	12	4.4	60
Lee Metcalf WA, Taylor-Hilgard Unit[1,2]	1	0	15	7	2	0	**0.123**	30	5.4	**290**
Lee Metcalf WA, Monument Mountains Unit[1,2]	1	0	13	7	2	0	**0.098**	27	5.6	**290**
Lee Metcalf WA, Spanish Peaks Unit[1,2]	1	0	9	6	1	0	**0.087**	21	4.5	**250**
Mount Naomi WA	16	3	1	1	0	0	**0.090**	13	5.8	30
Mount Rushmore National Memorial	1	0	0	0	0	0	0.070	8	3.4	20
Popo Agie WA	1	0	8	3	1	0	**0.077**	10	3.1	80
Sarvis Creek WA	1	0	1	1	0	0	0.071	7	3.1	30
Soldier Creek WA	2	1	0	0	0	0	0.070	8	3.7	20
Teton WA	1	0	4	2	1	0	0.074	12	3.9	70
Wellsville Mountain WA	17	5	1	1	0	0	**0.093**	16	7.4	40
Wind River IR	2	0	14	5	1	0	**0.134**	11	3.5	**180**

Note: Model-predicted concentrations that exceed the NAAQS are shown in **bold** text. For $PM_{2.5}$; ***bold and italic*** text indicates a modeled impact above the secondary $PM_{2.5}$ NAAQS.

1 Some sites have been further broken out to show impacts at spatially discrete locations.

2 Maximum impacts of CO, ozone, and particulate matter can be attributed to wildfires.

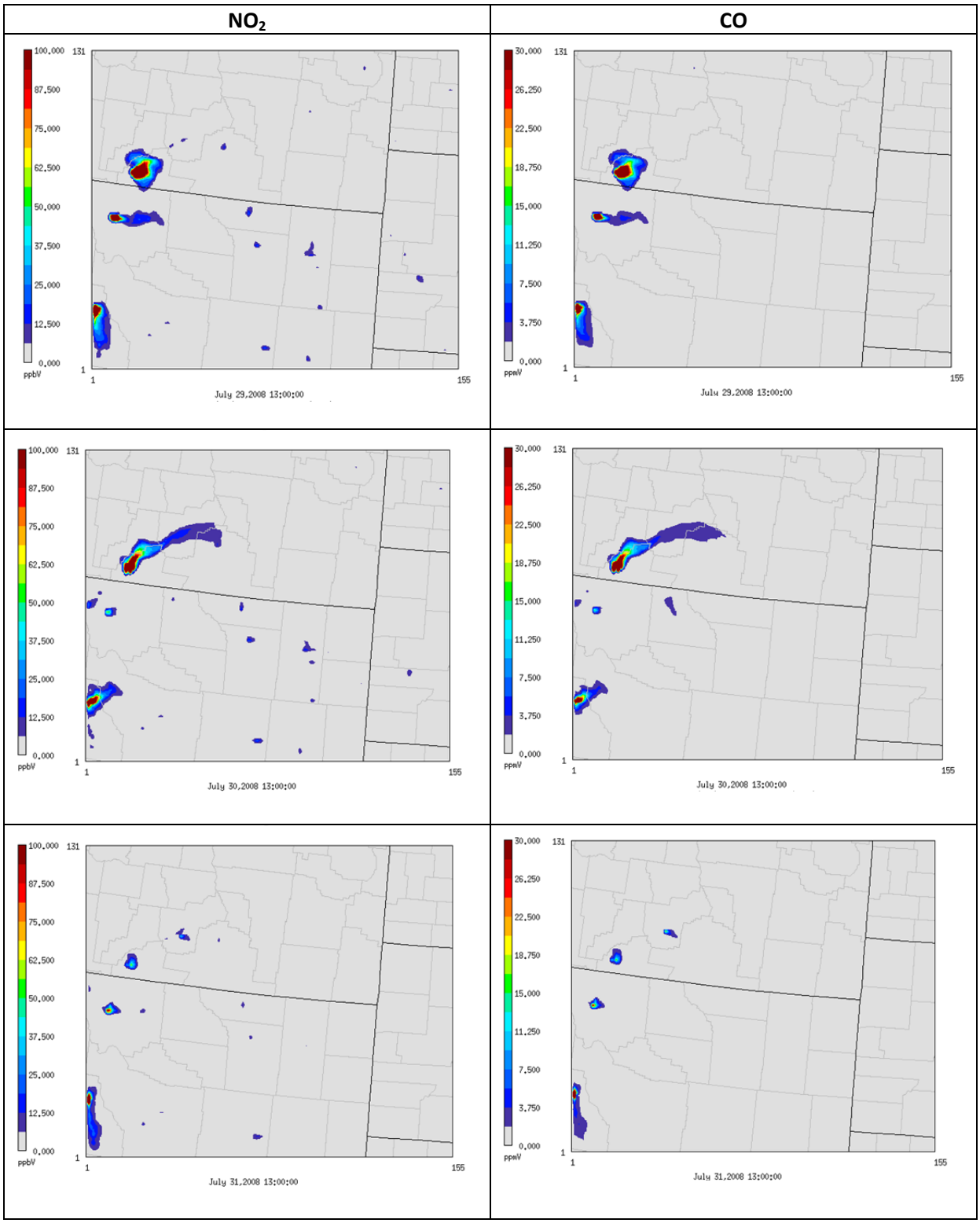


Figure 4-1 Base Year 2008 Model-predicted Hourly Average NO_2 and CO from July 29 through July 31

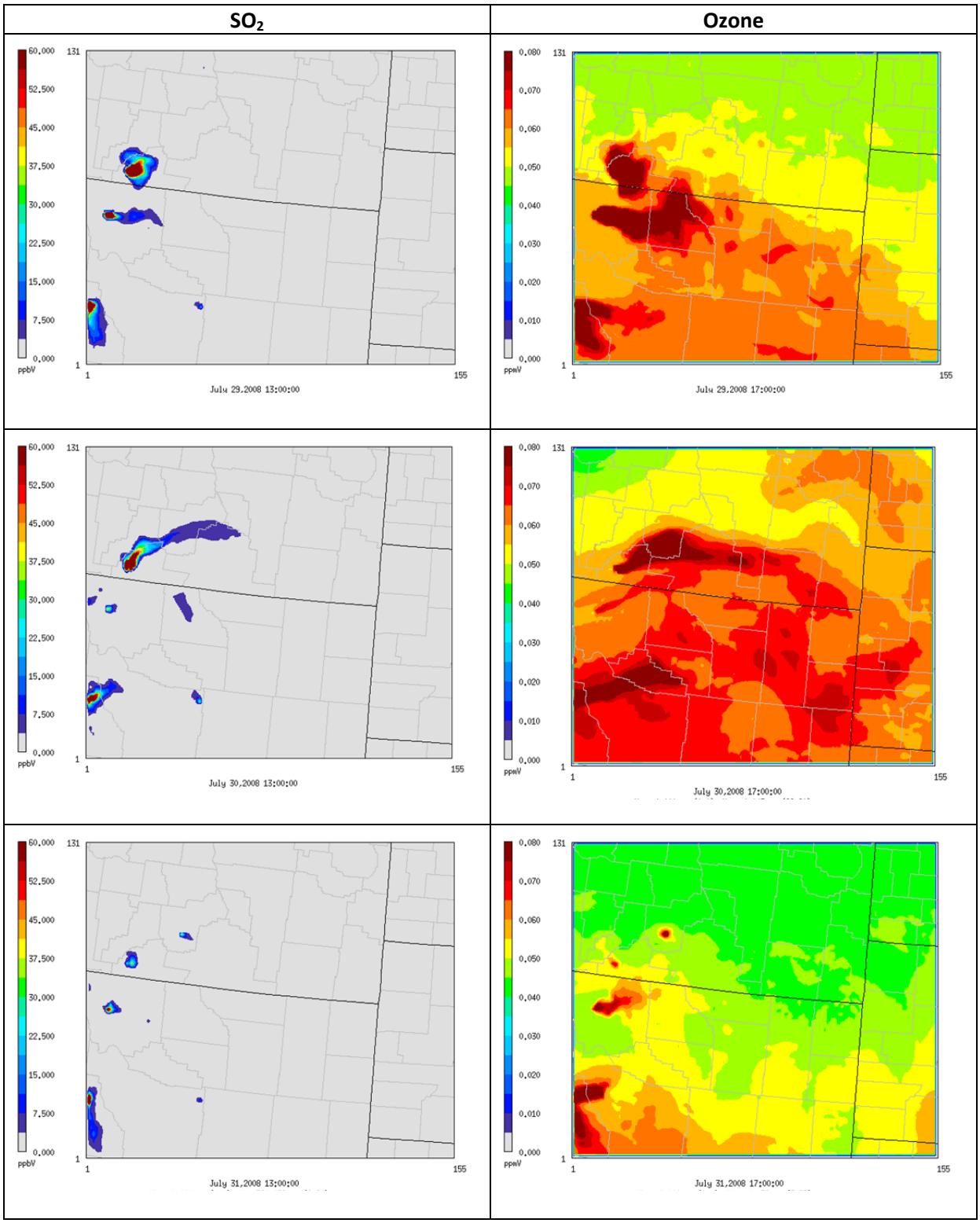


Figure 4-2 Base Year 2008 Model-predicted Hourly Average SO_2 and Ozone from July 29 through July 31

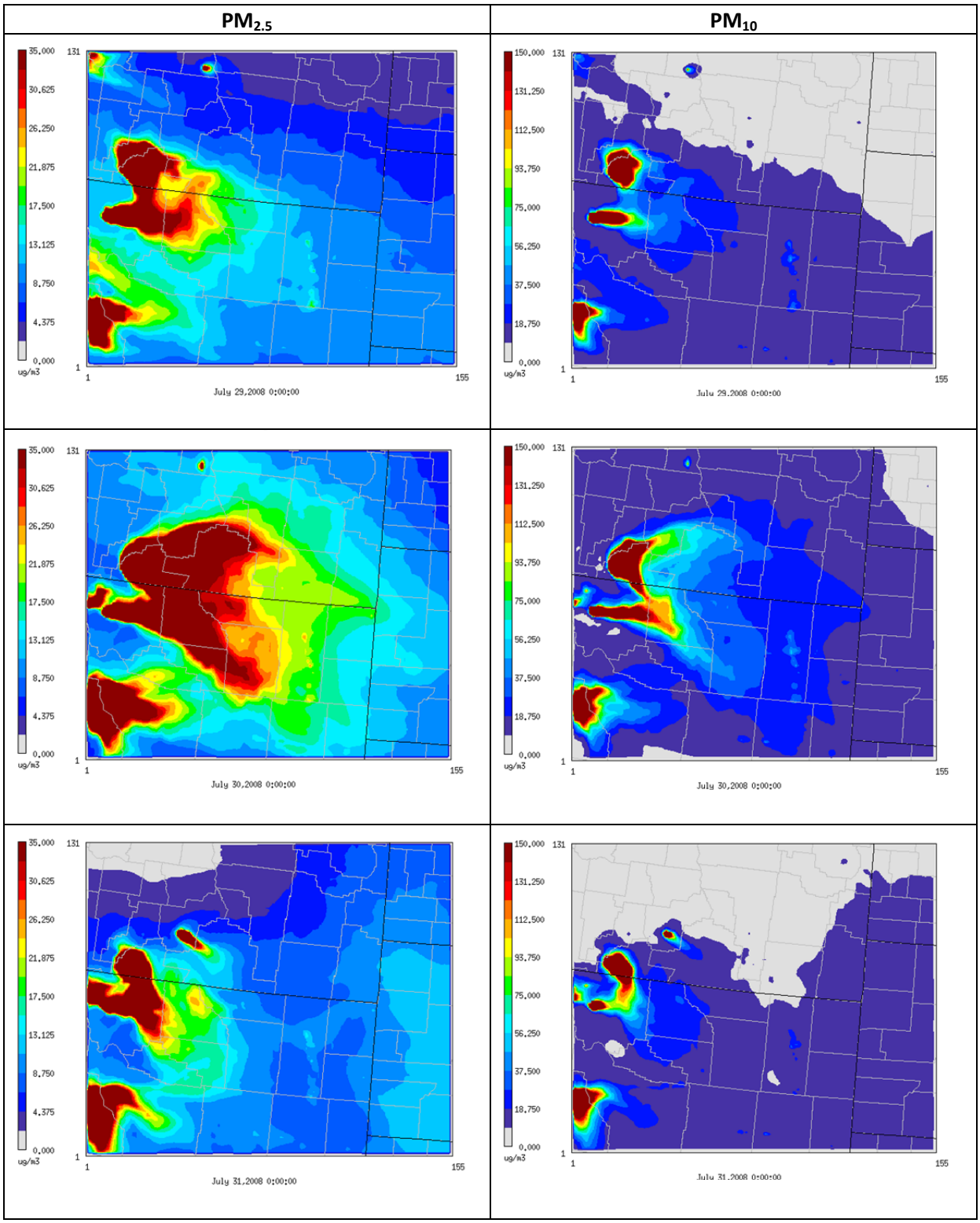


Figure 4-3 Base Year 2008 Model-predicted Daily Average $PM_{2.5}$ and PM_{10} from July 29 through July 31

4.3 Cumulative Impacts on Visibility

Under the CAA, visibility has been established as a critical resource for mandatory Class I areas, although currently there are no established thresholds for visibility impairment at Class I or sensitive Class II areas. The base year (2008) modeled visibility impacts for the Class I and sensitive Class II areas are provided in **Table 4-3**. The impacts were evaluated using a visibility analysis that relies on the IMPROVE equation and estimates the modeled baseline 20 percent best visibility days and the 20 percent worst visibility days at assessment area.

Table 4-3 Modeled Visibility Values for Class I and Sensitive Class II Areas – Base Year 2008

Assessment Area	20th Percentile Best Visibility (dv)	20th Percentile Worst Visibility (dv)	20th Percentile Best Visibility (Mm^{-1})	20th Percentile Worst Visibility (Mm^{-1})
Class I Areas				
Badlands NP	7.8	13.6	21.9	38.9
Badlands WA	8.0	13.8	22.2	39.6
Bob Marshall WA, Flathead NF[1]	6.6	12.1	19.4	33.4
Bob Marshall WA, Lolo NF[1]	6.4	11.6	19.0	31.7
Bob Marshall WA, Lewis and Clark NF[1]	6.4	11.9	19.0	33.0
Bridger WA	4.7	10.0	16.0	27.1
Fitzpatrick WA	4.4	9.6	15.5	26.1
Fort Peck IR	8.7	15.2	23.9	45.6
Gates of the Mountains WA	6.2	11.8	18.6	32.6
Grand Teton NP	6.7	12.3	19.5	34.2
Lostwood WA	9.6	16.3	26.1	50.9
Medicine Lake WA	9.1	15.8	24.9	48.5
Mount Zirkel WA	4.2	8.6	15.2	23.7
North Absaroka WA	5.2	11.2	16.7	30.6
Northern Cheyenne IR	6.3	12.1	18.8	33.6
Rawah WA	4.7	9.1	15.9	24.7
Red Rock Lakes WA	6.4	13.6	18.9	38.9
Rocky Mountain NP	4.6	9.3	15.9	25.3
Scapegoat WA	6.5	11.6	19.1	32.0
Theodore Roosevelt NP	8.8	14.1	24.0	40.8
UL Bend WA	7.5	13.0	21.2	36.8
Washakie WA	4.8	10.3	16.2	27.9
Wind Cave NP	6.4	12.1	19.0	33.4
Yellowstone NP	5.9	12.1	18.1	33.5

Table 4-3 Modeled Visibility Values for Class I and Sensitive Class II Areas – Base Year 2008

Assessment Area	20th Percentile Best Visibility (dv)	20th Percentile Worst Visibility (dv)	20th Percentile Best Visibility (Mm^{-1})	20th Percentile Worst Visibility (Mm^{-1})
Class II Areas				
Absaroka-Beartooth WA, Gallatin NF[1]	7.8	13.6	21.9	38.9
Absaroka-Beartooth WA, Custer NF[1]	8.0	13.8	22.2	39.6
Agate Fossil Beds NM	6.6	12.1	19.4	33.4
Bighorn Canyon National Recreation Area	6.4	11.6	19.0	31.7
Black Elk WA	6.4	11.9	19.0	33.0
Cloud Peak WA	4.7	10.0	16.0	27.1
Crow IR	4.4	9.6	15.5	26.1
Devils Tower NM	8.7	15.2	23.9	45.6
Dinosaur NM	6.2	11.8	18.6	32.6
Fort Belknap IR	6.7	12.3	19.5	34.2
Fort Laramie National Historic Site	9.6	16.3	26.1	50.9
High Uintas WA, Ashley NF[1]	9.1	15.8	24.9	48.5
High Uintas WA, Wasatch NF[1]	4.2	8.6	15.2	23.7
Jewel Cave NM	5.2	11.2	16.7	30.6
Jedediah Smith WA	6.3	12.1	18.8	33.6
Lee Metcalf WA, Taylor-Hilgard Unit[1]	4.7	9.1	15.9	24.7
Lee Metcalf WA, Monument Mountains Unit[1]	6.4	13.6	18.9	38.9
Lee Metcalf WA, Spanish Peaks Unit[1]	4.6	9.3	15.9	25.3
Mount Naomi WA	6.5	11.6	19.1	32.0
Mount Rushmore National Memorial	8.8	14.1	24.0	40.8
Popo Agie WA	8.8	14.1	24.1	41.1
Sarvis Creek WA	7.5	13.0	21.2	36.8
Soldier Creek WA	4.8	10.3	16.2	27.9
Teton WA	6.4	12.1	19.0	33.4
Wellsville Mountain WA	5.9	12.1	18.1	33.5
Wind River IR	5.1	10.9	16.7	29.7

[1] Some sites have been further broken out to show impacts at spatially discrete locations.

Based on the modeled base year 2008 data presented in **Table 4-3,** the assessment areas with the lowest light extinction (indicative of the best visibility) include the Class I Mount Zirkel WA and the Class II High Uintas WA (Wasatch NF portion), with extinction values of 15.2 Mm^{-1} (4.2 dv). The assessment areas with the highest light extinction, and therefore greater visibility impairment, include the Class I Lostwood WA and the Class II Fort Laramie National Historic Site, with extinction values of 50.9 Mm^{-1} (16.3 dv). Within the PRB study area, the worst 20th percentile visibility values range from

26.1 Mm^{-1} (9.6 dv) at the Class II Crow IR to 33.6 Mm^{-1} (12.1 dv) at the Class I Northern Cheyenne IR. For assessment areas located downwind from the PRB study area (generally east of the study area) and with the potential to have increased visibility impairment, the largest light extinction is observed at Mount Rushmore National Memorial and Theodore Roosevelt NP, with an extinction value of 40.8 Mm^{-1} (14.1 dv).

4.4 Cumulative Impacts on Atmospheric Deposition

Nitrogen and sulfur deposition resulting from emissions of NO_x and SO_2 can lead to increasing acidification of sensitive soils and lakes. Deposition of nitrogen and sulfur compounds was evaluated according to the Federal Land Managers Air Quality Guide (FLAG [2010]).

4.4.1 Deposition

Results of the total annual deposition modeling are provided in **Table 4-4** for the indicated Class I and Class II areas and sensitive lakes. Of the Class I areas, the highest modeled impact occurs at the North Absaroka WA, with nitrogen deposition reaching 9.89 kg N/ha/yr. Of the Class II areas, the largest impact occurs at the Mount Naomi WA, with nitrogen deposition of 9.90 kg N/ha/yr. The sensitive lake with the highest modeled nitrogen deposition (5.07 kg N/ha/yr) is Hobbs Lake in the Bridger WA. Of the Class I and sensitive Class II areas within or in close proximity to the PRB study area, the Cloud Peak WA located in Wyoming on the western side of the PRB study area shows the highest impacts, with nitrogen deposition of 3.30 kg N/ha/yr and sulfur deposition of 1.06 kg S/ha/yr.

In general, modeled nitrogen deposition is dominated by dry deposition, with less than one-third of total nitrogen deposition attributable to wet deposition. While the percent contribution of individual chemical species varies by assessment area, approximately 40 to 50 percent of dry deposition is from ammonia, 30 to 40 percent is from HNO_3, 5 to 10 percent is from NH_4, 5 to 10 percent is from NO_x, and trace amounts are contributed by other nitrogen species. For wet deposition, approximately 50 to 60 percent is from ammonium, 20 to 25 percent is from HNO_3, 5 to 10 percent is from particulate NO_3, and 5 to 10 percent is from NH_3. Modeled sulfur deposition is dominated by wet deposition; approximately 20 to 40 percent of total sulfur deposition is attributable to dry deposition. Particulate SO_4 is the dominant species contributing to wet sulfur deposition, while particulate SO_4 and SO_2 contribute almost equally to dry sulfur deposition.

Table 4-4 Modeled Base Year 2008 Deposition for Nitrogen and Sulfur

Assessment Area	Total Annual Deposition	
	Nitrogen (kg N/ha/yr)	Sulfur (kg S/ha/yr)
Class I Areas		
Badlands NP	2.98	0.60
Badlands WA	3.47	0.68
Bob Marshall WA, Flathead NF[1]	2.20	1.08
Bob Marshall WA, Lolo NF[1]	1.90	0.67
Bob Marshall WA, Lewis and Clark NF[1]	1.93	0.65
Bridger WA	4.67	1.29
Fitzpatrick WA	4.59	1.46
Fort Peck IR	1.64	0.32
Gates of the Mountains WA	1.61	0.36
Grand Teton NP	3.04	0.89

Table 4-4 Modeled Base Year 2008 Deposition for Nitrogen and Sulfur

Assessment Area	Total Annual Deposition	
	Nitrogen (kg N/ha/yr)	Sulfur (kg S/ha/yr)
Lostwood WA	1.99	0.44
Medicine Lake WA	1.63	0.30
Mount Zirkel WA	2.51	0.88
North Absaroka WA	9.89	1.11
Northern Cheyenne IR	2.16	0.55
Rawah WA	2.07	0.71
Red Rock Lakes WA	4.79	0.55
Rocky Mountain NP	2.30	0.78
Scapegoat WA	2.13	0.83
Theodore Roosevelt NP	2.72	0.59
UL Bend WA	1.43	0.23
Washakie WA	2.67	0.81
Wind Cave NP	3.00	0.62
Yellowstone NP	3.28	0.87
Class II Areas		
Absaroka-Beartooth WA, Gallatin NF[1]	2.67	0.80
Absaroka-Beartooth WA, Custer NF[1]	4.76	0.95
Agate Fossil Beds NM	2.40	0.45
Bighorn Canyon National Recreation Area	2.53	0.55
Black Elk WA	3.30	0.78
Cloud Peak WA	3.30	1.06
Crow IR	2.69	0.67
Devils Tower NM	1.86	0.50
Dinosaur NM	1.48	0.25
Fort Belknap IR	1.40	0.32
Fort Laramie National Historic Site	2.10	0.32
High Uintas WA, Ashley NF[1]	2.61	0.98
High Uintas WA, Wasatch NF[1]	2.60	0.97
Jewel Cave NM	2.32	0.44
Jedediah Smith WA	4.06	1.23
Lee Metcalf WA, Taylor-Hilgard Unit[1]	3.15	0.90
Lee Metcalf WA, Monument Mountains Unit[1]	3.56	0.97
Lee Metcalf WA, Spanish Peaks Unit[1]	2.78	0.95
Mount Naomi WA	9.90	0.86
Mount Rushmore National Memorial	3.57	0.94
Popo Agie WA	3.56	1.49

Table 4-4 Modeled Base Year 2008 Deposition for Nitrogen and Sulfur

Assessment Area	Total Annual Deposition	
	Nitrogen (kg N/ha/yr)	Sulfur (kg S/ha/yr)
Sarvis Creek WA	1.70	0.62
Soldier Creek WA	2.80	0.53
Teton WA	3.01	1.01
Wellsville Mountain WA	5.89	0.41
Wind River IR	2.14	0.46
Sensitive Lakes		
Black Joe Lake, Bridger WA	3.53	1.79
Deep Lake, Bridger WA	3.79	1.97
Hobbs Lake, Bridger WA	5.07	1.60
Ross Lake, Fitzpatrick WA	3.33	1.41
Upper Frozen Lake, Bridger WA	4.30	1.97
Emerald Lake, Cloud Peak WA	3.33	1.17
Florence Lake, Cloud Peak WA	3.84	1.56
Lower Saddlebag Lake, Popo Agie WA	3.40	1.59

[1] Some sites have been further broken out to show impacts at spatially discrete locations.

4.4.2 Cumulative Impacts on Sensitive Lake Acid Neutralizing Capacity

The analysis of impacts of atmospheric deposition was conducted in accordance with the screening methodology provided by the USFS (2000). Lake data for the background 10 percent ANC values for the evaluated lakes were obtained from the USFS (2011). The USFS (2000) methodology is intended to account for sensitive conditions that may occur on an episodic or seasonal basis. It is important to note that the background ANC presented in **Table 4-5** is based on measurements conducted in 2009. Input data included the CAMx-modeled deposition rates for nitrogen and sulfur compounds, the 10 percent ANC values, the watershed areas, and the annual precipitation data, which was generated from the annual depiction of precipitation for the State of Wyoming as prepared by the Spatial Climate Analysis Service at Oregon State University (2005).

The input data and calculated change in percent ANC based on nitrogen and sulfur deposition are provided in **Table 4-5** for each of the lakes analyzed. The ANC percent change calculated for each lake is based on the background ANC, with the additional base year (2008) nitrogen and sulfur deposition predicted by the CAMx model. Since the 2009 measured background ANC values shown in **Table 4-5** include deposition that actually occurred in 2008, the calculation of the ANC percent change presented in **Table 4-5** is provided as a historic basis to assist in analyzing projected future year changes, such as those presented in the Task 3A Report. Based on the analysis, if the modeled base year (2008) deposition rates continue to occur in the future, the changes in ANC would range from 41.5 percent (Emerald Lake, Cloud Peak WA) to over 300 percent (Upper Frozen Lake, Bridger WA). It should be noted that most of these lakes occur in an area of the 4-km model domain that was indicated to overestimate wet nitrogen and sulfur deposition as discussed in the Air Quality MPE (AECOM 2013a). This in turn could lead to overestimation of changes in ANC.

Table 4-5 Modeled Base Year 2008 Impacts on ANC of Sensitive Lakes

Lake	Number of Samples	Watershed Area (hectare)	Annual Precipitation (meter)	2009 Background ANC (µeq/L)	Nitrogen Deposition		Sulfur Deposition		ANC Change[1,2] (percent)
					(kg N/ha/yr)	(eq/m^2/yr)	(kg S/ha/yr)	(eq/m^2/yr)	
Black Joe Lake, Bridger WA	72	890	1.47	70.6	**3.53**	0.0252	1.79	0.0112	**52.3**
Deep Lake, Bridger WA	62	205	1.69	61.1	**3.79**	0.0271	1.97	0.0123	**56.9**
Hobbs Lake, Bridger WA	76	293	1.44	69.8	**5.07**	0.0362	1.60	0.0100	**68.6**
Ross Lake, Fitzpatrick WA	57	4,450	1.32	54.0	**4.30**	0.0307	1.97	0.0123	**68.4**
Upper Frozen Lake, Bridger WA	3	64.8	1.60	13.2	**3.33**	0.0238	1.17	0.0073	**304.7 (40.2 µeq/L)**
Emerald Lake, Cloud Peak WA	40	293	1.60	70.0	**3.84**	0.0275	1.56	0.0098	**41.5**
Florence Lake, Cloud Peak WA	42	417	1.77	34.4	**3.33**	0.0238	1.41	0.0088	**91.3**
Lower Saddlebag Lake, Popo Agie WA	58	155	1.44	55.6	**3.40**	0.0243	1.59	0.0099	**63.9**

Note: eq/m^2/yr = equivalence per square meter per year.

[1] For modeled nitrogen and sulfur deposition data, **bold** text indicates values that exceed the levels of concern (i.e., terrestrial nitrogen deposition of 1.5 kg N/ha/yr [Baron 2006] and terrestrial sulfur deposition of 5 kg S/ha/yr [Fox et al. 1989]). For ANC percent change, **bold** text indicates values that exceed the limit of acceptable change (i.e., 10 percent for lakes with a background ANC greater than 25 µeq/L and 1 µeq/L for lakes with a background ANC less than or equal to 25 µeq/L [Haddow et al. 1998]).

[2] ANC change (percent) is calculated according to the USDA Forest Service's *Screening Methodology for Calculating ANC Change to High Elevation Lakes* (USFS 2000).

5.0 References

Abt Associates Inc. 2009. Modeled Attainment Test Software User's Manual. Prepared for Office of Air Quality Planning and Standards, USEPA, Research Triangle Park, North Carolina. March 2009.

AECOM. 2013a. Powder River Basin Coal Review, Air Quality Model Performance Evaluation. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. July 2013.

_____. 2013b (in progress). Powder River Basin Coal Review, Air Quality Assessment Technical Support Document. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office.

_____. 2011a. Powder River Basin Coal Review, Meteorological Model Performance Evaluation. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. November 2011.

_____. 2011b. Task 2 Report for the Powder River Basin Coal Review – Past and Present and Reasonably Foreseeable Development Activities. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. December 2011.

_____. 2010. Powder River Basin Coal Review, Air Quality Assessment Protocol. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. September 2010.

_____. 2009a. Update of the Task 3A Report for the Powder River Basin Coal Review, Cumulative Air Quality Effects for 2020. Prepared for the Bureau of Land Management High Plains District Office, Wyoming State Office, and Miles City Field Office. December 2009.

_____. 2009b. Update of the Task 2 Report for the Powder River Basin Coal Review, Past and Present and Reasonably Foreseeable Future Development Activities. Prepared for the Bureau of Land Management High Plains District Office and Wyoming State Office. December 2009.

Baron, J. 2006. Hindcasting Nitrogen Deposition to Determine a Critical Load. Ecological Applications 16(2):433-439.

Bureau of Land Management (BLM). 2012. IHS data for study area. Email correspondence between M. Brogan, BLM High Plains District Office and C. Taylor, AECOM. February 7, 2012.

_____. 2010. Coal mine shapefiles provided by A. Meeks, BLM High Plains District Office, to D. Koontz, AECOM. June 22, 2010.

_____. 2003. Final Environmental Impact Statement and Plan Amendment for the Powder River Basin Oil and Gas Project. Wyoming State Office and Buffalo Field Office. January 2003.

_____. 1999. Wyodak Coalbed Methane Project Draft Environmental Impact Statement. Buffalo Field Office. May 1999.

_____. 1996. Coal Development Status Check Powder River Federal Coal Region Montana and Wyoming Data Tables. Data Compiled by: Wyoming Bureau of Land Management Buffalo Resource Area, Casper District, and State Offices, and Montana Bureau of Land Management Powder River Resource Area, Miles City District and State Offices.

Coats, C. J., Jr. 1995. High Performance Algorithms in the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System. MCNC Environmental Programs, Research Triangle Park, North Carolina.

ENSR. 2008. Update of the Task 3A Report for the Powder River Basin Coal Review, Cumulative Air Quality Effects for 2015. Prepared for the Bureau of Land Management Casper Field Office, Wyoming State Office, and Miles City Field Office. October 2008.

_____. 2006. Task 3A Report for the Powder River Basin Coal Review, Cumulative Air Quality Effects. Prepared for the Bureau of Land Management Casper Field Office, Wyoming State Office, and Miles City Field Office. February 2006 (with errata).

_____. 2005a. Task 1A Report for the Powder River Basin Coal Review, Current Air Quality Conditions. Prepared for the Bureau of Land Management Casper Field Office and Wyoming State Office. September 2005 (with errata).

_____. 2005b. Task 2 Report for the Powder River Basin Coal Review, Past, Present, and Reasonably Foreseeable Development. Prepared for the Bureau of Land Management Casper Field Office and Wyoming State Office. July 2005.

Federal Land Managers Air Quality Guide (FLAG). 2010. Federal Land Managers' Air Quality Relative Values Workgroup Phase I Report-Revised (2010). November 2010.

Foulke, T., R. Coupal, and D. Taylor. 2002. Economic Trends in Wyoming's Mineral Sector: Coal. University of Wyoming Cooperative Extension Service. January 2002.

Fox, D. G., A. M. Bartuska, J. G. Byrne, E. Cowling, R. Fisher, G. E. Likens, S. E. Lindberg, R. A. Linthurst, J. Messer, and D. S. Nichols. 1989. A Screening Procedure to Evaluate Air Pollution Effects on Class I Wilderness Areas. General Technical Report RM-168. USDA Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

Haddow, D., R. Musselman, T. Blett, and R. Fisher, Technical Coordinators. 1998. Guidelines for Evaluating Air Pollution Impacts on Wilderness within the Rocky Mountain Region: Report of a workshop, 1990. General Technical Report RMRS-GTR-4. Fort Collins, Colorado. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 31 pp.

Hand, J. L. and W. C. Malm. 2006. Review of the IMPROVE Equation for Estimating Ambient Light Extinction Coefficients. National Park Service. May 2006. ISSN 0737-5353-71.

Houyoux, M., R. and J. M. Vukovich. 1999. Updates to the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System and Integration with Models-3. Presented at The Emission Inventory: Regional Strategies for the Future, October 26-28, Raleigh, North Carolina, Air & Waste Management Association.

Montgomery Watson Harza. 2003. Coal Planning Estimates Report. Prepared for the Bureau of Land Management Wyoming State Office. March 2003.

National Atmospheric Deposition Program (NADP). 2013. National Trends Network (NTN) Data Reports. Internet website: http://nadp.sws.uiuc.edu/data/ntndata.aspx. Accessed June 12, 2013.

Simon, H., Baker, K., and Phillips, S. 2012. Compilation and Interpretation of Photochemical Model Performance Statistics Published between 2006 and 2012. Atmospheric Environment 61:124-139.

Spatial Climate Analysis Service at Oregon State University. 2005. Annual precipitation data. Internet website: http://www.ocs.orst.edu/pub/maps/Precipitation/Total/States/WY/wy.pdf. Accessed July 2005.

Sullivan, T., A. T. Herlihy, G. B. Lawrence, and J. R. Webb. 2012. Forest Service National Protocols for Sampling Air Pollution-Sensitive Waters. General Technical Report RMRS-GTR-278WWW. USDA Rocky Mountain Research Station. Fort Collins, Colorado.

Tesche, T. W., D. E. McNally, and C. Tremback. 2002. Operational Evaluation of the MM5 Meteorological Model over the Continental United States: Protocol for Annual and Episodic Evaluation. Prepared for P. Dolwick, USEPA Office of Air Quality Planning and Standards. July 2002.

U.S. Environmental Protection Agency (USEPA). 2013a. AirData Reports. Internet website: http://www.epa.gov/airdata. Accessed Jun 12, 2013.

_____. 2013b. Clear Air Status and Trends Network (CASTNET) Deposition Data. Internet website: http://java.epa.gov/castnet/clearsession.do. Accessed June 12, 2013.

_____. 2010. Personal communication between USEPA (Dolwick) and AECOM (Tonnesen) regarding the transmission and use of the USEPA 2008 WRF Meteorological Model Data. November, 12, 2010.

_____. 2007. Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze. U.S. Environmental Protection Agency, Office of Air Quality and Planning Standards, Research Triangle Park, North Carolina. EPA-454/B-07-002. April 2007.

_____. 1997. Visibility in our Nation's Parks and Wilderness Areas (Pollutants and Visibility Trends). Internet website: http://www.epa.gov/airquality/visibility/monitor.html. Accessed June 12, 2013.

U.S. Forest Service (USFS). 2011. Lake Water Chemistry Data provided by D. Miller (Forest Service) to C. Taylor (AECOM). January 14, 2011.

_____. 2000. Rocky Mountain Region. Screening Methodology for Calculating ANC Change to High Elevation Lakes. December 2000.

Western Regional Climate Center (WRCC). 2013. Climate Narrative of the States. Internet website: http://www.wrcc.dri.edu/CLIMATEDATA.html. Accessed June 12, 2013.

Wyoming Department of Environmental Quality (WDEQ). 2013. Annual Air Quality Reports. Internet web site: http://www.wyvisnet.com/reports.aspx. Accessed June 12, 2013.

Yarwood, G., S. Rao, M. Yocke, and G. Whitten. 2005. Updates to the Carbon Bond Chemical Mechanism: CB05. ENVIRON International Corporation, Novato, California. December 8, 2005.