Final

Regional Technical Support Document

for the

Requirements of §309 of the Regional Haze Rule

(64 Federal Register 35714 – July 1, 1999)

~~**December 15, 2003**~~
Revised May 7, 2008

May 7, 2008 revision – The Table of Contents for this December 15, 2003 document has been annotated to note the sections still applicable to §309 regional haze plans. The annotations direct the reader to the WRAP TSS for the most current data and analysis methods.

Several sections of this document are no longer current. There has been no editing of the body of this document.

WESTERN REGIONAL AIR PARTNERSHIP

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The technical evaluation work of the Western Regional Air Partnership (WRAP) Forums and Technical Oversight Committee (TOC) described in this document addresses the requirements of §309 of the federal Regional Haze Rule, and comprises a major step in completing the technical work begun by the Grand Canyon Visibility Transport Commission (GCVTC). The technical analyses performed and reviewed by staff from WRAP member organizations, interested stakeholders, and contractors are gratefully acknowledged. All of the contributing authors listed alphabetically above made important contributions to this document; doubtless there are other individuals not listed, also deserving particular recognition for their contributions to the §309 technical analysis process. The WRAP TOC thanks all individuals and organizations that have contributed their time and expertise to the preparation of this document.

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Preface: Regulatory Framework for Tribal Visibility Implementation Plans

The regional haze rule explicitly recognizes the authority of tribes to implement the provisions of the rule, in accordance with principles of federal Indian law, and as provided by the Clean Air Act §301(d) and the tribal authority rule (TAR) (40 CFR §§49.1– .11). Those provisions create the following framework:

1. Absent special circumstances, reservation lands are not subject to state jurisdiction.
2. Federally recognized tribes may apply for and receive delegation[1] of federal authority to implement Clean Air Act (CAA) programs, including visibility regulation, or "reasonably severable" elements of such programs (40 CFR §§49.3, 49.7). The mechanism for this delegation is a tribal implementation plan (TIP). A reasonably severable element is one that is not integrally related to program elements that are not included in the plan submittal, and is consistent with applicable statutory and regulatory requirements.
3. The regional haze rule expressly provides that tribal visibility programs are "not dependent on the strategies selected by the state or states in which the tribe is located" (64. Fed. Reg. 35756), and that the authority to implement §309 TIPs extends to all tribes within the GCVTC region (40 CFR §51.309(d)(12)).
4. The Environmental Protection Agency (EPA) has indicated that under the TAR tribes are not required to submit §309 TIPs by the end of 2003. Rather, they may choose to opt-in to §309 programs at a later date (67 Fed. Reg. 30439).
5. Where a tribe does not seek delegation through a TIP, EPA, as necessary and appropriate, will promulgate a federal implementation plan (FIP) within reasonable timeframes to protect air quality in Indian country (40 CFR §49.11). EPA is committed to consulting with tribes on a government-to-government basis in developing tribe-specific or generally applicable TIPs where necessary (See, e.g., 63 Fed. Reg. 7263-64).

The amount of modification, if any, needed for this report to fulfill tribal needs may vary considerably from tribe to tribe. The authors have striven to ensure that all references to tribes in the document are consistent with principles of tribal sovereignty and autonomy as reflected in the above framework. Any inconsistency with this framework is strictly inadvertent and not an attempt to impose requirements on tribes that are not present under existing law.

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[1] Tribes also possess a more fundamental source of authority to regulate their environments, based on their inherent authority as sovereign nations, which predates the formation of the United States. However, in the context of air pollution regulation and visibility planning in particular, tribal authority will more likely be based on delegation of federal authority.

Tribal Participation in the WRAP

Tribes, along with states and federal agencies, are full partners in the WRAP, having equal representation on the WRAP Board as states. Whether Board members or not, it must be remembered that all tribes are governments, as distinguished from the “stakeholders” (private interest) which participate on Forums and Committees but are not eligible for the Board.

Despite this equality of representation on the Board, tribes are very differently situated than states. There are over four hundred federally-recognized tribes in the WRAP region, including Alaska. The sheer number of tribes makes full participation impossible. Moreover, many tribes are faced with pressing environmental, economic, and social issues, and do not have the resources to participate in an effort such as the WRAP, however important its goals may be. These factors necessarily limit the level of tribal input into and endorsement of WRAP products.

The tribal participants in the WRAP, including Board members Forum and Committee members and co-chairs, make their best effort to ensure that WRAP products are in the best interest of the tribes, the environment, and the public. One interest is to ensure that WRAP policies, as implemented by states and tribes, will not constrain the future options of tribes who are not involved in the WRAP. With these considerations and limitations in mind, the tribal participants have joined the state, federal, and private stakeholder interests in approving this report as a consensus document.

Table of Contents

May 7, 2008 revision - the emissions inventory data and modeling data/methods for regional haze planning across the WRAP region were modified and improved during 2004 through 2006, to support preparation, review, and implementation of haze plans for all Class I areas in the WRAP region. The monitoring, emissions, and modeling data and technical methods for haze planning and implementation in the WRAP region are now provided though the WRAP TSS.

May 7, 2008 revision - base year emissions data were updated to 2002 and 2018 emissions projections were completely revised - these results are available through WRAP TSS. *Data presented in Section 1.1 of Chapter 1 are no longer current.*

May 7, 2008 revision - modeling was updated to a 2002 base year and 2018 emissions projections modeling analyses were completely revised - these results are available through WRAP TSS. *Data presented in Section 1.2 of Chapter 1 are no longer current.*

May 7, 2008 revision - The baseline year was updated to 2002, 2018 emissions projections were revised, and additional monitoring sites began providing data for the

2000-04 baseline period for regional haze planning. The methodology and current data showing projected visibility improvement in 2018 are available through WRAP TSS. ***Data presented in Chapter 2 are no longer current.***

May 7, 2008 revision - data for the baseline year was updated to 2002 and 2018 emissions projections were revised by WRAP, and specific revisions to the Regional Haze Rule addressing BART and Alternatives to BART were promulgated by EPA during 2005. The current emissions and modeling data and results for stationary sources in the WRAP region are available through WRAP TSS. The methodology and data for the revised SO$_2$ Milestone Program are available at: http://www.wrapair.org/forums/309/docs.html . ***Data presented in Sections 4.1 and 4.2 of Chapter 4 are no longer current.***

May 7, 2008 revision - data for the baseline year was updated to 2002 and 2018 emissions projections were revised by WRAP, and comprehensive national rules addressing mobile engines and fuels were promulgated by EPA since 2003. The current

emissions and modeling data and results for mobile sources in the WRAP region are available through WRAP TSS. *Data presented in Chapter 5 are no longer current.*

May 7, 2008 revision - data for the baseline year was updated to 2002, 2000-04 average fire emissions inventories were added to the analysis, and 2018 emissions projections were revised between 2004 and 2006 by WRAP. The current emissions and modeling data and results for fire sources in the WRAP region are available through WRAP TSS. *Data presented in Section 6.1 of Chapter 6 are no longer current.*

May 7, 2008 revision - The WRAP Fire Emissions Tracking System (FETS) was implemented in 2007 to address the ongoing fire tracking requirement for §309 regional haze plans. *Section 6.2 of Chapter 6 is no longer current.*

May 7, 2008 revision - data for the baseline year was updated to 2002 and 2018 emissions projections were revised between 2004 and 2006 by WRAP. The current emissions data for road dust sources in the WRAP region are available through WRAP TSS. *Data presented in Section 7.1 of Chapter 7 are no longer current.*

May 7, 2008 revision - the baseline year was updated to 2002 and 2018 emissions projections revised between 2004 and 2006 by WRAP. The methods for incorporating federal and state emissions control programs are detailed in a series of reports specific to point, area, mobile, fire, and dust sources. The references for these reports are available through WRAP TSS. *Appendix A is no longer current.*

May 7, 2008 revision - with the baseline year updated to 2002 and 2018 emissions projections revised between 2004 and 2006 by WRAP, the emissions data presented in Appendices C through K have been replaced with the emissions and modeling scenarios available through WRAP TSS. *Appendices C through K are no longer current.*

Technical Support Document Executive Summary

The purpose of this Technical Support Document (TSD) is to summarize and synthesize key information resulting from the regional technical analyses of regional programs developed (or under development) for states and tribes to use in preparing State Implementation Plans (SIPs) and Tribal Implementation Plans (TIPs) under §309 of the federal Regional Haze Rule (RHR). Underlying the key information presented in the chapters of the TSD are the contractor reports prepared for WRAP Forums and WRAP technical memoranda; complete versions (as web links) of these documents will be included in Appendix D of the TSD. The data files underlying these documents will also be available electronically on the WRAP website www.wrapair.org, or by request. The intent of WRAP is to have a web-based TSD, with CD-ROMs available to states and tribes as requested.

The technical analyses conducted by WRAP were designed to address §309 requirements for control strategy evaluations and related administrative programs. This TSD strives to maintain a regional focus and a consistent terminology, addressing the analysis of visibility impacts at the 16 Class I Areas on the Colorado Plateau, as well as at the additional Class I Areas in the 9-state Grand Canyon Visibility Transport Commission (GCVTC) transport region. This TSD will describe the history of the technical analysis process used by the GCVTC, with a detailed overview of the technical analysis approach used by the WRAP Forums, and succinct individual chapters summarizing and describing the various technical analyses needed to support development of SIPs and TIPs for §309. The chapters are listed next:

Executive Summary
GCVTC Technical Analysis History
1. WRAP Technical Analysis Approach
2. Projection of Improvement
3. Clean Air Corridors
4. Stationary Sources
5. Mobile Sources
6. Fire Programs
7. Road Dust
8. Pollution Prevention

The following appendices summarize technical and regulatory information:

A. State and local control programs included in WRAP emissions inventories
B. Use of EPA guidance and best practices
C. 1996 base case emissions used in air quality modeling
D. 2018 base case emissions used in air quality modeling
E. 2018 Scenario 1 emissions used in air quality modeling
F. 2018 Scenario 2 emissions used in air quality modeling
G. 2018 BART with Uncertainty Scenario emissions used in air quality modeling
H. 2018 SO_2 Annex Milestones Scenario emissions used in air quality modeling

I. 2018 Stationary Source 50% NO_x Reduction Scenario emissions used in air quality modeling
J. 2018 Stationary Source 50% PM_{10} Reduction Scenario emissions used in air quality modeling
K. 2018 Stationary Source Simultaneous 25% NO_x and 25% PM_{10} Increase Scenario emissions used in air quality modeling
L. Clean Air Corridor Change in Emissions 1996 to 2018 (County-level by pollutant)
M. References

Grand Canyon Visibility Transport Commission Technical Analysis History

The federal Clean Air Act (CAA) Amendments of 1990 required the creation of the Grand Canyon Visibility Transport Commission (GCVTC). Once chartered in 1991, the GCVTC was composed of the governors of eight western states (Arizona, Utah, California, New Mexico, Colorado, Nevada, Oregon, and Wyoming), four tribes (Acoma, Hopi, Hualapai, Navajo) four federal land managers (Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Forest Service, and the National Park Service), the Columbia River Inter-Tribal Fish Commission, and the Environmental Protection Agency (EPA). The GCVTC was charged with advising EPA as to strategies for protecting visual air quality in the 16 mandatory federal Class I areas on the Colorado Plateau. In particular, the GCVTC was to address clean air corridors, the effect of new or modified stationary sources, and the development of long-range strategies.

The technical analyses for the GCVTC were based on two primary technical tools. The VARED air quality model, a grid-based air quality model with simplified chemistry, provided estimates of visibility impairment for four Class I areas on the Colorado Plateau. This information was then used to derive transfer coefficients. Transfer coefficients quantify the relative transport relationship between a source and a receptor. They represent the composite effect of winds, chemical changes in the atmosphere, deposition, and other factors on emissions. The transfer coefficients were then integrated into a comprehensive control strategy analysis tool called the Integrated Assessment System (IAS). The IAS also includes a base year emission inventory of all visibility impairing pollutants. The base year is 1990, and the pollutants are sulfur dioxide, oxides of nitrogen, organic compounds, speciated fine particulate, and coarse particulate. Also included in the IAS are emissions growth and control factors that allow one to forecast future emissions out to the 2040 projection year, and in combination with transfer coefficients, predict visibility conditions. Cost information for controls is also included. In summary, the purpose of the IAS is to assess the effect of future control strategies on visibility and the cost of those controls.

The GCVTC identified several scenarios that were to be analyzed to assist in the evaluation of a range of control options. These included five scenarios:

1. Baseline Forecast Scenario;
2. Regional Emissions Cap;
3. Maximum Management Alternative;
4. Visibility Standard for the Colorado Plateau; and
5. Standardized Control Technology and Process Requirements.

The Baseline Forecast Scenario was intended to represent the effect of current laws, and based on several assumptions:

1. Emissions growth or decline was based on economic demand in the region;
2. Sources retire at a specific age on average;

3. New sources were a mixture of new technology and assumed control levels; State Implementation Plans (SIPs) under the CAA were accounted for through 2010 after which emissions growth is allowed based on economic demand;
4. There was no growth in paved road dust; and
5. Emissions from Mexico were held constant.

The range of visibility improvements associated with the emissions cap, the maximum management alternative, the visibility standard, and technology solution was estimated and compared to the Baseline Forecast Scenario.

In assessing these scenarios, the GCVTC advanced visibility science and improved understanding of visibility impairment significantly during its five-year existence. However, much remained to be done, in particular with respect to visibility modeling. The size and complex terrain characteristic of the transport region, along with time and resource constraints resulted in outputs that were sometimes limited in their applicability. Of particular concern were situations where a source and Class I area were near each other.

The GCVTC still had enough confidence in the insights provided by the work to make a number of recommendations for improving visibility and visibility science. The GCVTC recommended control strategies for selected stationary, mobile, and area sources. In addition, approaches were proposed with respect to air pollution prevention, clean air corridors, near-field emissions, emissions transport from Mexico, and visibility issues in Indian Country.

The stationary source recommendations call for the establishment of a series of emissions targets for sulfur dioxide that will be compared to actual emissions. If those targets were exceeded, then a backstop cap and trade program would be triggered. Hence, the technical need would be for an emissions tracking system, as well as estimating the visibility improvement associated with the emissions reductions.

The mobile source recommendations recommend support for national engine and fuel standards, as well as assessment of several potential regional and local approaches. One of the key local strategies calls for the assessment of the contribution of mobile sources in major urban areas on visibility on the Colorado Plateau, and the development of emissions budgets if deemed significant. A technical demonstration of this significance test would be needed.

As for area sources, two categories were targeted, road dust and fire. During the course of the GCVTC technical analyses, substantial uncertainty arose as to the accuracy of the road dust emissions, as well as how the air quality model transported those emissions. So, even though the analyses demonstrated that road dust was a significant contributor to visibility impairment on the Colorado Plateau, the GCVTC recommended further study before controls were undertaken. Therefore, the technical need would be to improve the science with respect to characterizing road dust, and then reevaluate its significance. With respect to fire, the GCVTC recommended the development of enhanced smoke management programs along with the establishment of a tracking system and the setting of emissions goals. Therefore, the tracking system and assessment of the effect of the goals on visibility are the technical products that would result.

The air pollution prevention recommendations call for additional utilization of renewable energy, energy efficiency, and pollution prevention, and to model the effect of reduced or avoided emissions associated with those programs. The GCVTC also suggested the exploration of specific approaches like incentives and environmental labeling. The technical product would be the modeling of the composite benefit and cost of the strategies undertaken.

As previously discussed, the evaluation of clean air corridors is specifically required by the CAA Amendments of 1990. The GCVTC assessed the existence of Clean Air Corridors, identified one to the northwest of the Colorado Plateau, and determined that establishing emissions control programs in the area was not needed at that time. The GCVTC did recommend that emissions and their effect on visibility be tracked, and that triggers be established. This is to ensure that clean visibility days stay that way. The technical need would again be for a tracking system.

The recommendations for emissions in and near Class I areas call for improved planning both within Class I areas and in adjacent communities. The recommendations with regard to Mexican emissions call for bi-national mechanisms like local initiatives and financial incentives, as well as the development of a comprehensive inventory. The technical need would then be to document the development of emissions estimates for Mexico. The tribal recommendations call for additional ambient monitoring and improved estimates of emissions.

There are also a number of recommendations related to improving future visibility assessment work related to emission inventories, ambient monitoring, air quality modeling, and assessment tools. With regard to emission inventories, these include:

1. Development of a regional inventory, with regular updates;
2. Standardization of data collection; and
3. The need for micro-inventories.

As for visibility monitoring, the continuation and expansion of the network is called for. With respect to modeling, both an improved regional model and development of a "reduced form model" are identified as critical needs. Better meteorology data is also suggested.

An additional recommendation of the GCVTC was the creation of a successor organization to implement its recommendations. Therefore, the Western Regional Air Partnership was created in 1997.

Chapter 1 – WRAP Technical Analysis Approach

This chapter describes the technical analysis approach used by the WRAP. These technical analyses were selected to satisfy the requirements of §309, and focus on the implementation requirements of control strategies recommended to EPA by the GCVTC. EPA had adopted the 1996 GCVTC recommendations in §309 of the Regional Haze Rule, and as such, the technical methodologies and analyses described in this TSD may differ from more traditional approaches, generally used by states to prepare a TSD. The purpose of WRAP technical work described in this TSD is to analyze and document the visibility benefits of GCVTC-recommended control strategies, and to present emissions inventory data for use in planning future emissions management programs, as required by §309. Summarized in the next two sections are the emissions estimates and modeling simulations performed by the WRAP.

1.1. Overview of Analytical Approach – Emissions

In order to develop technical information needed by states and tribes to prepare implementation plans, the WRAP needed to prepare base year and projection year emissions inventories. Calendar year 1996 was selected as the base year for two important reasons. EPA had prepared 1996 meteorological simulations, called MM5 data, which WRAP could use for modeling. The periodic national emissions inventory, called NEI, was available for 1996, following the every-third-year cycle of the NEI. WRAP used NEI data as the basis of some of the base year inventory, refining it as necessary. WRAP also built new emissions inventory sections as needed, particularly for fire emissions. Calendar year 2018 was selected as the projection year for emissions because EPA had identified it as the end of the planning period for §309. WRAP also prepared intermediate year inventories, particularly for point and mobile emissions sources.

WRAP needed to perform several critical emissions-related tasks to analyze §309 control strategies, and provide emissions estimates for future emissions management programs.

1. Prepare base case emissions inventories for both 1996 and 2018, to characterize, as fully and completely as possible, the change in emissions expected to occur without implementation of GCVTC-recommended control strategies.
2. Compare the visibility improvement of a declining SO_2 emissions cap program for major stationary sources, combined with a backstop SO_2 emissions trading program, against a more traditional “command and control” scenario of Best Available Retrofit Technology (BART) on the same group of major stationary SO_2 emissions sources, in 2018. The SO_2 emissions from the resulting from application of BART were characterized in two different scenarios, discussed later in this TSD.
3. Prepare emissions estimates for mobile sources and road dust emissions, to allow assessment of the significance of those emissions at the 16 mandatory federal Class I areas on the Colorado Plateau.
4. Analyze and estimate the emissions changes resulting from implementation of pollution prevention programs in the 9-state GCVTC transport region.

5. Characterize fire emissions for development of enhanced smoke management programs and annual emissions goals, across the WRAP region.
6. Following the preparation of the §309 implementation plans, provide an emissions tracking system, in support of stationary and fire emissions management programs.

1.1.1. 1996 Base Year and 2018 Projection Year Emission Inventories

The availability of point, area, mobile, and biogenic emissions inventory data from 1996 was the primary reason for its choice as the base year for §309 modeling and other technical analyses. The choice of 1996 emissions as the base year is complemented by the availability of 1996 MM5 meteorological data used in air quality modeling, described later in this chapter. 2018 was chosen as the projection year for emissions data for air quality modeling and other technical analyses, as required in §309.

Emission Inventory Sectors

Emission inventories traditionally consider 4 sectors, those being:

- Stationary Point Sources
- Area Sources
- Mobile Sources
- Biogenic Sources

Within the WRAP region, fire has been determined to be a unique, hard to quantify, and potentially a very significant emission source. Therefore, within the WRAP emission inventories, fire has been treated as its own separate emission sector.

Forums involved in producing the WRAP emission inventories include:

- The Emission Forum (EF), which produced the Stationary Point Sources', and Area Sources' inventories;
- The Mobile Sources Forum (MSF), which produced the On-Road (tailpipe, evaporative, tire, and brake wear emissions), the Non-Road (tailpipe and evaporative emissions only), and the Paved & Unpaved Road Dust (PM only) inventories;
- The Fire Emissions Joint Forum (FEJF), which produced Wildfire, Prescribed Wildland, and Agricultural (Ag) Fire inventories.

The Biogenics inventory represents natural emissions coming from vegetation, and was produced by the WRAP Regional Modeling Center (RMC), under the oversight of the Modeling Forum (MF). Emission values were calculated by the Sparse Matrix Operator Kernel Emissions (SMOKE) emissions preprocessor model, using the Biogenic Emissions Inventory System (BEIS2) module. There are no inventory values directly available for biogenic emissions; therefore these emissions were approximated as follows:

- SMOKE calculates a tons/day value for biogenic emissions from each state

- The RMC ran one day per month to obtain 12 representative values for each state
- The resultant average daily totals were summed for each month, for each state
- The resultant 12 monthly totals were summed to approximate biogenic emissions for the year

Pollutants Inventoried

The WRAP inventoried seven visibility-related pollutants for all emission sectors, except Biogenics. The seven pollutants in the WRAP emission inventory include:

- Volatile Organic Compounds (VOCs);
- Nitrogen Oxides (NO_x);
- Carbon Monoxide (CO);
- Sulfur Dioxide (SO_2);
- Particulate under 10 microns (PM_{10});
- Particulate under 2.5 microns ($PM_{2.5}$); and
- Ammonia (NH_3).

The only two pollutants emitted by surface vegetation are VOCs and NO_x; therefore the WRAP inventories contain only those two pollutants from the Biogenics sector. BEIS2 reports pollutants in the form of nitrogen oxide (NO), aldehydes (ALD2), isoprene (ISOP), non-reactive volatile compounds (NR), olefins (OLE), paraffins (PAR) and terpenes (TERPB). The VOC values were taken from the sum of ALD2, ISOP, OLE and PAR. It was determined that TERPB was already accounted for in the paraffins, and would cause double counting to add it in separately. The total mass of NO was added directly into the inventory as NO_x.

Emission Inventory Geographic Domain

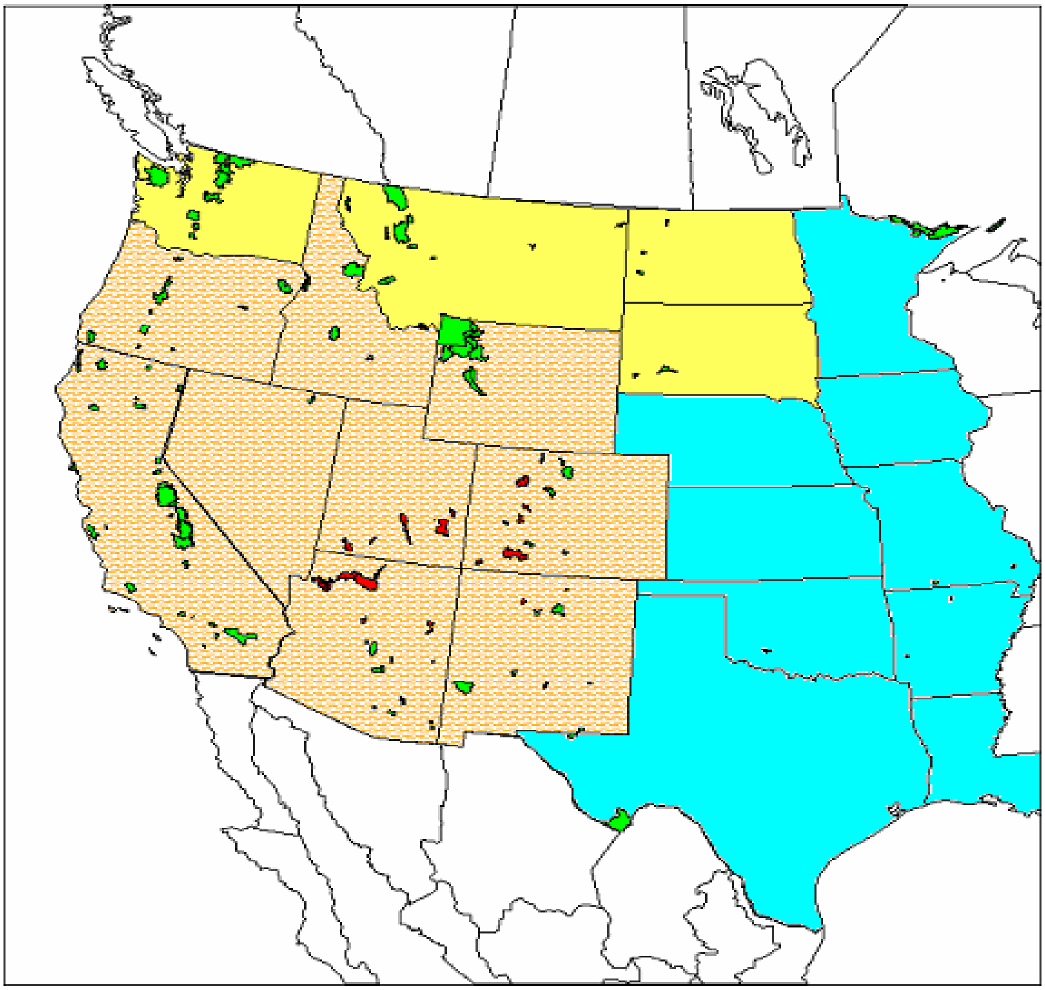
The WRAP Emission Inventory was compiled for two separate years; those being 1996, the Base Year and 2018, the Projection Year (represents the end of the first "Planning Period" under the Regional Haze Rule). Comparisons must be made between 1996 and 2018 to project the improvement in visibility resulting from implementing the requirements of §309, and to make a demonstration that the SO_2 Market Trading Program is "Better than BART".

The geographic domain for the WRAP Emission Inventories includes:

- 13 WRAP States (AZ, CA, CO, ID, MT, ND, NM, NV, OR, SD, UT, WA, and WY) {excludes Alaska, which was not in the §309 modeling domain}
- 9 CENRAP States (NB, KA, OK, TX, MN, IA, MO, AK, and LA)

Figure 1, below shows the states inventoried. The nine states in brown were part of the Grand Canyon Visibility Transport Commission, and are eligible for §309. The four additional states shown in yellow are also WRAP members. These 13 states are listed above. The four states shown in blue, in a tier south of North and South Dakota (Nebraska, Kansas, Oklahoma, and Texas) are referred to in some WRAP emissions inventories and visibility modeling work as “Tier 1” states. The remaining states in blue east of Tier 1, are referred to in some WRAP emissions inventories as “Tier 2” states.

Figure 1.1.1. Area of the contiguous WRAP and CENRAP regions’ states covered in emission inventories prepared for §309, as well as the Class I areas.



International Emissions

The WRAP also attempted to compile international emission inventories for the two countries bordering the WRAP region, Canada and Mexico.

Regarding Canada, an incomplete emission inventory provided by the emissions modeling contractor (MCNC) was used. That inventory contained 1995 data for area sources, and on-road and non-road mobile sources only. There were no point source data included. In "growing" this Canadian inventory to 2018, the effort was only partially completed for those sources with Source Classification Codes (SCCs) available in the Economic Growth Analysis System (EGAS) model. Also, no new emission controls were applied in this projection.

The EPA is working with Canada to improve the inventory, and future information will include some point source data. However, because of confidentiality provisions of Canadian laws, this point source data will be presented as gridded values, showing emission totals from a four-kilometer grid square. This data will be chemically speciated and temporally allocated, but because of the reporting format there will be no individual facility locations or stack parameters.

A crude emissions inventory was produced by a contractor (ERG) for states in northwestern Mexico. These included Baja California Norte, Sonora and Chihuahua. The Mexico point source information was incomplete, with data available for all seven visibility-related pollutants, only from three large sources previously considered by the GCVTC. Those included two copper smelters; Nacozari and Cananea. Cananea operated in 1996, but was shut down in 1999; consequently there were no emissions for the 2018 projection year for this smelter. The third large source that was included was the two units (I & II) of the Carbon coal fired power plant, located over the Chihuahua boarder in neighboring Coahuila. Point source data was available for only 15 other individual Mexico plants and factories, and the data were only for SO_2 emissions.

Regarding the area source data, there were urban area emissions for three border towns; Ciudad Juarez, Mexicali, and Tijuana. This data was spatially allocated throughout the three Mexican States, using population as the surrogate. Unfortunately that means that the data assumes an "urban profile", which skews the results. For example, the inventory data probably contains more automobile emissions than in reality because there are more cars in the towns than in rural area; while agricultural dust is underreported, because urban inventories have less unpaved surface than in rural areas. Because this Mexico inventory has so much uncertainty, it was decided that it would be impractical to attempt to "grow" the data to the 2018 projection year. Consequently the 2018 values were "flat-lined", and represent the same emission totals as reported for 1996.

1996 Emission Inventory Results

For the 1996 inventory summaries shown at the end of this section, it should be noted that the area source category contains no "Wind Erosion Fugitive Dust". The EF determined that data for this wind-blown dust component was so unreliable that it would be detrimental to the modeling effort to try to include it. The Forum will develop a fugitive dust module to fill this hole in future WRAP inventories.

Regarding the fire sector, the FEJF was able to collect information on wildfire (> 100 acres in size), and prepare a partial wildland prescribed fire inventory. The FEJF collected agricultural burning activity data for 1996, however the temporal and spatial resolution of the information was not adequate for calculating emissions to be used in regional air quality modeling.

Only the EF attempted to compile data directly from the nine Central Regional Air Planning Association (CENRAP) states, in addition to the 13 WRAP states. The MSF and FEJF completed their work solely for the 13 WRAP states. However, all CENRAP data was based on the EPA's National Emission Trends (NET) Emission Inventory for 1996, regardless of whether compiled by the forums (for point and area sources), or not (mobile and fire sources). Regarding paved/unpaved road dust emissions, the MSF compiled this information separately for the 13 WRAP states, while the paved/unpaved road dust data for the nine CENRAP states was already included in their NET area source files.

2018 Emission Inventory Results

For the area, mobile and road dust emission sectors, only one 2018 emission projection was made. However, a variety of different scenarios were developed for the stationary point source sector, and for the fire emissions sector.

Because biogenic emissions are affected solely by the annual meteorology (primarily temperature), and because the WRAP has no way of predicting future year meteorology, the 2018 biogenic emission inventory was the same as used for 1996 when actual meteorological conditions are known.

Regarding the stationary point source sector, there were five different simulations projected for 2018, two of which are described in this document. These different point source scenarios affected nine WRAP region states only, leaving the point source projections in the remaining four WRAP states (WA, MT, ND, and SD), and CENRAP constant in all five alternatives. The alternative 2018 scenarios only affected SO_2 emission totals in those nine states, except for Pollution Prevention (P2), that also affected NO_x. The five scenarios were compiled to address the Backstop SO_2 Market Trading Program, and the Renewable Energy and Energy Efficiency (RE/EE) mandates of the RHR. These five scenarios include:

- 2018 Base Case (642,000 tons per year (tpy) of SO_2)
- Annex Milestones Case (510,000 tpy of SO_2)
- Command & Control BART Implementation Case (486,000 tpy of SO_2)
- Command & Control BART Implementation w/ Uncertainty Case (550,000 tpy of SO_2)
- Pollution Prevention Case (510,000 tpy of SO2)

The SO_2 emission totals did not change between the Annex and the P2 case because the Market Trading milestones put an absolute cap on sulfur emissions, and any savings due to RE/EE implementation simply allows that tonnage to remain uncontrolled under the Point Source limit. Because NO_x is not subject to this cap and trade program, any energy saving due to RE/EE implementation reduces the demand for fossil fuel-fired electricity, and the associated NO_x emissions go down. The table below highlights the state-by-state differences in EGU emissions when the Annex case is compared with the P2 case. Negative emission values indicate where P2 case emissions are lower than Annex case emissions.

State/Pollutant	NO_X	SO_2
Arizona	-3,267	5,558
Colorado	-1,370	-1,119
Nevada	- 430	- 307
New Mexico	-7,053	-5,135
Utah	- 780	-595
Wyoming	-1,374	1,598
Regional change	-14,274	0

Regarding the fire emissions sector, it was determined that actual 1996 wildfire activity was abnormally high, compared with the historical trend. Therefore for 2018, the FEJF determined what an average wildfire year would look like and used that "typical wildfire" scenario as their 2018 projection.

While wildfire is largely uncontrollable, the FEJF determined that there are measures that can be taken to reduce emissions from Prescribed Wildland and Ag burning. Thus for both of these fire categories, they developed two different scenarios for 2018. These are referred to as the Base Smoke Management (BSM) and the Optimal Smoke Management (OSM) scenarios.

Inventory Summaries

The options selected for the 2018 Emission Inventory Summary Results presented here represents a "maximum control scenario", which includes:

- SO_2 Annex Milestones for the Stationary Source Inventory;
- Optimal Smoke Management for both the Prescribed Wildland and Ag Burning Inventories; and
- "Typical" Year for the Wildfire Inventory.

Table 1.1.1. Changes in annual emissions by pollutant, within the 13-state WRAP region, between 1996 and 2018.

Changes in Pollutant Totals in the 13 State WRAP Region: 1996 to 2018	
VOC	down 30%
NO_x	down 28%
CO	down 31%
SO_2	down 23%
PM_{10}	up 4%
$PM_{2.5}$	up 4%
NH_3	up 13%

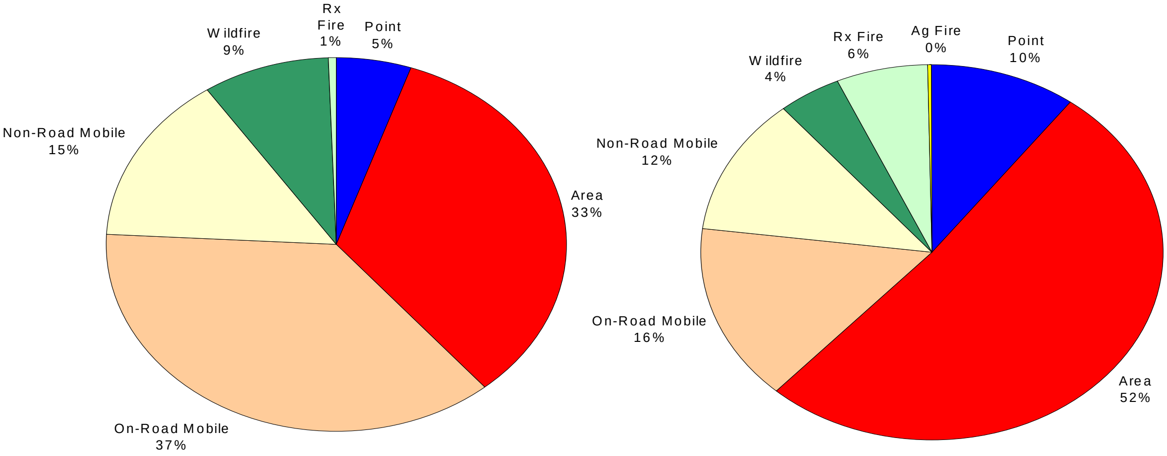
The following eight pairs of pie charts (Figures 1.1.2 through 1.1.9) show the emission totals for the 13-state inventory region, and the changes that are predicted to occur, from 1996 through 2018. The data and additional plots are shown at: http://wrapair.org/forums/ef/inventories/combined/index.html.

VOC Emissions

1996
4,217,014 tons

2018
2,934,752 tons

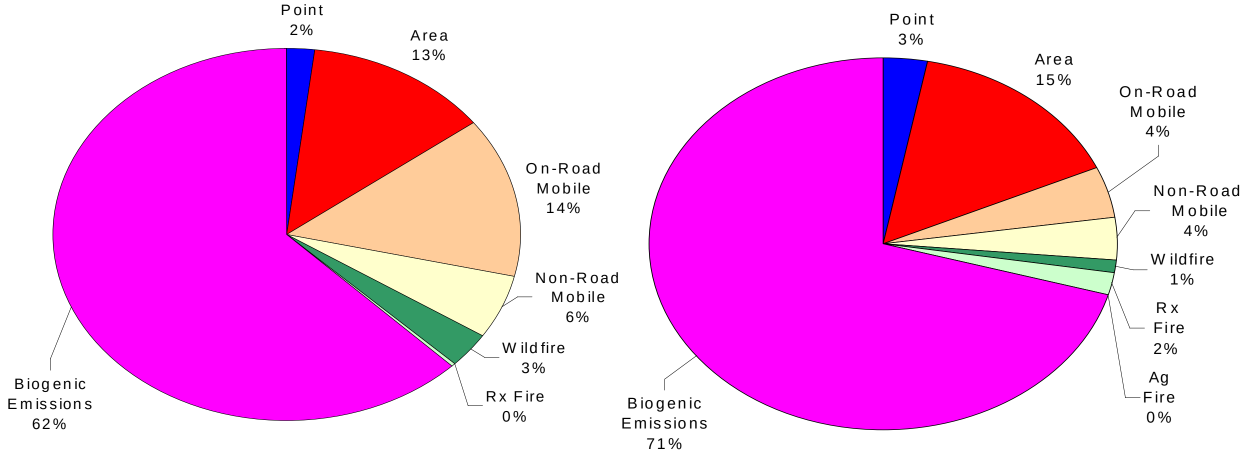
Decrease = 1,282,260 tons (-30%) from 1996



VOC Emissions w/ Biogenics

1996
11,215,433 tons

2018
9,933,173 tons



NOx Emissions

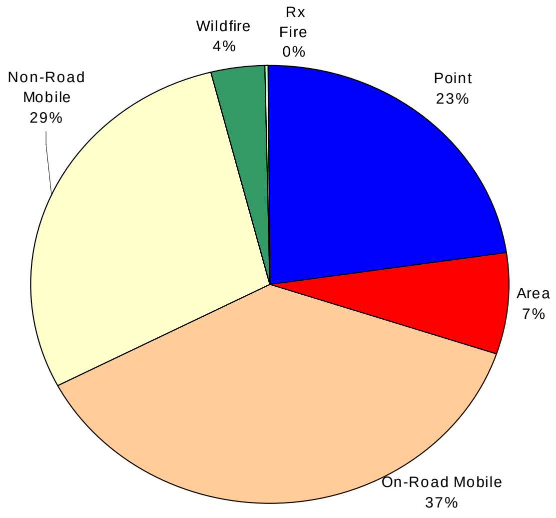
1996

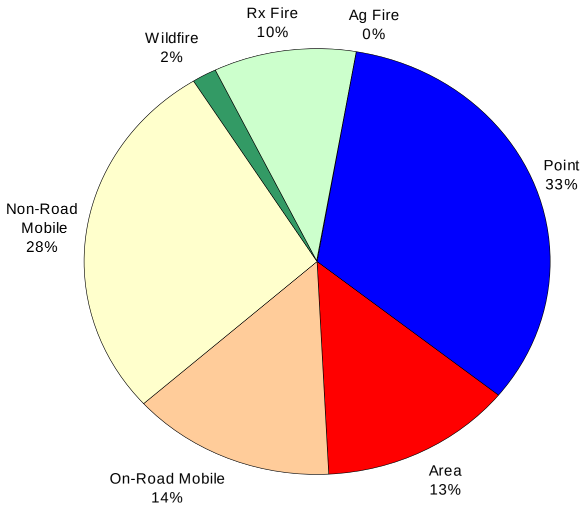
4,745,231 tons

2018

3,420,265 tons

Decrease = 1,324,967 tons (-28%) from 1996





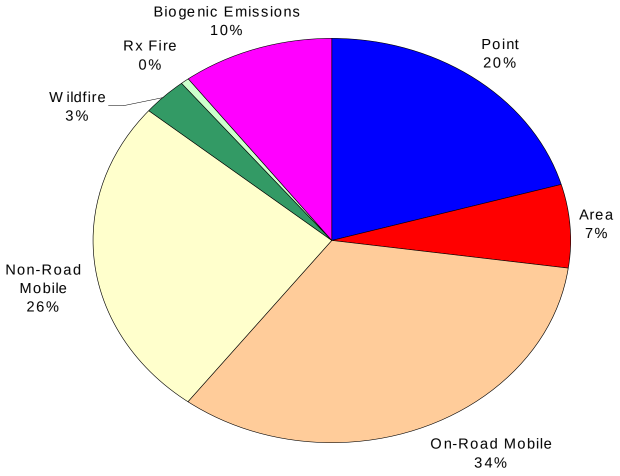
NOx Emissions w/ Biogenics

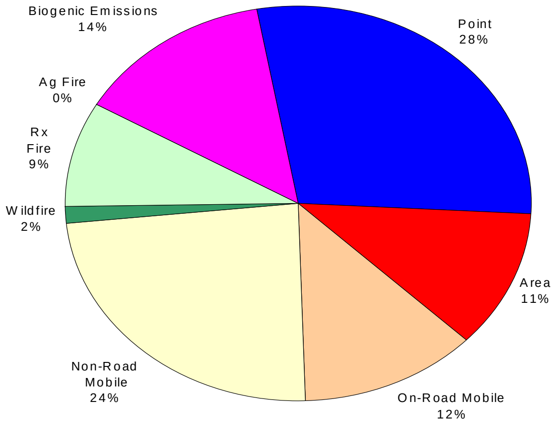
1996

5,294,966 tons

2018

3,969,999 tons





SO2 Emissions

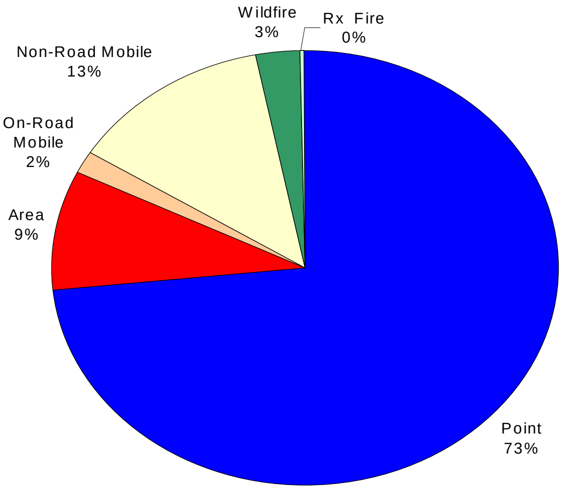
1996

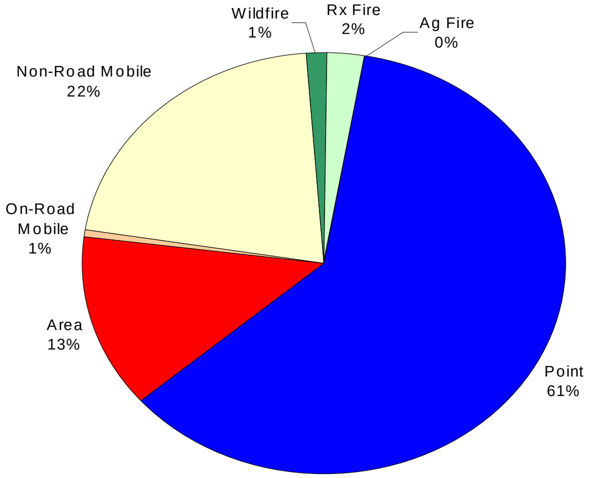
1,630,218 tons

2018

1,263,134 tons

Decrease = 367,083 tons (-23%) from 1996





NH3 Emissions

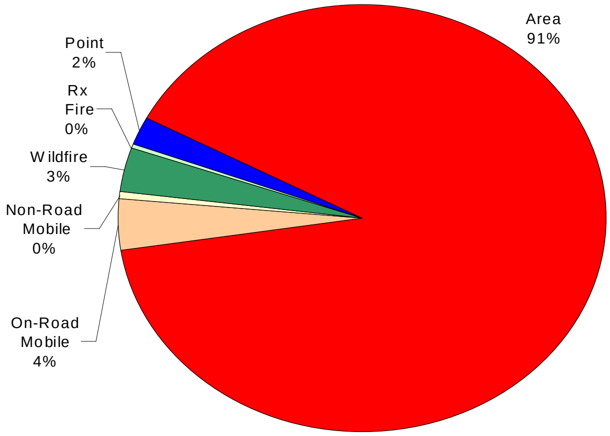
1996

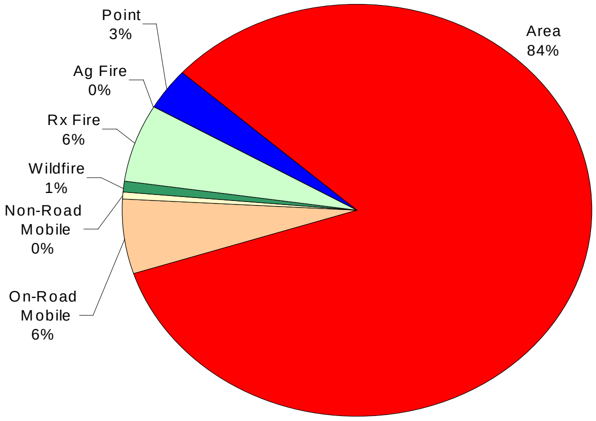
1,020,181 tons

2018

1,157,569 tons

Increase = 137,389 tons (+13%) from 1996





PM-2.5 Emissions

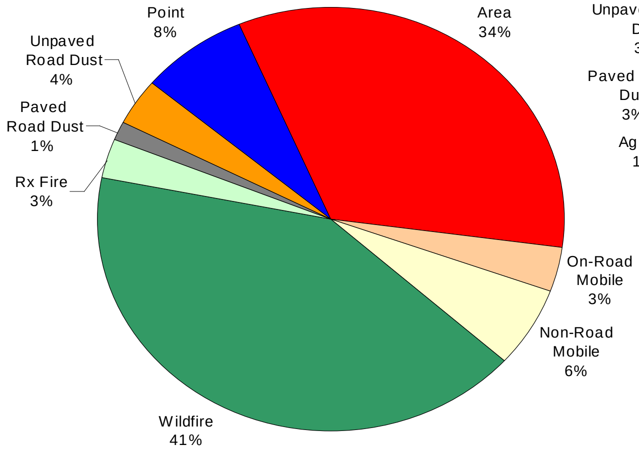
1996

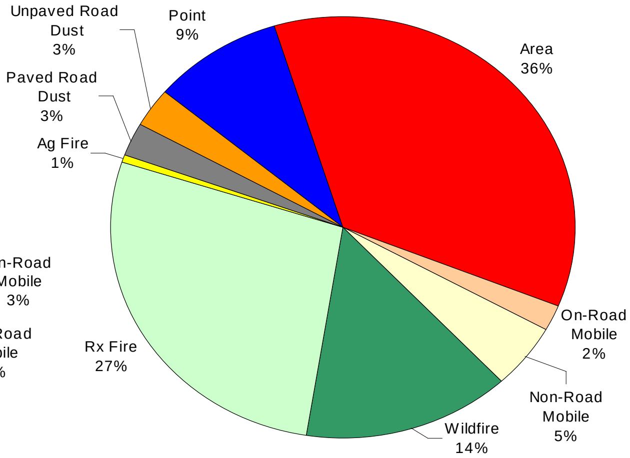
1,557,098 tons

2018

1,620,072 tons

Increase = 62,975 tons (+4 %) from 1996





PM-10 Emissions

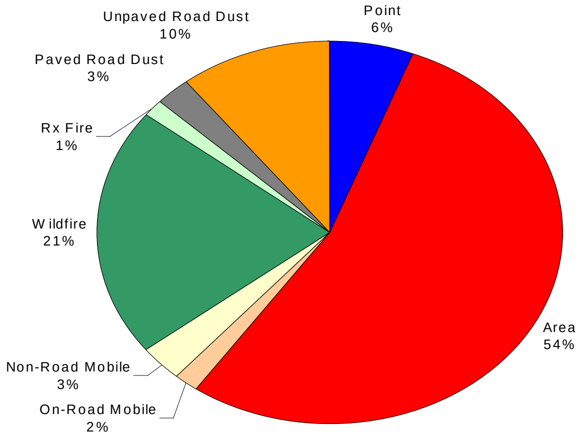
1996

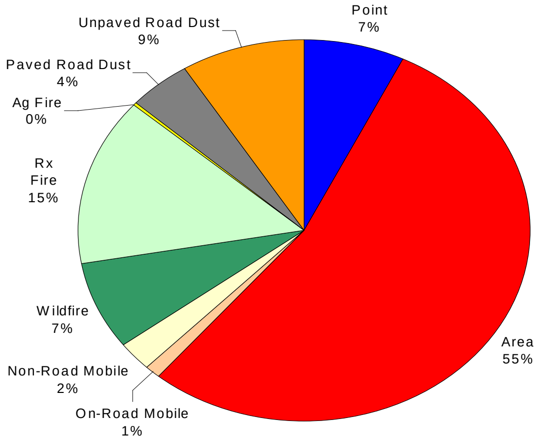
3,559,201 tons

2018

3,684,776 tons

Increase = 125,574 tons (+4%) from 1996





1.1.2. Stationary Source Emissions

Emissions inventories for stationary sources were developed as inputs to various technical analyses as needed for the requirements of §309, consisting of air quality modeling described later in this chapter, and separate emissions control analyses by the WRAP Market Trading Forum, largely described in other reports. The WRAP Emissions Forum developed a 1996 base case of known emissions, and several future versions of 2018 emissions inventories (a base case [expected changes in emissions with no additional control programs], a command and control [BART] inventory, a BART with an uncertainty factor inventory, and an emissions cap and backstop trading program inventory [SO_2 Annex Milestones]). The results of those inventories are presented next. The terms “stationary source emissions” and “point source emissions” are used interchangeably in this document.

Base Year (1996)

The 1996 base year stationary point source emission estimates that were used in this analysis were prepared by Pacific Environmental Services, Inc. (PES) and Eastern Research Group, Inc., under contract to the Western Governors’ Association (WGA) (PES, 2001). The WRAP Emissions Forum contracted with PES to compile the 1996 WRAP region base year emission inventory, utilizing the 1996 U.S. EPA National Emission Inventory (NEI) as the initial basis for this inventory. PES augmented and updated the NEI with information solicited directly from State, local, and tribal agencies in the WRAP region. The 1996 point source file used in this analysis had the filename WGA_PT96.DBF and was retrieved from the WRAP website on August 15, 2001. This file contains information on unit-level criteria pollutant emissions (plus ammonia) for 1996 operations, along with stack coordinates, stack parameters, and operating schedules (hours per day, days per week, weeks per year). While each State may use different criteria to determine which sources to include in their point source file, the official definition of a point source at the time of inventory development was actual emissions greater than: 100 tpy for SO_2, NO_x, VOCs, and particulate matter with an aerodynamic diameter of 10 microns or less (PM_{10}), 1,000 tpy for CO, and 5 tpy for lead (Pb).

Table 1.1.2.1. 1996 point source emissions by State for the 22-state modeling domain.

	1996 Emissions (tpy)						
State	**VOC**	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Arizona	10,473	108,736	17,991	195,851	22,243	11,670	20
Arkansas	14,863	72,440	101,790	112,096	31,855	19,324	15,031
California	69,564	134,844	96,397	43,353	30,135	17,535	15,304
Colorado	37,791	130,552	34,323	106,003	19,932	11,943	245
Idaho	482	6,292	4,522	23,957	12,976	8,035	2
Iowa	11,087	106,311	11,724	243,494	11,333	6,314	8,122
Kansas	26,547	195,309	81,756	131,192	14,632	9,900	12,592
Louisiana	127,270	349,255	700,613	262,457	37,308	27,690	62,797
Minnesota	39,137	169,842	82,626	127,067	81,954	36,691	1,006
Missouri	60,194	214,365	107,128	482,636	49,385	19,407	21,884

Montana	7,682	42,517	48,553	45,925	14,366	7,635	405
Nebraska	11,221	61,532	13,934	72,303	8,976	3,867	19
Nevada	1,718	65,005	14,403	55,858	16,235	6,153	54
New Mexico	16,493	146,023	38,374	158,646	10,149	3,045	83
North Dakota	1,128	114,229	13,222	243,670	4,992	3,328	22
Oklahoma	56,949	208,954	221,065	140,951	11,883	7,489	16,614
Oregon	16,179	26,005	76,001	15,211	11,384	8,439	15
South Dakota	1,386	22,022	366	16,077	906	485	1
Texas	272,914	920,366	470,866	962,042	57,873	40,596	2,907
Utah	16,936	100,434	38,405	43,091	19,381	11,545	1,185
Washington	21,242	56,771	171,132	120,436	12,706	8,716	4,618
Wyoming	23,460	131,552	57,827	128,470	32,565	19,535	1,050
Point Source Totals	**844,716**	**3,383,356**	**2,403,018**	**3,730,786**	**513,169**	**289,342**	**163,976**

Forecast Year (2018)

This section describes the methods and results used to estimate 2018 emissions for the 2018 base case, which includes controls applied after 1996.

Table 1.1.2.2. 2018 Base Case Scenario - Point Source Emissions - 22-State Region

	2018 Emissions (tpy)						
	VOC	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Arizona	17,152	138,583	32,723	131,499	38,211	20,117	33
Arkansas	19,068	73,001	124,170	108,738	34,346	18,471	25,423
California	104,337	106,812	152,122	32,079	45,419	24,399	26,900
Colorado	44,386	130,922	54,980	91,684	31,371	18,252	180
Idaho	275	7,295	6,410	14,510	6,979	4,314	2
Iowa	13,496	106,820	19,088	194,510	14,126	7,967	13,764
Kansas	34,474	196,081	87,634	120,444	20,990	14,507	19,302
Louisiana	152,153	317,031	593,941	222,884	38,862	27,971	73,139
Minnesota	46,047	175,765	103,413	109,321	131,675	58,398	1,288
Missouri	93,122	154,590	207,781	451,579	80,213	30,962	36,398
Montana	7,856	44,566	60,608	37,062	15,241	7,944	298
Nebraska	13,468	61,242	25,235	70,107	12,163	5,112	27
Nevada	2,109	52,859	29,814	22,763	22,260	8,362	89
New Mexico	23,936	154,192	59,770	148,352	11,677	3,476	132
North Dakota	1,646	115,180	20,277	252,125	5,196	3,538	31
Oklahoma	76,633	206,228	255,821	130,218	13,948	7,930	27,325
Oregon	23,715	33,226	111,960	26,828	14,117	10,142	19
South Dakota	1,553	22,493	615	15,236	770	432	2

Texas	347,864	624,122	585,932	867,479	66,132	44,982	4,338
Utah	21,548	122,277	63,845	43,438	30,706	18,589	1,715
Washington	26,510	65,291	276,092	39,305	14,438	9,753	6,660
Wyoming	28,711	139,554	70,587	130,978	32,040	19,720	1,153
Totals	**1,100,062**	**3,048,131**	**2,942,819**	**3,261,141**	**680,878**	**365,337**	**238,217**

The Integrated Assessment System (IAS) model was developed for the GCVTC to evaluate the visibility benefits of air pollution emission control strategies. This model started with a 1990 base year and made emissions forecasts in ten-year increments. The objective for this analysis was to prepare a 2018 emission forecast from a 1996 base year. Because the 2018 scenario results needed to be in the appropriate form to provide inputs to regional visibility models like the Community Multiscale Air Quality (CMAQ) model, and the Regulatory Modeling System for Aerosols and Deposition (REMSAD), if the IAS model was used directly for projecting 2018 emissions, an additional reporting step would be needed to take the aggregated source category level/IAS region results and allocate them to specific emission units. It was decided that it would be preferable to use the IAS algorithms and apply them to the unit-level information in the 1996 WRAP point source data base in order to provide 2018 emission forecasts at the same level of detail.

At the same time that the IAS model algorithms were being adapted for use with the 1996 point source file, a number of model upgrades were accomplished. These included determining the initial year of operation for large point sources in the core WRAP States in order to better simulate source retirements, and replacement with sources that emit at lower, new source rates. Another initiative was to review federal, state, and local regulations and incorporate up-to-date information about western state control programs in the 2018 forecast. In addition, information on unit lifetimes by source type was collected and evaluated, and the IAS model unit lifetime assumptions were changed. New source technology information about controlled pollutants and control efficiencies from the IAS model was also reviewed and updated with current information. Finally, growth factors were updated using recent REMI model projections, with State-supplied projections substituted when provided.

Projections for two sectors were performed outside the IAS model framework – those for electric utilities and copper smelters. Estimates of 2018 SO_2 emissions for the major electric utility plants use 2018 forecasts of electricity generation by unit that were developed for the WRAP Market Trading Forum. Because the WRAP-sponsored work only included SO_2 emission estimates, E.H. Pechan & Associates, Inc. (Pechan) used 1999 Emissions Tracking System/Continuous Emission Monitoring (ETS/CEM) data, if available, or the emissions computed based on EIA-767 data to estimate 1999 NO_x emissions. Then, the same unit level growth assumptions (2018 versus 1999 generation estimates) that were applied to estimate 2018 SO_2 emissions were used to estimate 2018 NO_x levels. Information provided by individual utility companies about known future NO_x emission limits was compared with 1999 emission rates, and it was found that 1999 pounds per million British thermal units (lbs/MMBtu) emission rates are at or below future limits, with the exception of the Cherokee plant in Colorado. Additional known NO_x controls were applied to all four units at Cherokee. These reductions ranged from 14 to 28 percent.

The 2018 forecasts of future utility PM_{10} and $PM_{2.5}$ emissions (and all other criteria pollutants plus ammonia) use the 1996 WRAP point source inventory emission estimates and estimates of 1996 generation by unit to establish base year conditions, and the ratio of 2018 generation to 1996 generation by unit to estimate activity changes.

For copper smelters, 2018 SO_2 emissions are set at the levels defined by the stepped reduction milestones through 2018 established by the Annex to the GCVTC's recommendations. The current year allocation for the six copper smelters in the 9-State region is 86,000 tons. This allocation is reduced to 78,000 tons by 2018. The plant-level emissions difference between 86,000 tons and 78,000 tons SO_2 was simulated by subtracting 2,000 tons each from the four largest smelters, which are ASARCO-Hayden, BHP-San Manuel, Phelps Dodge-Chino Mines, and Phelps Dodge-Hidalgo.

SO_2 Annex Milestone Case (2018)

The Annex Milestones case emission forecast begins with a base case simulation that accounts for the expected controls and activity changes by State and source category that are expected to occur between 1996 and 2018. For utilities, estimates of 2018 SO_2 emissions were provided by the WRAP Market Trading Forum from Integrated Planning Model simulations of the effects of a backstop regional (9 State) cap-and-trade program. Total utility SO_2 emissions in the 9-State Commission Transport Region are 286,000 tpy.

The WRAP submitted an Annex to the Report of the GCVTC (SO_2 Annex) to EPA on October 2, 2000, and EPA has since adopted the Annex in rule. The Annex shows the details of regional SO_2 milestones and a backstop cap-and-trade program that would be triggered if the milestones were not met. The milestones were designed to show steady and continuing progress towards reducing SO_2 emissions, and to show greater reasonable progress than the application of BART for the purposes of regional haze visibility impairment.

Table 1.1.2.3. 2018 SO_2 Annex point source emissions by State for the modeling domain

	2018 Emissions (tpy)						
State	**VOC**	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Arizona	17,152	138,583	32,723	109,877	38,211	20,117	33
Arkansas	19,068	73,001	124,170	80,821	34,346	18,471	25,423
California	104,337	106,812	152,122	32,650	45,419	24,400	26,900
Colorado	44,386	130,922	54,980	56,929	31,371	18,252	180
Idaho	275	7,295	6,410	14,769	6,979	4,314	2
Iowa	13,496	106,820	19,088	144,377	14,126	7,967	13,764
Kansas	34,474	196,081	87,634	89,505	20,990	14,507	19,302
Louisiana	152,153	317,031	593,941	167,373	38,862	27,971	73,139
Minnesota	46,047	175,765	103,413	82,930	131,675	58,398	1,288
Missouri	93,122	154,590	207,781	335,137	80,213	30,962	36,398
Montana	7,856	44,566	60,608	27,802	15,241	7,944	298
Nebraska	13,468	61,242	25,235	52,180	12,163	5,112	27

Nevada	2,109	52,859	29,814	23,167	22,260	8,362	89
New Mexico	23,936	154,192	59,770	135,280	11,677	3,476	131
North Dakota	1,646	115,180	20,277	186,751	5,196	3,538	31
Oklahoma	76,633	206,228	255,821	97,121	13,948	7,930	27,325
Oregon	23,715	33,226	111,960	12,129	14,117	10,142	19
South Dakota	1,553	22,493	615	11,337	770	432	2
Texas	347,864	624,122	585,932	645,980	66,132	44,982	4,338
Utah	21,548	122,277	63,845	35,506	30,706	18,589	1,715
Washington	26,510	65,291	276,092	32,410	14,438	9,753	6,660
Wyoming	28,711	139,554	70,587	89,693	32,040	19,720	1,153
Point Source Totals	**1,100,062**	**3,048,131**	**2,942,819**	**2,463,724**	**680,878**	**365,337**	**238,217**

BART with Uncertainty Case (2018)

For this scenario, emission reductions that would be expected to be achieved by applying controls to BART-eligible sources are applied within the 9-State Commission Transport Region, and then 10 percent of the Base Case SO_2 emissions were added back into the point source inventory emissions from the 2018 Command and Control Case prorated across the 9-State Commission Transport Region in proportion to the Base Case inventory. The purpose of this analysis is to show the potential variability of emissions under the command-and-control scenario compared with a regional emissions cap, where regulatory consequences occur if total emissions exceed milestones. In addition, this 2018 scenario examines uncertainties in the command-and-control scenario that need to be accounted for in order to make a fair comparison with the market trading program (which includes an absolute cap on emissions). These uncertainties might include assumed retirements, the level of control applied to BART sources, new source emissions, utility unit capacity factors, and whether existing sources increase their actual emissions to be closer to permitted levels.

BART Case SO_2 emission estimates for utilities in the 9-State Commission Transport Region are taken from column J (BART Case) from the utilin2.xls file provided by the WRAP Market Trading Forum. SO_2 emission reductions from BART-eligible non-utility sources were estimated using the WRAP Market Trading Forum provided allstat7.xls file. States with non-utility BART sources and associated SO_2 emission reductions in this scenario included Arizona, Colorado, New Mexico, Oregon, and Wyoming. Eight non-utility BART sources were expected to be retired by 2018, so no BART-estimated SO_2 emission reductions were applied to these units.

The net result of the BART application is that modest SO_2 emission reductions were estimated for BART controls applied to non-utility units in the 9-State Commission Transport Region. The largest SO_2 emission reductions are estimated to occur in Colorado, and these are mostly attributable to BART controls applied to Trigen-Colorado Energy Corporation. For the 8 retired BART sources, SO_2 emission reductions that might have been attributed to BART application were already captured in the 2018 emission forecast.

Within the GCVTC Transport Region States, increasing SO_2 emissions by 10 percent brings the GCVTC point source SO_2 emission total to 550 thousand tons, which is 40 thousand tons above the milestone amount.

Table 1.1.2.4. 2018 BART plus Uncertainty case results for point sources

	2018 Annual Emissions (tpy)						
State	**VOC**	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Arizona	17,152	138,583	32,723	110,887	38,211	20,117	33
Arkansas	19,068	73,001	124,170	80,821	34,346	18,471	25,423
California	104,337	106,812	152,122	35,287	45,419	24,400	26,900
Colorado	44,386	130,922	54,980	63,648	31,371	18,252	180
Idaho	275	7,295	6,410	15,962	6,979	4,314	2
Iowa	13,496	106,820	19,088	144,377	14,126	7,967	13,764
Kansas	34,474	196,081	87,634	89,505	20,990	14,507	19,302
Louisiana	152,153	317,031	593,941	167,373	38,862	27,971	73,139
Minnesota	46,047	175,765	103,413	82,930	131,675	58,398	1,288
Missouri	93,122	154,590	207,781	335,137	80,213	30,962	36,398
Montana	7,856	44,566	60,608	27,802	15,241	7,944	298
Nebraska	13,468	61,242	25,235	52,180	12,163	5,112	27
Nevada	2,109	52,859	29,814	25,039	22,260	8,362	89
New Mexico	23,936	154,192	59,770	147,631	11,677	3,476	131
North Dakota	1,646	115,180	20,277	186,751	5,196	3,538	31
Oklahoma	76,633	206,228	255,821	97,121	13,948	7,930	27,325
Oregon	23,715	33,226	111,960	13,302	14,117	10,142	19
South Dakota	1,553	22,493	615	11,337	770	432	2
Texas	347,864	624,122	585,932	645,980	66,132	44,982	4,338
Utah	21,548	122,277	63,845	37,426	30,706	18,589	1,715
Washington	26,510	65,291	276,092	32,410	14,438	9,753	6,660
Wyoming	28,711	139,554	70,587	101,054	32,040	19,720	1,153
Totals	**1,100,062**	**3,048,131**	**2,942,819**	**2,503,960**	**680,878**	**365,337**	**238,217**

1.1.3. Area Source Emissions

Emissions inventories for area sources were developed as inputs to various technical analyses as needed for the requirements of §309, consisting of air quality modeling described later in this chapter. The WRAP Emissions Forum developed a 1996 base case of known area source emissions, and a 2018 base case, accounting for growth resulting from the expected increases in the population of the region, and including federal, state, and local area source emissions control programs already adopted.

Base Year (1996)

Area sources are generally described as those sources that are too small, numerous, or difficult to be inventoried individually. The EPA 1996 NEI was selected as the starting point for estimating area source emissions. EPA prepares the NEI with input from State, local, and tribal organizations. EPA uses the NEI to track long-term emission trends on a national scale, to evaluate the effectiveness of national emission standards, and to satisfy some international obligations. The 1996 base year was selected because it was the most recent, quality assured inventory that was available when the analysis began. The 1996 data summaries presented here are based on Version 3.12 of the 1996 NEI.

A detailed description of the area source emission estimation methods used in the NEI is described in the EPA Procedures Document (EPA, 2001). This report is available through the EPA website www.epa.gov/ttn/chief (Clearinghouse for Emission Inventories and Factors).

The 1996 NEI included State-supplied area source emission inventories for Washington, California, Oklahoma, Texas, Missouri, and Louisiana. For other States, the 1996 area source emission estimates were those prepared by EPA. For the purposes of the WRAP analysis, additional area source data were provided by Oregon, Utah, and Colorado.

The 1996 area source emission estimates used in this analysis had the file name WGA_AR96.DBF. This file includes emission estimates for all source categories traditionally inventoried as area sources by the States, with the following exceptions: highway vehicles, nonroad engines/vehicles, dust from either paved or unpaved roads, or emissions from wild fire, prescribed burning, and agricultural burning. Emission estimates for geogenic wind blown dust from undisturbed natural soils have been set to zero for all States in this file.

The WRAP Mobile Sources Forum prepared estimates of on-road and off-road vehicle emissions and paved and unpaved road dust separately. The Fire Emissions Forum prepared estimates of fire-related emissions separately.

Forecast Year (2018)

The 2018 area source emission forecasts were developed using methods consistent with those used to develop the point source emission projections. This includes using algorithms from the GCVTC IAS. The original IAS model had 10 source categories (scc_ids) that were used to represent expected growth and controls affecting western State area source emissions. This relatively small number of source categories provides a reasonable aggregate picture of how area source emissions might be expected to change in future years because the focus of WRAP has been on SO_2, PM_{10}, and NO_x emissions. There are a relatively small number of important area source categories that emit these pollutants. However, because VOC emissions are also included in the regional modeling efforts, and are important in both ozone and PM formation, it was decided to expand the source category-level modeling process to the source classification code (SCC) level in order to capture VOC controls likely to occur via maximum achievable control technology (MACT) standards, or nonattainment area level ozone control plans. In making this change, what was formerly included in the area source IAS algorithms as new source control technology control efficiencies was incorporated in the control factors, rule effectiveness, and rule penetration values by SCC that are used to estimate 2018 area source emissions.

In order to develop area source control factors by pollutant, area-specific PM_{10} control plans and information were collected and compiled from EPA Regional Offices, and State and local agencies for each of the selected nonattainment areas. PM_{10} control factors were developed for PM_{10} emitting source categories such as construction activity, residential wood combustion, vacant land/improved lots, open burning, and agricultural tilling. These control factors are applied in the nonattainment areas where such PM_{10} controls are applied.

Growth surrogate data were compiled for this effort from contacts with the WRAP States, Regional Economics Model, Inc. (REMI) economic models incorporated into Version 4.0 of the Economic Growth Analysis System (EGAS) (Pechan, 2001), U.S. Department of Agriculture agricultural baseline projections (USDA, 2001), and the U.S. Department of Energy's Annual Energy Outlook (DOE, 2000).

Growth factors used in the 2018 emission forecasts for most sectors are based on constant dollar output data that correspond directly with REMI industry sectors. Population is used as the growth surrogate for most non-combustion area source categories. Western States were given an opportunity to provide their own growth forecasts to be used for their States. Each of the 13 WRAP States and the 9 Tier 1/Tier 2 States were asked to submit their projections for constant dollar output, population, and personal income data. Population data were the most readily available. Colorado, Kansas, Louisiana, Minnesota, Missouri, Montana, Texas, and Washington provided comprehensive population data. Four States provided personal income projections: California, Montana, Nevada, and South Dakota.

Area Source Inventory Results

Table 1.1.3.1. 1996 Base Case - Area Source Emissions

		1996 Annual Emissions (tpy)						
State	**State**	**VOC**	**NO_X**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Arizona	AZ	115,376	49,266	69,193	3,191	72,047	23,022	31,491
Arkansas	AR	129,757	37,375	152,507	19,797	219,684	58,064	136,874
California	CA	351,245	108,202	393,657	10,746	223,455	74,308	167,725
Colorado	CO	90,573	11,004	65,578	1,915	215,931	44,747	96,298
Idaho	ID	54,195	12,737	73,152	7,557	100,419	26,661	63,124
Iowa	IA	137,257	29,594	79,613	13,663	356,507	77,668	290,821
Kansas	KS	119,378	67,755	68,309	3,376	435,444	91,497	215,345
Louisiana	LA	126,405	97,348	79,348	93,437	214,683	50,892	64,537
Minnesota	MN	193,447	23,872	134,465	6,108	344,244	82,268	183,513
Missouri	MO	167,505	13,904	205,511	32,006	287,545	74,964	180,035
Montana	MT	49,669	11,312	62,958	1,180	175,511	39,796	89,797
Nebraska	NE	79,048	14,546	43,159	9,912	272,469	56,246	228,745
Nevada	NV	37,915	6,998	19,135	3,494	34,366	9,985	14,966
New Mexico	NM	55,225	24,667	44,438	7,836	72,329	18,517	46,655
North Dakota	ND	57,178	18,512	17,142	56,891	274,090	55,229	88,223
Oklahoma	OK	109,069	30,147	83,788	5,023	249,239	56,701	187,370
Oregon	OR	328,414	15,103	406,351	2,239	188,803	82,644	59,517
South Dakota	SD	39,237	6,485	26,094	19,288	240,226	49,011	129,468
Texas	TX	557,354	30,908	93,708	8,409	1,044,558	217,054	459,674

Utah	UT	41,701	5,067	58,529	8,148	41,647	12,511	31,641
Washington	WA	171,261	19,160	246,298	3,419	229,051	74,832	46,498
Wyoming	WY	19,906	64,109	30,949	15,882	53,514	11,926	49,084
Area Source Totals		**3,031,118**	**698,072**	**2,453,881**	**333,518**	**5,345,761**	**1,288,542**	**2,861,401**

Table 1.1.3.2. 2018 Base Case - Area Source Emissions

		2018 Annual Emissions (tpy)						
State	**State**	**VOC**	**NO_X**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Arizona	AZ	140,467	79,000	81,181	5,347	73,467	25,236	33,212
Arkansas	AR	136,601	53,446	134,873	29,937	221,657	58,875	143,387
California	CA	421,653	111,355	350,340	12,216	216,950	72,048	177,918
Colorado	CO	90,443	11,896	69,713	2,057	217,316	44,747	102,820
Idaho	ID	59,355	17,739	73,613	8,904	102,654	28,273	66,613
Iowa	IA	163,616	37,901	74,653	17,778	357,862	77,880	308,253
Kansas	KS	141,587	94,609	69,057	4,346	437,677	92,211	227,985
Louisiana	LA	115,005	132,163	78,712	132,514	217,330	52,200	66,680
Minnesota	MN	223,912	28,098	124,882	7,349	345,612	83,190	192,281
Missouri	MO	176,763	19,171	181,748	43,352	290,796	75,975	190,720
Montana	MT	52,131	15,145	53,349	1,326	177,201	39,904	94,708
Nebraska	NE	93,879	19,126	41,996	13,931	275,017	56,735	243,144
Nevada	NV	43,408	9,008	19,568	4,729	35,137	10,401	15,946
New Mexico	NM	59,634	35,501	47,839	12,017	74,529	19,942	49,760
North Dakota	ND	71,041	22,504	16,822	61,483	275,213	55,347	91,618
Oklahoma	OK	110,837	41,001	76,844	7,408	252,046	57,527	198,103
Oregon	OR	275,647	22,729	712,906	3,230	233,328	126,271	62,501
South Dakota	SD	45,266	8,057	24,905	25,496	242,520	49,479	137,329
Texas	TX	668,175	36,030	90,137	11,412	1,053,273	220,122	488,403
Utah	UT	45,883	5,540	65,035	8,219	43,008	13,298	33,703
Washington	WA	183,733	26,020	253,564	4,425	235,008	80,864	48,920
Wyoming	WY	19,617	85,065	32,126	17,975	54,730	12,225	52,286
Area Source Totals		**3,338,657**	**911,104**	**2,673,863**	**435,450**	**5,432,331**	**1,352,751**	**3,026,289**

As a general rule, regional area source emissions for all of the criteria pollutants plus ammonia are expected to be higher in 2018 than they were in 1996. For example, total VOC emissions in the modeling domain are expected to be 10 percent higher in 2018 than they were in 1996.

Table 1.1.3.3. Regional area source emissions changes, 1996 to 2018.

Pollutant	**Regional Percentage Change (1996 to 2018)**
VOC	**+10**
NO_x	**+30**
CO	**+9**
SO_2	**+31**
PM_{10}	**+2**
$PM_{2.5}$	**+5**

NH$_3$	**+6**

1.1.4. Mobile Source Emissions

Emissions inventories for mobile sources were developed as inputs to various technical analyses as needed for the requirements of §309, consisting of air quality modeling described later in this chapter, and originally, the separate "determination of significance" requirement. The WRAP Mobile Sources Forum developed a 1996 base case of known emissions, and future cases for 2003, 2008, 2013, and 2018, accounting for growth resulting from the expected increases in the population and vehicle miles traveled of the region, and including federal, state, and local programs for control technologies and fuel formulation changes already adopted.

Emissions Inventoried Under Mobile Sources

Mobile sources include on-road and off-road vehicles and engines. On-road mobile sources include vehicles certified for highway use – cars, buses, trucks, and motorcycles. For reporting on-road mobile source emissions, vehicles are divided into two major classes – light-duty and heavy-duty. Light-duty vehicles include passenger cars, light-duty trucks (up to 8500 lbs gross vehicle weight [GVW]), and motorcycles. Heavy-duty vehicles are trucks of more than 8500 lbs GVW.

Off-road mobile equipment encompasses a wide variety of equipment types that either move under their own power or are capable of being moved from site to site. Off-road mobile equipment sources are defined as those that move or are moved within a 12-month period and are covered under the EPA's emissions regulations for nonroad mobile sources. Off-road mobile sources are vehicles and engines in the following categories:

- Agricultural equipment, such as tractors, combines, and balers;
- Aircraft, jet and piston engines;
- Airport ground support equipment, such as terminal tractors;
- Commercial and industrial equipment, such as fork lifts and sweepers;
- Construction and mining equipment, such as graders and back hoes;
- Lawn and garden equipment, such as leaf and snow blowers;
- Locomotives, switching and line-haul trains;
- Logging equipment, such as shredders and large chain saws;
- Pleasure craft, such as power boats and personal watercraft;
- Railway maintenance equipment, such as rail straighteners;
- Recreational equipment, such as all-terrain vehicles and off-road motorcycles; and
- Underground mining and oil field equipment, such as mechanical drilling engines.

Scope Of The Mobile Sources Inventory

The scope of the WRAP mobile sources emission inventories is as follows:

Geographic domain: Emissions were estimated by county for all counties in 13 states: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. Alaska was not a WRAP member at the time the emissions were estimated, and so is not included in the mobile sources emission inventories.

Temporal resolution: Emissions were estimated for an average weekday in each of the four seasons, and for an average annual weekday. Seasons are defined as three-month periods: Spring (March–May), Summer (June-August), Fall (September-November), and Winter (December-January). In addition to the 1996 base year and 2018 future modeling year, on-road and off-road mobile sources were estimated for the intermediate years 2003, 2008, and 2013.

Pollutants: Emissions were estimated for PM_{10}, $PM_{2.5}$, NO_x, SO_x, VOCs, carbon monoxide (CO), NH_3, elemental and organic carbon (EC/OC), and sulfate (SO4). For all pollutants, emissions were estimated separately for gasoline and diesel-fueled engines.

General Approach For Estimating On-Road & Off-Road Mobile Emissions

As with most emissions sources, on-road and off-road mobile source emissions are estimated as the products of emission factors and activity estimates. Except for California, the on-road mobile sources emission factors were derived from the EPA MOBILE6 and PART5 models (the latter modified for this project). Activity for on-road mobile sources is vehicle miles traveled (VMT). States were provided default modeling inputs and VMT levels for base and future years for review and update; several states provided revised data. California provided on-road emissions estimates by county directly.

EPA’s NONROAD2000 model was used to estimate so-called traditional off-road sources, all sources listed above except aircraft, commercial marine, and locomotives. The NONROAD model includes estimates of emission factors, activity levels, and growth factors for all traditional off-road sources. The default activity levels were provided to state agencies for input and update; however, no state provided updated off-road activity data. Emissions estimation methods for aircraft, commercial marine, and locomotives were similar to approaches EPA has recently used in developing national emission inventories. California also provided off-road emissions estimates by county directly.

Models for estimating on-road mobile source emissions

EPA on-road emission factor models were used as the basis for estimating on-road emissions. EPA’s MOBILE6 model was used to estimate vehicle VOC, NO_X, and CO emissions. For WRAP on-road emissions estimates, the latest available version of draft MOBILE6 that was available at the time was used. Specifically, the March 2001 draft version was used for estimating 1996 base year on-road emissions, and the September 2001 draft version was used for estimating on-road emissions for all future years. The model was officially released in January of 2002[1].

The MOBILE6 model includes the effects of all Federal motor vehicle control programs:

- Tier 1 light-duty vehicle standards, beginning with the 1996 model year;
- National Low Emission Vehicle (NLEV) standards for light-duty vehicles, beginning with model year 2001;
- Tier 2 light-duty vehicle standards, beginning with model year 2005, with low sulfur gasoline beginning in the summer of 2004;
- Heavy-duty vehicle standards, beginning with model year 2004; and
- Heavy-duty vehicle standards (with low sulfur diesel), beginning with model year 2007.

EPA's PART5 model was the basis for estimating PM_{10}, $PM_{2.5}$, SO_4, NH_3, and EC/OC emissions, but was modified for use in this project. For PM, the model estimates exhaust, tire wear, and brake wear emission factors. At the time of inventory development, the PART5 model was the only publicly available tool from EPA with which to generate particulate matter emissions estimates for on-road motor vehicles. The PART5 emission factors are outdated, and were revised to incorporate the results of more recent testing programs. Changes were made to both light-duty vehicle and heavy-duty vehicle exhaust emission factors, and some of the non-exhaust processes (e.g., brake wear) were updated as well. Where new data existed, particle size distributions for estimating $PM_{2.5}$ from PM_{10} were also updated. Fleet characteristic data (e.g., registration fractions, mileage accumulation rates, etc.) were updated to be consistent with MOBILE6. Finally, the model was modified to estimate ammonia emission factors for all vehicle classes, and to estimate EC/OC emission factors as fractions of PM emission factors. All of these model revisions and the data upon which they are based are fully described in the ENVIRON (2003) report. After the PART5 modifications were made and the WRAP on-road emissions inventories were generated, EPA incorporated the PART5 emission factors into an updated version of MOBILE6 (version 6.2), which is now the regulatory model for on-road emissions.

The California Air Resources Board (CARB) has developed its own model for estimating California on-road emissions, EMFAC. The model includes both emission factors and VMT activity data. The version of the model that was used to generate the WRAP base and future year on-road emissions was EMFAC2000. CARB ran the models for WRAP and provided the emissions estimates in the geographic, temporal, and source category detail as needed for WRAP.

Models For Estimating Traditional Off-Road Mobile Source Emissions

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[1] - The September 2001 draft model differs from the March 2001 draft version only in VOC refueling emissions (by a few percent). There were several changes from the September 2001 draft version to the January 2002 public release (described in ENVIRON, 2003); effects of these changes vary by county and year and depend on fleet composition, Inspection and Maintenance program parameters, and speed and temperature inputs.

Emissions for traditional nonroad sources are estimated with EPA's NONROAD model. Until late June 2003, the draft version of the model that was publicly available was the June 2000 version; this is the version that was originally used to develop the WRAP off-road emissions estimates. The June 2000 NONROAD model incorporates the effects of off-road equipment regulations that were in effect at the time:

- Phase 1 and 2 emission standards for new nonroad spark-ignition engines at or below 25 horsepower (hp);
- Emission standards for new gasoline spark-ignition marine engines;
- Tier 1 and Tier 2 emission standards for new nonroad compression-ignition engines below 50 hp, including recreational marine engines less than 50 hp; and
- Tier 1 through Tier 3 emission standards for new nonroad compression-ignition engines at or above 50 hp, not including recreational marine engines greater than 50 hp.

In December 2002, EPA confidentially released an updated version of the model, NONROAD2002, to WRAP and other air quality planning agencies. The NONROAD2002 model was publicly released on the NONROAD model website in late June 2003, along with an updated User Guide and technical reports[1]. The NONROAD2002 model incorporates updated population data, load factors, and median life; increased PM deterioration rates; revised PM and SO_x calculations (correcting coding in the prior version); revised equipment growth and scrappage; revised activity data for all terrain vehicles; and revised algorithms for allocating national to county-level equipment populations.

With all of these changes, the emission inventory estimates from the NONROAD2002 model are substantially different from the June 2000 draft version. Total U.S. emissions for 1996 are 13 percent lower for VOC in NONROAD2002, 35 percent lower for NO_X, 28 percent lower for $PM_{2.5}$, and 72 percent lower for SO_2. The percent changes vary by equipment type and fuel, as shown in Figure 10. Construction and mining equipment are the largest source of emissions for NO_X, $PM_{2.5}$, and SO_2. Diesel emissions for construction and mining and other equipment types are reduced in NONROAD2002 because the population numbers are lower, and also because lower average equipment lifetimes result in the age distribution with more newer equipment. Pleasure craft are the largest source of VOC emissions. Pleasure craft and other SI equipment are on average lower by about 10 percent in NONROAD2002, though recreational equipment VOC emissions increased primarily because the activity rates and increased. Note that these are 1996 U.S. total comparisons. Comparisons for individual states or counties will be different because of changes in geographical allocation and differences in fuel properties. The differences between NONROAD2000 and NONROAD2002 over time will also vary in amount, but not in direction. Comparisons of the two models for U.S. total emissions for years 2000, 2010, 2020, and 2030 may be found in an EPA memo released along with the confidential December 2002 model release (Harvey, 2002).

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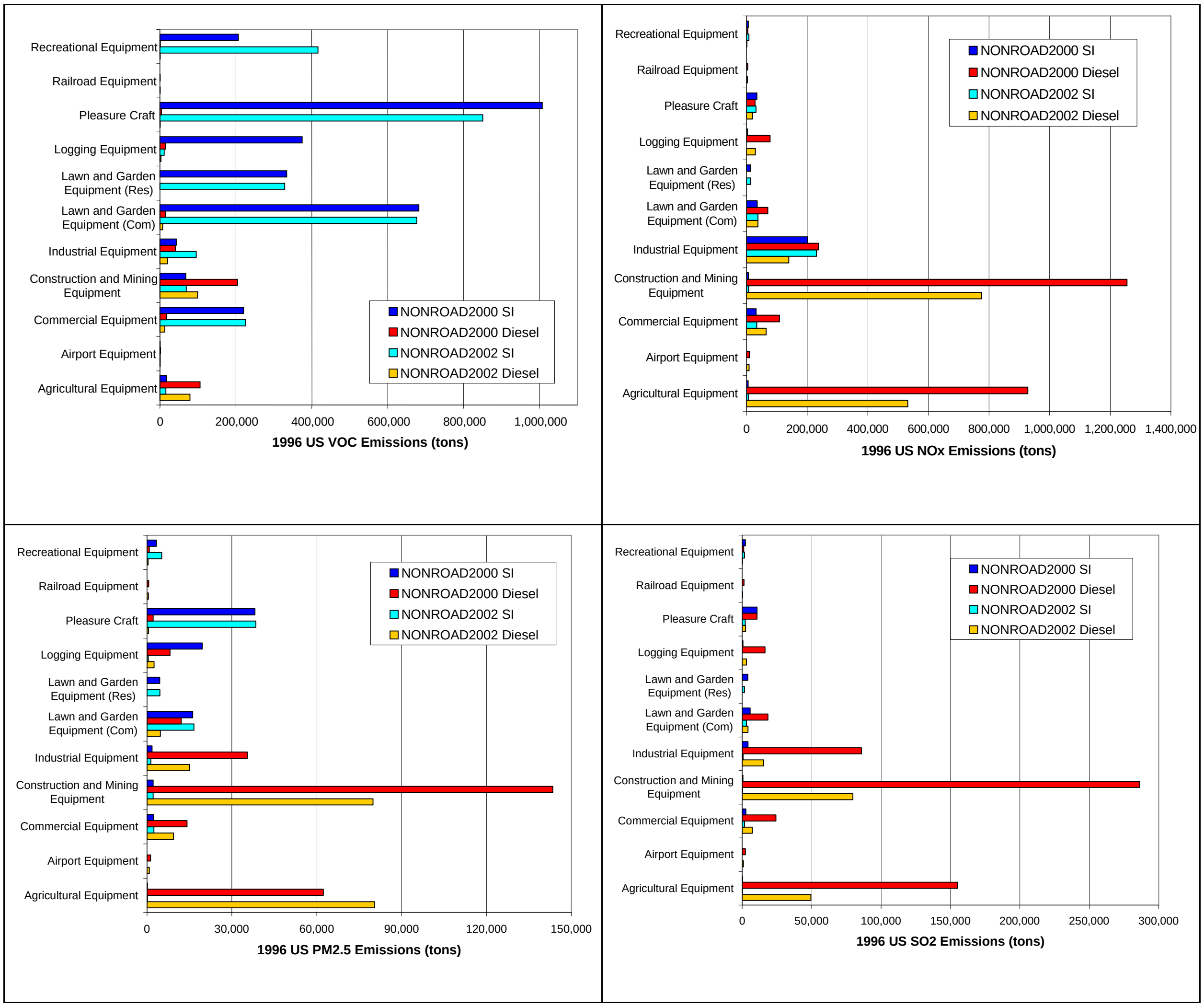
[1] - http://www.epa.gov/oms/nonrdmdl.htm

Figure 1.1.4.1. Changes in 1996 U.S. emissions from NONROAD2000 to NONROAD2002 by source category and fuel.



The NONROAD2002 model does not incorporate the effects of the September 2002 off-road equipment regulations for large (> 25 hp) spark-ignition equipment, recreational equipment, and compression-ignition (diesel) pleasure craft above 50 hp. ENVIRON obtained updated NONROAD2002 model input files from EPA that incorporate these new exhaust standards (the effects of the evaporative standards are not yet modeled). Emissions for traditional off-road equipment were estimated with the NONROAD2002 model, with the updates for the September 2002 rulemaking.

The NONROAD2002 emission factors for future years incorporate the effects of all promulgated off-road equipment regulations (except as noted above). The NONROAD2002 model also includes equipment population growth factors, but they are based on a confidential and undocumented data source, and they are national-level only. ENVIRON developed state-level growth factors so that state-to-state growth differences could be taken into account for estimating future year emissions. The growth factors were based on analyses of historical Gross State Product (GSP) data by economic sector available from the Bureau of Economic Affairs (BEA), Census population data, or other appropriate activity trend data; full details are in the ENVIRON (2003) report.

In April 2003, EPA proposed new standards for off-road compression-ignition (diesel) equipment. The proposal is for new engine standards to phase in between 2008 and 2013, with smaller engine standards phasing in earlier than for larger engines. Emissions standards for the largest engines, between 175 and 750 horsepower, phase in from 2011 to 2013. With these so-called Tier 4 emission standards, fuel sulfur levels need to be reduced to 15 ppm to enable the PM and NO_X emission control technology. Nonroad diesel sulfur is proposed to be 500 ppm in 2008 and 15 ppm in 2010.

The NONROAD2002 modeling was completed prior to the release of these proposed new standards. While the NONROAD2002 emissions modeling performed for WRAP did not include the anticipated emissions effects of the Tier 4 technology, the diesel fuel sulfur levels were set to 15 ppm in the NONROAD2002 modeling for years 2008, 2013, and 2018. The emission estimates were adjusted to back out the effects of the low sulfur diesel, by applying the known state averages of diesel fuel sulfur to the NONROAD2002 data.

For many years, CARB has been developing its own off-road emissions model, called OFFROAD. The model has not yet been released, though CARB has developed many of the emission factor and population/activity inputs and assumptions as part of their analyses in support of their off-road equipment regulations. For this project, CARB provided county-level emissions estimates for all off-road sources by fuel type for the 1996 base and future years; these estimates were derived from an internal working version of the OFFROAD model.

Emissions Estimation Methods - Aircraft, Commercial Marine, & Locomotive

Aircraft, commercial marine vessel, and locomotive emissions are not addressed in EPA's NONROAD model. Emissions from these sources were estimated using EPA guidance and/or EPA methodology as used in the 1996 and 1999 national emission inventories. The analysis approach for each of these sources is summarized briefly here; complete details of the methods and assumptions are provided in the ENVIRON (2003) report. The methods described here were used to estimate emissions for these three source categories in all states except California; for California the ARB provided county-level emission inventories.

Aircraft

For the 1996 base year, aircraft emissions were estimated per airport, and then assigned to counties. For the nine large "hub" airports in the region (outside California), emissions for commercial air carriers were estimated using detailed data on monthly landings and take-offs (LTO) by airframe model, and emission factors by airframe model from the Federal Aviation Administration's (FAA) Emissions and Dispersion Modeling System (EDMS). Commercial air carrier emissions from other airports were estimated using total air carrier LTO data and the fleet average emission factor for air carriers. For all airports, emissions from air taxis, general aviation, and military aircraft were estimated using total LTO data by aircraft group and EPA fleet average emission factors for these smaller aircraft. The base and future years' emissions estimates account only for exhaust below 10,000 feet above sea level, and do not include cruising emissions.

Future year aircraft emissions projections were estimated by applying state-level growth factors to the 1996 aircraft emissions estimates. The state-level growth factors for commercial aircraft (air carriers and air taxis) are based on historical FAA LTO data; for military and general aviation, the growth factors are based on BEA state-level air transportation GSP data. There were no reductions in emission factors from 1996 base year values for commercial aircraft.

Commercial marine

Base year commercial marine vessel activity was estimated by vessel type – ocean-going, tug, ferries, dredges, and fishing vessels. For each vessel type, the activity estimates were derived from a number of data sources, including EPA contractor reports, Army Corps of Engineers data, State Implementation Plan (SIP) emission inventory submittals, and locally derived information from ferry schedules and conversations with Harbor Pilots. The activity estimates were converted to engine activity parameters in terms of work or fuel consumed, and then multiplied by EPA engine emission factor estimates.

For future year emissions estimates, historical freight tonnage data from the US Army Corps of Engineers were used to forecast growth factors by state. EPA projections of the effects of commercial marine emissions standards were incorporated into emission factors for future years.

Locomotives

The methodology used to estimate emissions from railroad locomotives is similar to what EPA used to generate the locomotive inventory for the 1996 National Emission Trends (NET96) project. For the 1996 base year, annual estimates of railroad locomotive fuel consumption generated as part of the 1996 NET project were used to define locomotive activity levels. Emissions were estimated as the product of these activity levels and EPA emission factors for uncontrolled line-haul and switch locomotives. National activity allocations of fuel consumption used in line-haul and switch engines were used to allocate line-haul and switch engine activity within each county (as no local estimates were available).

Future year locomotive emissions were projected from the 1996 base year emission estimates. State-level growth factors were estimated from historical railroad fuel consumption data. EPA projections of the effects of locomotive emissions standards were used to determine future year locomotive emission factors.

1.1.5. Dust emissions from paved and unpaved roads

Fugitive dust from paved and unpaved roads is a significant source of PM emissions. For the 1996 base case WRAP modeling and the early 2018 modeling, estimates of road dust emissions estimates were initially generated using methodologies defined in EPA's AP-42. However, significant inconsistencies in the resulting road dust emissions were observed between states, and revised road dust emissions were estimated. This section describes both the original road dust calculations, and the revised calculations.

Original road dust estimates - standard EPA approach

Unpaved Roads

For the WRAP 1996 base case modeling, the EPA 1996 NEI estimates of paved and unpaved road dust emissions were used. Road dust emissions for 2018 from paved and unpaved roadways were estimated for WRAP based on the NET96 emissions estimates.

These road dust emissions estimates are based on the standard AP-42 method. The following equation, from AP-42, was used to calculate emission factors for unpaved road dust for each month:

$$E_{ext} = [k * (s/12)a * (W/3)b / (M_{dry}/0.2)c] * [(365 - (p*12))/365]$$

where:

E_{ext} = monthly PM_{10} emission factor extrapolated for natural mitigation (lb/mile)
k = empirical constant (2.6 lb/mile)
2000 = conversion factor, number of pounds per ton
s = surface material silt content (%)
a = empirical constant (0.8)
W = mean vehicle weight (tons)
b = empirical constant (0.4)
M_{dry} = surface material moisture content under dry, uncontrolled conditions (%)
c = empirical constant (0.3)
p = number of days in a given month with greater than 0.01 inches of precipitation

This equation is representative of a fleet average emission factor rather than a vehicle-specific emission factor. A default value of 2.2 tons was used nationally as the mean vehicle weight, as recommended in the AP-42 documentation for travel on publicly accessible unpaved roads. A value of 1.0 percent was applied nationally for the surface material moisture content under dry, uncontrolled conditions as a conservative estimate based on available data. Silt content values were from a database developed for the 1985 National Acid Precipitation Assessment Program (NAPAP) inventory with silt contents of over 200 unpaved roads from over 30 states. Average silt contents of unpaved roads were calculated for each state that had three or more samples; for other states the national average across all samples was used. The number of days per month with more than 0.01 inches of rain for each state was estimated from ten years of data from a meteorological station in each state selected to be representative of rural areas within the state.

Vehicle miles traveled (VMT) on unpaved roads in the NET96 were estimated using data reported to the Federal Highway Administration (FHWA). For the 2018 unpaved road dust emissions, two factors were applied to the NET96 VMT to estimate changes in unpaved road VMT from 1996 to 2018. First, a population growth factor was calculated at the state level as the projected 2018 population divided by the 1996 population. The second factor was a regional unpaved roadway mileage growth factor, developed based on historical trends in unpaved roadway mileage, to account for regional differences in the counter-acting trends to increase unpaved road mileage in some areas while paving over existing unpaved roads in other areas.

Unpaved road fugitive dust emissions were estimated for 2018 at the state and roadway type level by multiplying the state/roadway type-specific emission factors by the corresponding VMT estimate. The state-level emissions were then allocated to the county using the ratio of each county's rural population to the state rural population.

Paved Roads

PM emission factors for reentrained road dust from paved roads were calculated using EPA's PART5 model. The PART5 equation, from AP-42, is:

$$PAVED = PSDPVD * (PVSILT/2)^{0.65} * (WEIGHT/3)^{1.5}$$

where:

PAVED = paved road dust emission factor for all vehicle classes combined (grams per mile),
PSDPVD = base emission factor for particles of less than 10 microns in diameter from paved road dust (7.3 g/mi for PM_{10}),
PVSILT = road surface silt loading (g/m^2), and
WEIGHT = average weight of all vehicle types combined (tons).

Paved road silt loadings were assigned by roadway type based on traffic volume. For local roads, a silt loading of 1 gm/m^2 was assigned; for all other roadway types, 0.20 or 0.04 gm/m^2 was assigned for roadway types that had an estimated average daily traffic volume (ADTV) of less than or more than 5,000 vehicles per day, respectively. ADTV was calculated by dividing annual VMT by state and roadway type by state-specific mileage by roadway type.

These emission factors were modified to account for the number of days with a sufficient amount of precipitation to prevent road dust resuspension, using ten-year monthly average meteorological data from a selected urban meteorological station in each state. The PART5 emission factors were multiplied by the fraction of days in a month with less than 0.01 inches of precipitation, reduced by 50 percent (i.e., the rain correction factor is calculated as: [365 – (p * 12 * 0.5)] / 365, where p represents the number of days in a given month with greater than 0.01 inches of precipitation).

Paved road fugitive dust emissions for 2018 were estimated at the state and roadway type level by multiplying the state/roadway type-specific emission factors by the corresponding VMT estimate. The state-level fugitive dust emissions were then allocated to the county level in a three-step process. First, the total VMT (from paved and unpaved roads combined) was summed by county and roadway type and by state and roadway type. Next, the ratio of county to state total VMT by roadway type was calculated for each county and roadway type combination. Finally, the paved road emissions at the state and roadway type level were multiplied by the ratio of the county to state total VMT for the given roadway type. The result of this calculation was a database of 2018 paved road emissions at the county and roadway type level of detail.

Revised road dust emissions estimates

Unexpected inconsistencies were observed in the road dust emissions estimates developed using the standard AP-42 approach. There was large variation in emission estimates from state to state, and in adjacent counties. In particular, there is unexpectedly large variation in the unpaved road dust emissions among the Colorado Plateau states. The underlying data used to estimate the road dust emissions were reviewed, and significant variation was found in both the emission factors and the activity data.

Variability in the state-level emission factors is largely because of variability in the assumed state-level silt content values. For the revised road dust emissions estimates, changes were made to the state-level silt content vales. An updated database was obtained, and an extremely high outlying value (for Montana) was deleted from the database. The state-level and Western state averages were recalculated, and the Western states average was used for those states with inadequate data (less than three measurements), rather than the national average.

Changes were also made to the ADTV assumptions. The unpaved road VMT data are the product of road mileage and the assumed ADTV, obtained from FHWA reporting systems. The FHWA data were submitted by each state, with varying data collection methods across states and counties — some jurisdictions performed surveys; others relied on road owners/managers (usually Federal agencies). The ADTV estimates were revised based on survey work done for the Clark County, NV June 2001 PM_{10} State Implementation Plan (SIP), and traffic volume estimates from National Forest Service unpaved roads (NFS is the largest manager of unpaved roads in the west). Complete details of all of these changes are described in the ENVIRON (2003) report.

For air quality modeling, the revised road dust emission estimates were multiplied by a factor to account for deposition and other removal mechanisms that tend to lower the amount of dust that is transported on a regional basis (i.e., outside the 36 km grid cells in the modeling domain). In the past, EPA and others have reduced the road dust emissions by a factor of four to account for these effects. For this project, county-specific transport fractions, developed by members of the WRAP Dust Expert Panel, were applied. The transport fractions depend on the vegetative characteristics of each county, and were calculated as the weighted average of vegetation-specific transport fractions in each county. The transport fractions for each vegetation type are as follows: barren and water, 97%; agricultural, 85%; grasses, 70%; urban, 40%; scrub and sparse wooded, 30%; and forested, 5%.

The effect of all of these changes was an overall 89 percent reduction in road dust emissions estimates in the Western states. Revision of the silt loading values resulted in a 15 percent reduction; revisions to the ADTV data resulted in a 68 percent reduction; and application of the transport fractions resulted in a 60 percent reduction. The WRAP Expert Panel is reviewing these road dust estimates, as well as other potential modeling changes for estimating road dust transport.

1.1.6. Pollution Prevention Emissions Inventory

Two key recommendations from the GCVTC focused on the development of renewable energy sources and promotion of energy conservation. Labeled the 10/20 goals, the recommendation on development of renewable energy sources encouraged States and tribes in the Transport Region to undertake steps that would increase the use of renewable energy to 10 percent of the regional power needs by 2005 and 20 percent of the regional power needs by 2015. For energy conservation, the Commission supported the continued development of energy efficiency standards and suggested that the emphasis on energy conservation be maintained within the changing electric power markets. In addition to the 10/20 goals and energy conservation recommendations, the GCVTC suggested that future modeling work be conducted to analyze the potential emission reductions, cost savings, and secondary benefits associated with the use of renewable energy, energy efficiency, and pollution prevention.

The Air Pollution Prevention Forum of the WRAP has been charged with implementing the air pollution prevention recommendations of the GCVTC. The Air Pollution Prevention Forum commissioned the ICF Consulting Group to analyze the potential emission reductions, costs, and secondary regional economic impacts of meeting the 10/20 goals and energy efficiency recommendations (ICF, 2002). The analysis of this case incorporates the results of the ICF analysis for the Air Pollution Prevention Forum in a scenario that includes 2018 milestone case emission estimates for non-utility point sources.

The estimated SO_2 and NO_x emissions by utility unit for existing facilities, and by State for new sources, were provided by the ICF Consulting Group. The percentage changes in SO_2 and NO_x emissions by unit were applied to the 2018 Milestone Case emissions to estimate air pollution prevention case emissions for this analysis. The ICF model also provided estimated SO_2 and NO_x reductions for new sources. These new source emission reductions were applied to the utility units in each State in proportion to 2018 milestone case emissions. Because of the regional SO_2 trading program, the regional SO_2 emissions total is the same in the air pollution prevention case as it was for the milestone case. There is some shifting of SO_2 emissions among units and States, though. Regional NO_x emissions decline by about 14 thousand tons (air pollution prevention case versus milestone case). A State-level summary of utility emission changes by State from the 2018 milestone case is provided below. The tribal new source changes were allocated to Arizona. States not listed had no emissions change.

Table 1.1.6.1. State-Level Emissions Changes from Regional Pollution Prevention Program.

	Air Pollution Prevention Case Emissions Change	
State	**NO_x tpy**	**SO_2 tpy**
Arizona *	-3,267	5,558
Colorado	-1,370	-1,119
Nevada	-430	-307
New Mexico	-7,053	-5,135
Utah	-780	-595
Wyoming	-1,374	1,598
Regional Changes	-14,274	0

* - All new Tribal source emissions reductions (–990 for NO_X and –430 for SO_2) were assigned to Arizona.

This 2018 scenario is described separately from the other 2018 emission forecasts because it was developed from a revised 1996 base year emissions database. The 1996 point source file used in this analysis includes revisions made by Pechan during the summer of 2002 after quality control checks were made on the original PES data file. The revised point source file used in this analysis is the September 2002 revised WGA_96pt.zip file, which is posted at www.wrapair.org. This revised file includes some changes to SO_2 emission estimates so that facility-level emissions would be as close as possible to those in the true-up inventory. The true-up inventory contains the plant-level SO_2 emission estimates used to measure the region’s progress in meeting emission milestones. In addition, corrections were made to problems found with point source coordinates, stack parameters, and SCC assignments. Thus, Table 1.1.6.2 below shows the resulting emissions, after changing from version 1 to version 2 of the 1996 WRAP point source data base, and the following summary table the net effect on 2018 Annex/Milestone case emission estimates.

Table 1.1.6.2. 2018 Regional Pollution Prevention Case Point Source Emissions for the SO_2 Annex Milestones Case – State Totals (22 State Region)

	2018 Emissions (tpy)						
State	**VOC**	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
Arizona	10,775	134,615	31,917	113,915	26,736	9,524	30
Arkansas	19,068	73,001	124,170	80,468	34,346	18,471	25,423
California	104,337	106,707	152,122	31,197	45,419	24,400	26,900
Colorado	44,386	129,551	54,980	57,619	31,371	18,252	180
Idaho	275	7,295	6,410	13,613	6,979	4,314	2
Iowa	13,496	107,005	19,088	145,785	14,140	7,971	13,764
Kansas	34,474	195,204	87,634	86,662	20,967	14,491	19,302
Louisiana	152,153	317,031	593,941	164,979	38,862	27,971	73,139
Minnesota	46,047	177,235	103,413	83,048	131,699	58,412	1,288
Missouri	93,122	155,670	207,781	338,407	80,224	30,968	36,398
Montana	7,856	44,566	60,608	27,440	15,241	7,944	298
Nebraska	13,468	61,705	25,235	52,548	12,177	5,121	27
Nevada	2,109	52,426	29,814	22,648	22,260	8,362	89
New Mexico	23,941	148,706	59,834	133,121	11,736	3,477	131

North Dakota	1,967	120,051	23,747	183,811	5,585	3,534	31
Oklahoma	76,633	206,228	255,821	96,390	13,948	7,930	27,325
Oregon	23,634	31,888	108,312	8,388	13,638	9,740	19
South Dakota	1,553	22,076	615	11,275	770	432	2
Texas	347,864	624,359	585,932	642,106	66,132	44,982	4,338
Utah	13,250	103,310	60,882	36,233	20,977	12,244	1,162
Washington	26,510	64,816	275,981	31,283	14,320	10,007	6,660
Wyoming	28,711	138,180	70,587	93,264	32,040	19,757	1,153
Totals	**1,085,632**	**3,021,623**	**2,938,824**	**2,454,201**	**659,566**	**348,303**	**237,661**

The primary result of the above-mentioned changes to the 1996 WRAP point source database is to reduce GCVTC transport region criteria pollutant emissions. The table below shows how much lower the 2018 Milestone Case emissions are after the 1996 point source emission file revisions were made. SO_2 emissions are, by definition, 510,000 tpy in the Milestone Case, so the SO_2 emissions difference is zero. Regional emissions for all of the other pollutants are lower when the revised 1996 point source database was used to generate 2018 emission forecasts. These emissions were not included in the air quality modeling of the §309 control strategies.

Table 1.1.6.3. Regional Changes in Emissions in 2018 Base Case resulting from changing the 1996 Base Case from Version 1 to Version 2.

Pollutant	**2018 Regional Emission Reductions in the Milestone Case (tpy)**
VOC	14,751
NO_x	18,768
CO	7,354
SO_2	0
PM_{10}	21,624
$PM_{2.5}$	17,301
NH_3	556

1.1.7. Fire Emissions

The Emissions Task Team (ETT) of the FEJF prepared a historical fire emission inventory for 1996 and fire emission projections for 2018. This section is a summary of the two final technical reports for these WRAP emission inventory projects. The reports are entitled: “1996 Fire Emission Inventory”, and “Integrated Assessment Update and 2018 Emissions Inventory for Prescribed Fire, Wildfire, and Agricultural Burning”. The complete technical reports are listed in Appendix M. For detailed discussion of the topics summarized in the fire portions of the TSD, please refer to the appropriate section in the technical reports.

Basic concepts of the WRAP fire emission inventories

The FEJF inventoried fire emissions for 1996 and projected fire emissions for 2018. The term fire refers inclusively to wildfire, wildland fire managed for resource benefits (formerly prescribed natural fire), prescribed fire and agricultural fire.

The WRAP Air Quality Modeling and Emissions Forums provided the FEJF specific data resolution requirements for the fire emission inventories. For spatial resolution, each fire event needed a specific latitude and longitude in order to satisfy the spatial resolution goal of one minute of latitude and longitude. For temporal resolution, the hourly emission estimates for each fire event were required.

Estimating emissions from fire events involves considerable scientific uncertainty. For the 1996 inventory, historic data were of varying quality and for some areas unavailable. For the 2018 prescribed fire projections, future activity levels were estimates based on an emissions inventory product of the GCVTC, called the Fire Emissions Project (FEP). Detailed historical agricultural residue burning data proved to be particularly challenging to compile. Additional scientific uncertainty in emission estimates of all fire types can be introduced by emission factors, fuel loadings, and plume rise equations.

The specifications required by the Emissions and Modeling Forums combined with the limitations of existing data and emission estimation methods shaped the emission inventory development. Fire, traditionally considered an "area" source, is treated as "point" sources in the model. In both the 1996 and 2018 inventories, fire emissions are placed at a latitude/longitude coordinate location for each day. From the daily and spatially resolved emission inventory, hourly consumption and plume rise are estimated.

The 1996 fire emissions inventory is summarized in the following section. This emission inventory was based on data collected by state and federal agencies. The 1996 inventory included separate calculations for wildfire and prescribed burning. No estimate of agricultural residue burning was included.

The 2018 fire emission projections are summarized following the section dedicated to the 1996 inventory. The 2018 effort produced three control scenarios (two of which were used for the WRAP modeling effort) for prescribed burning and agricultural burning. A single "typical year" wildfire emission inventory was prepared to complete the suite of fire emission inventory files for the 2018 project.

The 2018 fire projections should not be compared directly with the 1996 fire emission inventories. The nature of inventories and the methods utilized to derive them are fundamentally different. For example, the historic inventory was based on recorded activity data while the activity estimates of the 2018 projections were developed in an independent effort and based largely on expert opinion. Importantly, the 2018 projections were not "grown" from the 1996 inventory. A more appropriate use of the fire emission inventories is to evaluate the 2018 emission reduction estimates resulting from the implementation of the different emission reduction scenarios.

All emission inventory datasets were made available to the WRAP digitally as database files and text files formatted for input to the Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System.

The 1996 fire emission inventory

The FEJF's stated objective for producing the 1996 inventories was to provide the Air Quality Modeling and Emissions Forums with wildfire and prescribed fire emission inventories that could be used to establish the performance of the WRAP's dispersion model to estimate the air quality impact of smoke from fire. Calculation methods and data quality standards were devised with this objective in mind. The FEJF emission inventory reflected *consistent* methods and *specific* fire event data. Data quality standards were set for the historic activity data collected. Consistent calculation methods and calculation parameters (such as literature-based fuel loadings) were implemented.

The ETT established a number of fire event data objectives that would be used to identify and utilize fire event data suitable for the 1996 fire emissions inventory. Each individual entry in the “raw” fire activity database was analyzed to determine if all of the fire event data objectives were met in order for the record to be included in the fire emissions inventory. The data objectives are:

- A specific location for each fire event;
- A specific calendar day in 1996 for each fire event;
- A specific size for each fire event; and
- Sufficient information to assign a fuel loading for each fire event.

The FEJF determined that, as a whole, available agricultural residue burning activity data did not meet these data quality objectives. As a result, no historical agricultural burning emission inventory for 1996 was produced.

The wildfire and prescribed burning emission inventories were developed with parallel data gathering and emission calculation techniques. The same basic inventory process was utilized with a few specific variations implemented. A summary of the technical methods follows.

Activity data

Wildfire activity data were collected using a tiered process. Only wildfires greater than 100 acres in size were considered. Detailed activity data with sufficient spatial and temporal resolution were contained in the National Interagency Fire Center’s (NIFC) daily National Situation Report publication and ICS-209 wildfire forms. The National Situation Report database and ICS-209 databases were merged. Procedures were implemented to avoiding including duplicate records in the merged dataset.

In a companion effort, 1996 records from the Department of the Interior's Wildland Fire Management Data and the Department of Agriculture’s Forest Service National Interagency

Fire Management Integrated Database were appended to form an independent "federal database" of fire events. Fire events in the National Situation Report/ICS-209 database were then paired with fire events in the "federal database." The National Situation Report/ICS-209 database was supplemented on a record-by-record basis with location, fire size, and fuel loading information from the "federal database" where necessary. Lastly, Wyoming State Forestry provided additional wildfire information for Wyoming.

For the prescribed fire activity database, the FEJF set no de-minimus activity level for prescribed burning. The FEJF made requests of air quality officials of each state the WRAP region to provide wildland prescribed fire activity conducted by state and federal agencies for 1996. Individual fire records would be needed to satisfy rather precise temporal, spatial, and activity criteria for WRAP modeling purposes. Therefore, the FEJF requested:

1. Any information that could be used to ascertain a prescribed fire's location (i.e., legal location, latitude/longitude coordinates, and county);
2. Timing information (burn date or season) and/or fire duration; and
3. Such fuels information as vegetation type, acres burned, tons burned, burn type (piles or broadcast).

1996 prescribed fire information was received from each of the WRAP states except for Nevada and North Dakota. Generally, information received from interagency or state-facilitated smoke management programs encompassed prescribed fire data for multiple federal and state land management. Some activity data were received independently from federal agencies. Fire records having sufficient spatial, temporal, and activity components were formatted into a single region-wide prescribed fire activity inventory. Many of the records in the prescribed fire activity dataset did not have latitude and longitude coordinates but did have location information in the form of a Township Range and Section (TRS). A geographic information system (GIS) algorithm was developed to convert, or geo-reference, TRS codes to a latitude and longitude coordinate pair. Fire records ultimately not meeting the data quality objectives were dropped from the dataset.

Fire events in the wildfire and prescribed burning activity databases that did not contain fuel type in the source data were assigned a fuel model using GIS techniques. The fire's location was plotted on the National Fire Danger Rating System (NFDRS) fuel model map and the corresponding fuel model code was recorded to the activity record.

Fuel loading and emission factors

In the event that fire event specific fuel loading values were not contained in the database record, fuel loading values for the wildfire inventory were assigned using the NFDRS fuel model codes (see above) and a table of fuel loading values for NFDRS fuel model categories (Cohen and Deeming, 1985). In addition to the default NFDRS fuel loadings, additional fuel loading was added to each category to adjust for fuel present as duff and tree crowns. Similarly, for prescribed fire events for which no fuel loading value was available, the prescribed fire fuel loading values were the same as those used for the wildfire inventory.

“Adjusted" NFDRS fuel loading assignments for wildfire and prescribed burning differ by the percent consumption assumed for live fuels, duff and crown components.

An emission factor suite was developed to apply to wildfire and prescribed fire activity data. The emission factor suite included one lookup table for wildfire and prescribed broadcast burns and one table for prescribed pile burns. The twelve pollutants included were total suspended particulate matter (TSP), particulate matter less than 10 microns in diameter (PM_{10}), particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), elemental carbon (EC), organic carbon (OC), non-methane volatile organic compounds (VOC), methane (CH_4), ammonia (NH_3), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2) and coarse particulate matter– defined as the difference between PM_{10} and $PM_{2.5}$ (PMC). The emission factor suite consists of two lookup tables. Two emission factor references were drawn upon: the US Environmental Protection Agency’s AP-42 section 13.1 and an emission inventory methods survey report (Battye, 2001) funded by the US EPA Office of Air Quality Planning and Standards. The emission factor suite is a compilation of emission factors and emission factor relationships (multipliers) from both documents.

Emission calculations

For wildfire and prescribed burning, daily emissions were calculated as fuel consumed (tons of fuel) multiplied by each emission factor (pounds of pollutant per ton of fuel). Total fuel consumed was either extracted directly from the activity data (as was often the case with prescribed fire) or was calculated as the size of the fire (acres burned) multiplied by the "adjusted" NFDRS fuel loading value (tons fuel per acre burned). For wildfires and prescribed broadcast burns of particular "heavy" fuel model types, additional smoldering emissions were assigned in that location on the following calendar day.

A plume profile tailored for wildland fire was assigned to each daily fire event. The plume values included the top and bottom of the plume and the percent of emissions fumigated to the surface layer of the atmosphere. These three plume parameters were assigned for each of the 24 hours of each daily fire event. Normally, plume rise is predicted using hourly pyrotechnical and meteorological information. However, given the unique physical characteristics of wildland fire events and previous experience with dispersion models that indicated poor performance with regard to dispersing smoke plumes, the FEJF utilized expert opinion to assign plume characteristics to each fire event. Five plume classes were defined with increasing potential plume heights to reflect the range of "heat releases" possible in wildland fires. Plume bottom heights and percent of the plume fumigated to the first layer of the atmosphere were also developed for the five plume classes. Fire size and fuel loading from the activity data were used to estimate heat release, categorize the fire event into one of the five plume classes, and assign the corresponding plume parameters for each daily fire event. In this fashion, physical plume characteristics were explicitly assigned to each daily fire event. The plume characteristics are used by the WRAP dispersion model in lieu of calculated plume dimensions.

A diurnal fuel consumption table was created to allocate daily wildland fire emissions by hour. The table, consisting of a percent of fuel consumed for each hour of the day– summing to 100, was submitted to the Modeling Forum for implementation within SMOKE.

Emission Inventory Summaries

A total of 1,348 wildfires are included in the 1996 wildfire emissions inventory with a mean duration for each fire of 3.6 days. These fires represent a total of 4,902 reported fire days and 5,311 fire days when an extra smoldering day was included for a subset of the fire events (based on the NFDRS fuel model for the fire event). An estimated total of approximately five million acres and 48 million tons of fuel were consumed by wildfire in 1996. Wildfire activity was highest during the summer months and peaked in the month of August. Wildfire activity differed widely by state with the highest activities in California, Idaho and Oregon.

The 1996 prescribed fire emission inventory is comprised of significantly more events than the wildfire inventory with 14,696 events and 16,603 fire days after smoldering days were added. The total acreage consumed by prescribed burns was 555,000 acres and the total fuel consumed was approximately 5.2 million tons. Over 80% of the prescribed burning activity records are piled fuels. Temporally, prescribed burning had two peaks: one in the Spring and a higher peak in the Fall.

When expressed as fire days, about 25% of the fire activity occurred as wildfires and 75% as prescribed fires. However, emission estimates for wildfire were an order of magnitude higher than for prescribed fire due to a combination of larger (acres) events and higher fuel consumption estimates.

2018 fire emission projections

The FEJF produced 2018 emission projections for wildfire, prescribed burning and agricultural burning. Control scenarios were developed for each source. Prescribed fire and agricultural burning each have "base," "no control" and "maximum control" scenarios. (Note: Only the “base” and “maximum control” scenarios are used in the WRAP modeling.) A single wildfire dataset was submitted to represent constant "natural" emissions for application in every scenario. The FEJF 2018 control scenarios are described in more detail in Chapter 6.

The Air Quality Modeling and Emissions Forums' spatial and temporal resolution requirements apply to the 2018 projections for fire. The FEJF's 2018 wildfire projection was derived from the 1996 fire emissions inventory. Wildfire events retain their location and timing and only their emissions are adjusted for the future case.

Prescribed burning and agricultural burning projections are based on a 50-kilometer (km) gridded inventory and county-level inventory, respectively. The temporal scale of the source data for these two fire types was also in aggregate; seasonal for prescribed fire and monthly for agricultural burning. Because the activity data was of coarse scale yet the modeling required fine resolution, the FEJF decided to "simulate" event-based emission inventories from the available datasets. This is to say the technical methods, for prescribed and agricultural emission projections, included spatial and temporal refinements to allocate emissions to specific coordinates and dates. The objective was to create a "representative" and resolved emission inventory from coarse projections.

Prescribed fire

The emission estimates used in the 2018 prescribed fire emissions inventory were extracted from the Fire Emissions Project (FEP) emissions inventories prepared for the Grand Canyon Visibility Transport Commission in 1995. The FEP emissions inventories were based on a survey of land managers' projections of future prescribed burning activity. Emission estimates for three fire emission control strategies were developed from this survey information and technical execution of an emission-estimating model developed for the FEP.

The resulting FEP emission inventories are regarded to be “possible” inventories for prescribed fire in 2018. Any number of other inventories for prescribed fire in 2018 are also possible. Many factors that went into the assumptions underlying FEP (e.g., budget (or other resource) constraints, land management priorities, etc.) may have changed since the FEP was originally developed. Those who utilize the data in the WRAP’s fire emission inventories or the dispersion modeling results produced using these data should recognize the potential year-to-year variability in all types of fire activity (wildfire, prescribed fire, and agricultural burning). They should also be mindful that the 2018 burning activity levels are hypothetical and that emission estimates are imprecise.

The FEP developed emission projections for ten states: Arizona, California, Colorado, Idaho, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming. The FEP emissions inventory included seasonal (fall, winter, spring, summer) emission totals for all of the WRAP pollutants of interest except for SO_2. Emissions factors for SO_2 were estimated by multiplying the $PM_{2.5}$ emissions factor by a factor of 0.07054 which is the ratio of the SO_2 to $PM_{2.5}$ emission factors used in the FEJF 1996 emission inventory (1.7 and 24.1 lbs per ton of fuel consumed, respectively). In the FEP database, the emission estimates were summarized as the mass of pollutant (tons) per land cover type, season, and FEP grid point (coordinate).

“FEP-like” emissions were estimated for the three WRAP-region states not included in the original GCVTC study: Montana (MT), North Dakota (ND), and South Dakota (SD). Emissions were assigned to these three states by summarizing fire emissions by land cover classification in neighboring GCVTC states, then applying those emission rates to land cover in the new states. That is, the average seasonal emission per land cover (ton per square km) across representative states was assigned to each same classification of land cover (square km) in the new states. Oregon, Washington, Idaho, and Wyoming were the representative states for ND and MT, while Colorado and Wyoming were the representative states for SD. The new prescribed fire emissions inventory for these states was produced without the use of any true fire activity data. The resulting levels of activity and smoke management controls for MT, ND, and SD are the average of the activity levels and controls for the representative states.

Seasonal FEP emissions totals (in tons) were refined to daily fire-event-based emissions using a combination of rules and stochastic processes. The FEJF created several "burn calendars" to sub-divide seasonal emissions into two-week periods. The calendars, developed from expert opinion, were intended to typify intra-seasonal activity in different ecological regions within the WRAP. Once individual fire events were simulated (described below), each event was randomly assigned to a specific day in the two-week period. This temporal allocation achieved the daily "resolution" required by the modelers.

The FEP emissions were also spatially disaggregated from total emissions for the square 50-km grid to latitude/longitude locations within the grid cell. The original FEP grid-wide emission estimates could be broken down by owner and land cover classification. For every FEP grid cell, emissions were aggregated by land management agency. Using a geographic information system to map the federal land management for every 1 km pixel in the 13-state domain, emissions were assigned to the respective land-manager portions of the 50-km grid. Once individual fire events were simulated, they were randomly assigned to a latitude and longitude within the land manager's boundary. This spatial allocation achieved the coordinate "resolution" required for the WRAP modeling.

With the seasonal and 50-km gridded FEP emission projections systematically disaggregated in time (two-week period) and to areas (management portion of grid cell), realistically sized fire events were created. Consistent with the effort to produce a "representative" 2018 emission inventory for modeling, the FEJF strove to produce 2018 emission inventories that contain a representative variety of fire sizes. The *distribution* of fire sizes in the 1996 prescribed fire inventory was used as a template for breaking up the two-week period totals into realistically sized daily events. A nominal fire size (in tons of emissions of $PM_{2.5}$) was assigned to each of the five plume classes. The *frequency* of the different plume classes governed the size and number of "fire events" created out of each 2018 subtotal.

Wildfire

The FEJF produced a wildfire emission inventory for the year 2018 that represents a “typical year” of wildfire activity within the 13-state WRAP region. The 2018 wildfire activity projection is a modification of the 1996 wildfire activity database. The FEJF came to consensus that 1996 was a high wildfire-occurrence year in the West. To reflect more typical conditions for 2018, the FEJF developed a methodology to normalize the 1996 wildfire inventory to a longer running historical average. Fire occurrence statistics were collected from the USDA Forest Service Wildfire Statistics Database for 1971 through 1990. The 20 years of wildfire events were classified into the five fire size/plume parameter classes used elsewhere in FEJF inventory development. Average fire size per class was calculated within each state for this long-term period. Next, the ratio of the mean 1971-1990 wildfire acreage to the 1996 wildfire acreage was calculated by state and by fire size class. This ratio was used to scale acreages appearing in the 1996 inventory to a more typical projection for 2018, on a fire-by-fire basis. Since the average 1971-1990 fire size was usually smaller than the average fire sizes in 1996, the ratio generally served to scale fire sizes down.

The wildfire normalizing process projected acres burned for a typical wildfire year and this was used to represent wildfire events in 2018. The time, location, and fuel loading of each of the fire events were carried over directly from the 1996 inventory. With updated acreage, 2018 emissions and plume characteristics were then calculated using the same methodology as used for the original 1996 inventory.

The total number of wildfire acres in the 2018 emission projections was considerably lower than for 1996, with 1.2 million acres (2018) compared to 5.0 million acres (1996). The larger fire size classes tended to contribute most to the higher wildfire acreage in the 1996 emissions inventory. Compared to the original 1996 emissions inventory, the 2018 projections show a decrease in the frequency and acreage of wildfires greater than 1,000 acres and relatively little change in fires in the size class from 100 to 999 acres.

Agricultural Burning

The FEJF produced agricultural burning emission projections for 2018 using simulation methods comparable to those for prescribed burning. However, rather than creating the emissions inventory from emission projections from FEP, historical agricultural burning data were used. The agricultural activity database commissioned by the FEJF (see the report titled "Non-Burning Management Alternatives on Agricultural Lands in the Western United States", Eastern Research Group/Enviro-Tech Communications, February 2002, included in Appendix D) was by-crop at the county-level. It was an "annual" inventory of residue burned (in tons) that, in an effort to be more complete in terms of coverage of the 13-State WRAP domain, incorporated agricultural burning data from calendar years 1996 through 2001. The FEJF came to consensus that this historic activity database, and resulting emissions, would serve as the 2018 "no control" emission projection.

The agricultural activity data included utilization of a "gap filling" approach to acquire as much crop data for as many counties in the WRAP region as feasible. The source data fell into three categories: permits issued or other mechanisms for determining actual burn activity, emissions inventory estimates, and anecdotal information. For some counties daily resolved activity data was gathered. For the majority of the 13-state WRAP domain only monthly totals were available. The agricultural burning activity database did not include quantification of burning on tribal lands. Activity records without valid date, state, county, or residue-loading data were not used in final agricultural burning emission inventories for 2018.

Emission factors were identified and compiled by the ETT and the Alternatives to Agricultural Burning Task Team of the FEJF. To estimate emissions, the pollutant-specific emission factors (in pounds of pollutant per ton of residue burned) were multiplied by the residue loading values (tons of residue burned) in the agricultural burning activity database. For single fire events in the database (as opposed to monthly totals), plume characteristics were assigned using the same five-category scheme developed for wildland fire. Due to lower fuel loadings and fire size, agricultural burning events fell into only the smallest three plume classes.

The FEJF resolved the by-county by-month agricultural burning data to a temporally and spatially resolved inventory in a similar way as the 2018 prescribed fire projections. Approximately 48,000 records in the agricultural burning database were daily fire event records and 2,000 records were monthly records. The monthly tonnages were disaggregated to "simulated" fire events. The FEJF intended to represent a variety of fire sizes with these events. Plume classes were determined for the 48,000 daily events. The frequency of occurrence of the three possible classes was recorded along with a nominal emission (in tons $PM_{2.5}$) for each class. This frequency table was used to break the monthly emission totals into a plausible distribution of individual fires.

Simulated agricultural fire events were then merged with the true daily events to complete the refined emission projection. All fire events that did not have a specific date (but were keyed to a month) were randomly assigned a day. Inferring "black-out" periods from the historic daily data, fires were not assigned to particular dates during harvest time or considered a holiday. All fire events, true and simulated, came to the FEJF spatially resolved to the county. Using a geographic information system to map agricultural land cover in every county of the WRAP, fire events were concentrated to the portion of the county classified as agricultural. Fire events were assigned a random latitude and longitude coordinate within the agricultural delineation.

The FEJF devised, through expert opinion, an hourly consumption template for agricultural burning that apportioned daily emissions to the hour of the day. Using the smallest three plume categories and accompanying methods developed for wildland fire, plume top height, bottom height, and percent fumigated into the first layer was assigned to every agricultural fire.

Emission estimates

Averaging across the three 2018 projection scenarios, wildfire represents about one-third, prescribed fire two-thirds, and agricultural burning between one and three percent of all fire emissions. For 2018, $PM_{2.5}$ emissions from wildfire are projected to be most prevalent from late spring to early fall with the majority of the emissions occurring in the month of August. $PM_{2.5}$ emissions from prescribed fire are projected to peak in the spring and fall. Agricultural burning tends to be more equally distributed over the whole year, but has minor peaks in the spring and late summer. The optimal control scenario results in a 13 percent reduction of $PM_{2.5}$ emissions from prescribed burning. The projected $PM_{2.5}$ emissions from agricultural burning differ considerably across the three control scenarios.

Interpretation of the fire emissions data

The 1996 fire emission inventory and 2018 fire emission projections were developed to best satisfy WRAP modeling requirements. The FEJF endeavored to deliver a complete and timely emission inventory product given imperfect science and limited data over the large WRAP domain. There are important caveats and limitations of the inventories. Activity data from jurisdictions without data reporting systems are omitted or may be under-represented. For example, the 1996 emission inventory of prescribed burning lacks data from various counties and rangeland burning. Similarly, agricultural burning activity was not readily and consistently available. Wildfire activity in 1996 was believed to be a drought year "high." A compounding error may be that, as a consequence of wildfire conditions, prescribed fire activity was therefore "low" in 1996. An understanding of the data sources, quality assurance, and correction of some errors not withstanding, source data is incorporated into the emissions databases "as is."

The 2018 projections are based on theoretical policy and technical assumptions. 2018 projections are not grown from the 1996 inventories. Additional uncertainties were introduced in the process of distributing the quarterly FEP emissions and county agricultural emissions over time and space. The FEJF employed custom fire size and plume characteristic algorithms throughout the 1996 and 2018 inventory development. Designed to be reasonable and representative classification schemes, these methods were based on a combination of empirical data and expert judgment. In conclusion, the efforts of the Fire Emissions Joint Forum were dedicated to using professional judgment to select the best or most appropriate methods and parameters to estimate emissions from fire. However, the 1996 and 2018 emission inventories for wildfire, prescribed fires, and agricultural burning are not advanced by the FEJF as being “right” or “correct” in an absolute sense.

1.1.8. Biogenics

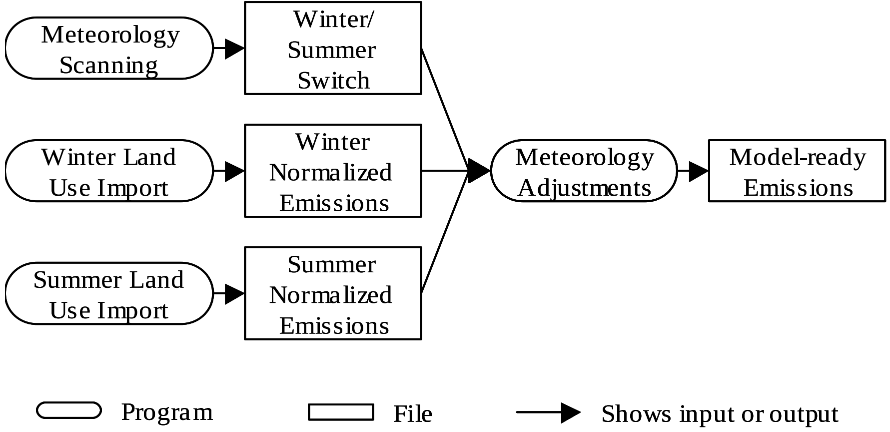
MCNC prepared the model-ready biogenic emissions inventory using the SMOKE version of the Biogenic Emission Inventory System, version 2 (BEIS2), available at: www.epa.gov/asmdnerl/beis_bkgrnd.html. BEIS2 modeling begins with gridded biogenic land use data, biogenic emission factors, and meteorology data. In this section, we first provide a summary of the biogenic emissions inventory development process and input files. Then, we document the land use data file. Lastly, we provide county-total emissions summaries and describe what data are available for states and counties to use for getting further understanding of their §309 biogenic inventories.

Summary of biogenic inventory generation

Biogenic inventories depend heavily on the meteorological conditions of each day and hour. Temperature and solar radiation data are components of the biogenic inventory calculation. For this §309 modeling effort, we used the prognostic meteorological data provided by MCIP for input to the CMAQ. Since the inventory is really a modeling exercise, the inventory is computed by the SMOKE system during emissions processing, and not as a separate inventory preparation process. The main preparation activity is creating the gridded land use data, which in this case was done in another EPA modeling project.

Figure 11 shows the major steps involved in preparation of the biogenic inventory. First, the annual meteorology data are scanned to determine the first and last freeze dates of the year for each grid cell. Then, then land use data are combined with winter emission factors and summer emission factors to create winter and summer normalized emissions of isoprene (ISOP), terpenes (TERP), and other volatile organic compounds (OVOC). These emissions are time independent and do not contain any adjustments for meteorology; this is what is meant by the “ normalized” nomenclature. For each hour of the year, SMOKE makes adjustments to the normalized emissions using temperature and solar radiation data from the MCIP meteorology data used by CMAQ. During these adjustments, SMOKE uses the summer normalized emissions during dates between the last freeze date in the spring, and the first freeze date in the fall; otherwise, the winter normalized emissions are the starting point for this calculation. These calculations convert the time-independent normalized emissions to hour-specific emissions of VOC and NO. Lastly, SMOKE applies a single speciation profile for VOC emissions, to compute the chemical species needed for the air quality model.

Figure 1.1.8.1. Creating biogenic model-ready inventories using SMOKE



The names and origins of the data files that we used for preparing the biogenic inventory are listed next. The CMAQ input meteorology files were used as well, but these are not included in the list because there are too many files to list, and are listed elsewhere in this document.

Table 1.1.8.1. Input files used for creating the biogenic emissions inventory.

File description	**File name**	**Source**	**Date**
BEIS2 gridded land use data	cmaq36beld.5_nhdr	Ellen Kinnee, DynCorp, RTP NC	July 2000
Winter emission factors	bfac.winter.txt	Tom Pierce, U.S. EPA, ORD	November 1998
Summer emission factors	bfac.summer.txt	Tom Pierce, U.S. EPA, ORD	November 1998
Speciation profiles	gspro.cmaq.cb-iv.091101.txt, profile 0000	Tom Pierce, U.S. EPA, ORD	November 1998

Of these files, the only non-standard file is the land use data. The winter and summer emission factors (Pierce et al., 1998) are taken directly from the BEIS2 system available at EPA’s web site (http://www.epa.gov/ttn/chief/emch/models/beis/index.html), although different files names are different in the EPA installation. The winter data are based on the assumption that deciduous vegetation can be mostly ignored and the summer data are based on the assumption of full leaf biomass conditions.

The speciation profile 0000 in the main SMOKE profile file used for this project (and listed above) was simply created from the factors within the BEIS2 code, after having confirmed with Tom Pierce at the U.S. EPA during the development of SMOKE for the Models-3 system. This profile converts the ISOP, TERP, and OVOC emissions available from the emission factors to the model-ready species for the CB-IV chemical mechanism for isoprene (ISOP), aldehydes (ALD2), paraffins (PAR), olefins (OLE), nonreactive VOC (NR), and terpenes (TERPB) needed by CMAQ. The "mole factor" converts the mass-based normalized emissions to emissions in moles by incorporating the molecular weights of isoprene (68.12 g/mole), other VOC (148 g/mole), and terpenes (136.23 g/mole). The "mass factor" is simply the mass fraction of the CMAQ species. Please note that the mole factor is not simply the mass factor divided by the molecular weight.

Table 1.1.8.2. SMOKE-BEIS2 speciation profile 0000 factors

BEIS2 pollutant	BEIS2 species	Mole factor	Mass factor
ISOP	ISOP	1.46799E-02	1
OVOC	NR	3.33784E-03	0.05
OVOC	OLE	3.33784E-03	0.10
OVOC	PAR	5.74324E-02	0.85
TERP	ALD2	1.10108E-02	0.30
TERP	OLE	3.67026E-03	0.1
TERP	PAR	4.40432E-02	0.6
TERP	TERPB	7.34053E-03	1

Land use data

One of the main input files to preparing a biogenic emission inventory is the land use data. The emissions provided for the WRAP cover both of the modeling domains, including all regions of Mexico and Canada within the domain. The land use data are used by SMOKE to compute normalized emissions using Biogenic Emission Inventory System, version 2 (BEIS2) emission factors. DynCorp prepared the land use data used in this project for an EPA project known as the "Proof-of-Concept" modeling project. The file prepared by Dyncorp has an extensive metadata header, which cannot be used in a SMOKE input file. We have included the contents of the header here to document the biogenic land use data used in this project. The following indented text is this header.

> *Introduction:*
>
> This file was designed for use with the Biogenic Emissions Inventory System (BEIS -2) and is being adapted for meteorological processing with the EPA's Third Generation Air Quality Modeling System (MODELS-3).
>
> *Grid Definition:*
>
> CMAQ 36 km national domain has 132 columns and 90 rows. The longitude and latitude of the lower left corner are 132.730 west and 21.350 north, and the upper right corner is 62.609 west and 54.373 north. The size of each grid cell is 36km by 36km.

File Description:

The ASCII data file is free formatted with land use data given for every column and row as shown below.

COL ROW TOT_AREA <repeated for every COL ROW>
FOR_AREA NREC1
SPEC_ID AREA <repeated NREC1>
URBFOR_AREA NREC2
SPEC_ID AREA <repeated NREC2>
AGR_AREA NREC3
SPEC_ID AREA <repeated NREC3>
OTH_AREA NREC4
SPEC_ID AREA <repeated NREC4>

Variable list:

COL	column (integer)
ROW	row number (integer)
TOT_AREA	grid area (hectares)
FOR_AREA	non-urban forest area (hectares)
NRECx	n of records for each x type, where x is each major group
SPEC_ID	4 char id enclosed in single quotes (such as 'Quer')
AREA	area (hectares) for SPEC_ID in group x
UFOR_AREA	total urban forest area (hectares)
AGR_AREA	total agriculture area (hectares)
OTH_AREA	total of remaining areas (hectares)

Notes:

(1) COL and ROW depend on grid definition.
(2) VEGID has mixed upper case and lower case, such as 'Quer'. Descriptions of all current land use classes are given below. However, file structure is designed to allow additional VEGIDs depending on land use classification system.
(3) Sum of areas for each of 4 major groups should equal total area in grid cell. Sum of individual SPEC_IDs should also equal total area in grid cell.
(4) If a major group has NRECx = 0, it will not have any records following.

The remainder of this section of the header that was provided with the original Data from DynCorp is available in Appendix A. It contains a list of VEGIDs values that can be used in the above file format for the biogenic land use file, along with a brief description.

Source of Data:

This land use data set is documented in a paper by Kinnee, et. al., Ecological Applications, 7(1), 1997 pp. 46-58. The source of the data was county resolved data in the US, based on an amalgamation of US Forest Service tree coverage (circa 1990), US Agricultural Census (1987), US urbanized areas (1990 Census Bureau), USGS AVHRR classification (1990), and Environment Canada 1.1 km land use data. As indicated, the data have been resolved to the county level in the US and similar census tract levels in Canada.

Version: July 2000

Biogenic inventory totals

Below are state summaries of January 5th, 1996 and July 3rd, 1996. These emissions totals were used in the inventory summaries provided later in this document. The totals include *only* those emissions that are inside the modeling grid, because they are computed from model-ready, gridded emissions. This will not impact the totals for any of the WRAP states listed in these tables, because these are all entirely within the CMAQ modeling grid.

Table 1.1.8.3. Biogenic emission totals within CMAQ grid for January 5, 1996.

State	**NO** [tons/day]	**ALD2** [tons/day]	**ISOP** [tons/day]	**NR** [tons/day]	**OLE** [tons/day]	**PAR** [tons/day]	**TERPB** [tons/day]
Arizona	88.16	29.59	28.57	5.40	20.66	150.97	98.63
California	72.39	142.63	126.66	26.46	100.47	735.16	475.45
Colorado	28.09	23.30	6.55	3.83	15.43	111.72	77.67
Idaho	25.07	23.70	5.37	4.19	16.29	118.70	78.99
Montana	2.17	14.40	2.27	2.54	9.87	71.92	48.01
Nevada	63.84	4.11	1.46	0.83	3.03	22.33	13.71
New Mexico	93.81	22.32	19.59	4.13	15.70	114.85	74.41
North Dakota	0.00	0.01	0.00	0.00	0.01	0.04	0.03
Oregon	29.86	81.56	20.56	14.83	56.85	415.25	271.87
South Dakota	0.40	0.76	0.08	0.14	0.54	3.97	2.54
Utah	40.51	12.97	4.30	2.22	8.77	63.77	43.24
Washington	16.44	57.44	10.57	10.13	39.40	287.02	191.46
Wyoming	20.12	6.92	0.94	1.12	4.54	32.84	23.05

Table 1.1.8.4. Biogenic emission totals within CMAQ grid for July 3, 1996.

State	**NO** [tons/day]	**ALD2** [tons/day]	**ISOP** [tons/day]	**NR** [tons/day]	**OLE** [tons/day]	**PAR** [tons/day]	**TERPB** [tons/day]
Arizona	243.84	333.70	1205.77	53.61	218.46	1578.79	1112.32
California	170.40	689.31	3684.06	136.96	503.69	3706.96	2297.70
Colorado	207.78	361.21	2344.45	66.94	254.29	1860.44	1204.04
Idaho	125.00	461.61	2746.10	89.00	331.86	2436.17	1538.69
Montana	349.11	606.15	3164.16	108.41	418.86	3055.21	2020.49
Nevada	198.76	141.43	280.42	18.37	83.87	595.07	471.44
New Mexico	254.98	292.20	1114.19	44.96	187.32	1348.74	974.00
North Dakota	271.44	55.58	278.08	6.72	31.96	225.34	185.27
Oregon	100.10	446.38	1871.24	86.71	322.22	2366.85	1487.93
South Dakota	303.56	123.58	335.88	17.59	76.38	546.27	411.92
Utah	141.85	227.12	1283.95	38.35	152.41	1106.23	757.05

Washington	72.68	387.18	1424.72	77.23	283.51	2087.22	1290.61
Wyoming	187.08	281.26	1275.03	45.65	185.06	1338.60	937.54

In addition to these data for sample days, day-specific summaries of biogenic emissions by model-species can be obtained by contacting the Regional Modeling Center through their website at http://pah.cert.ucr.edu/rmc. These totals are created in SMOKE starting with hourly, model-ready data files. SMOKE uses the "cell area" spatial surrogate to determine the fraction of each county within each grid cell, which in turn is used to estimate the county-total and state-total emissions for each day. These values are estimates because the variation within each grid cell is not accounted for when computing these totals.

1.1.9. Windblown Dust

Due to the inaccuracy and unreliability of windblown dust emissions estimation techniques for use in regional-scale air quality modeling, the WRAP Technical Oversight Committee and Technical Forums did not attempt to develop a windblown dust emissions inventory for 1996 or 2018, or to model it for §309. Specifically, the Emission Forum determined that data for the windblown dust component was so unreliable that it would be detrimental to the modeling effort to try to include it. As described earlier, road dust and area source dust were inventoried, and used in the air quality modeling described later in this chapter. No specific control strategy evaluations or determinations of the contribution of windblown dust to Class I area visibility were identified specifically, or required in §309. The WRAP Technical Oversight Committee and Technical Forums understand the importance of properly and accurately characterizing windblown dust in future technical analyses, and they have undertaken several projects to accomplish that task.

The WRAP convened a Dust Expert Panel, and this panel has published a report on various technical issues associated with the characterization of dust emissions, available at www.wrapair.org. The WRAP has created and budgeted for a Dust Emissions Joint Forum (DEJF), with technical and policy development responsibilities within the WRAP organizational structure. The DEJF has a number of projects underway to characterize the ambient constituents of dust as collected from IMPROVE and other aerosol monitors, better understand activity levels and spatial/temporal patterns of the construction and agriculture source sectors, and to classify natural and manmade dust emissions sources. Directly related to windblown dust emissions, the DEJF has contracted ENVIRON Corporation to develop an algorithm and computer code, to generate $PM_{2.5}$ and PM_{10} windblown dust emissions inventories using the wind fields in the regional air quality model. This project will be completed for testing in the air quality model by Fall 2003.

1.2. Overview of Analytical Approach – Modeling

The WRAP Air Quality Modeling Forum selected staff from the University of California at Riverside, ENVIRON Corporation, and Carolina Environmental Programs (formerly MCNC) to work together to set up a Regional Modeling Center (RMC) for the WRAP region. The organizations involved in the RMC had a large number of challenging tasks to accomplish over the past 2 years, including characterizing 1996 base year and 2018 projection year air quality and visibility, for a variety of §309 scenarios. Their efforts are described next.

1.2.1. Processing of emissions inventories in SMOKE

The emissions inventories used in the WRAP modeling summarize the mass of pollutants emitted annually into US counties, Canadian provinces, and Mexican states. Covering each of the major air pollution source categories: on-road mobile, non-road mobile, stationary point, and area sources, the inventories contain emission information for individual pollution generating processes. Emissions models associate the inventories with information about the nature and timing of polluting activities and allocate the pollution data spatially in 3-dimensions. Integrating meteorology, chemistry, and geospatial data, emissions models produce daily estimates of pollution emissions that are resolved in both space and time. MCNC used the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system to prepare daily CMAQ and REMSAD emissions inputs for the entire modeling years of 1996 and 2018 for the respective WRAP modeling domains.

WRAP emissions forum contractors provided MCNC with SMOKE-ready inventories and tabulated summaries of the inventory data for quality assurance (QA) purposes. MCNC provided all of the SMOKE ancillary input files, such as the chemical and temporal allocation inputs, used for the WRAP emissions modeling. Most of these non-inventory SMOKE input files originated from the US EPA Office of Air Quality Planning and Standards (OAQPS). MCNC made some slight modification to these files based on the inventory data used for the WRAP modeling. Details on all of the input files, the scripts used to run SMOKE, the configuration and set-up of SMOKE on the RMC computers, and pitfalls encountered during the emissions generation process are provided in the following sections. Discussion about the QA procedures taken to ensure the accuracy of the emissions generation process is provided below.

Table 1.2.1.1. WRAP emissions scenarios used in most current modeling[+]

Release Date	Simulation	Version Tag	Source category	Description (includes inventory files used in the simulation)
01/21/02	1996 REMSAD Base case f	Us36f		The inventory configuration for CMAQ base case f applies to these emissions; final set of 1996 REMSAD emissions
06/20/02	1996 CMAQ Base case g	wrap96g		Typical-year average wildfires, agricultural burning, and prescribed fires replace the actual 1996 fires, and revised road dust inventory replaces the NEI96 road dust; current 1996 base case emissions used for CMAQ modeling
			area	ar96_wrap_073001.ida ar96_wrapTier2.nei96.060801.ida ar96_eastus+can.nei96_nwrap.060801.ida ar96_Mexico_060701.ida armb96_Canada_060801.ida
			point	pt96_wrap_102901a.ida pt96_wrap_102901b.ida pt96_wrap_102901c.ida pt96_wrap_102901d.ida ptinv_eastus.net96.ida_nwrap.txt pt96_Mexico_061101.ida
			on-road mobile	ca_or96_{season}.ida wrap_or96_{season}ida Vmt9631x.nei_Tier1.ida Vmt9631x.nei_Tier2.ida Vmt9631x.nei_east.ida mb96h{MON}_Tier1.ida mb96h{MON}_Tier2.122101.ida mb96h{MON}_east.122101.ida (NOTE: inadvertent double-counting of SO_2, NH_3, $PM_{2.5}$, and PM_{10} for all WRAP states except CA)
			nonroad mobile	wrap_nr96_{season}.ida nr96_wrapTier1.nei96.ida nr96_wrapTier2.nei96.060801.ida nr96_east.nei96.060801.ida
			road dust	unp_96emis{season}_env.ida pvd_rd96emis_env.ida
			wildfire	ptinv_wrap96.wf.043002.{month}.ida ptday_wf_043002.mod.{month}.ida pthour_wf_043002.mod.{month}.ida
			agricultural fire	ptinv_wrap96.agbase.043002.{month}.ida ptday_agbase_043002.mod.{month}.ida pthour_agbase_043002.mod.{month}.ida
			prescribed fire	ptinv_wrap96.rxbase.043002.{month}.ida ptday_rxbase_043002.mod.{month}.ida pthour_rxbase_043002.mod.{month}.ida

Release Date	Simulation	Version Tag	Source category	Description (includes inventory files used in the simulation)
			biogenic	cmaq36beld.5_nhdr
06/06/02	2018 CMAQ Base case g	wrap2018g		Typical-year average wildfires, agricultural burning, and prescribed fires replace the actual 1996 fires, and revised road dust inventory replaces the NEI96 road dust; current 2018 base case emissions used for CMAQ modeling.
			area	ar2018_wrap_021102.ida arinv_g+c.east_nei.wrap96f_2018.ida ar96_g+c_Mexico_wrap96f_2018.ida armb96_g+c_Canada_wrap96f_2018.ida
			point	pt2018_wrap_noSO2_02112.ida ptinv_g+c.nei_east_noSO2.wrap96f_2018.ida pt2018_wrap_SO2_02112.ida ptinv_g+c.nei_east_SO2.wrap96f_2018.ida
			on-road mobile	ca_or18_{season}.ida wrap_or18_{season}ida Vmt9631x.nei_Tier1.wrap96f_2018.ida Vmt9631x.nei_Tier2.wrap96f_2018.ida Vmt9631x.nei_east.wrap96f_2018.ida mbinv.nei_Tier1.wrap96f_2018.{month}.ida mbinv.nei_Tier2.wrap96f_2018.{month}.ida mbinv.nei_east.wrap96f_2018.{month}.ida
			nonroad mobile	wrap_nr18_season.ida nrinv.wrapTier1.nei.wrap96f_2018.ida nrinv.wrapTier2.nei.wrap96f_2018.ida nrinv.east_nei.wrap96f_2018.ida
			road dust	rd.v4_2018emis{season}.wrap.tfrac.ida rd.v4_2018emis{season}.Tier1.tfrac.ida rd.v4_2018emis{season}.Tier2.tfrac.ida rd.v4_2018emis{season}.eastUS.tfrac.ida
			wildfire	ptinv_wrap96.wf.043002.{month}.ida ptday_wf_043002.mod.{month}.ida pthour_wf_043002.mod.{month}.ida
			agricultural fire	ptinv_wrap96.agbase.043002.{month}.ida ptday_agbase_043002.mod.{month}.ida pthour_agbase_043002.mod.{month}.ida
			prescribed fire	ptinv_wrap96.rxbase.043002.{month}.ida ptday_rxbase_043002.mod.{month}.ida pthour_rxbase_043002.mod.{month}.ida
			biogenic	cmaq36beld.5_nhdr
02/18/03	2018 Base case g2	wrap2018_ g2		CMAQ base case wrap2018g with corrected layer fractions for point sources
03/03/03	2018 Base case g3	wrap2018_ g3		CMAQ base case g2 with agricultural fires from July 31, 2002, distribution

Release Date	Simulation	Version Tag	Source category	Description (includes inventory files used in the simulation)
06/01/02	2108 CMAQ Milestone Point SO_2 sensitivity	wrap2018g_ ptSO2_ milestone		Case wrap2018g emissions with milestone stationary source SO_2 controls in the 9 Grand Canyon states, and BART controls in the rest of the WRAP, tier 1, and tier 2 states applied
			point	pt2018_wrap_noSO2_02112.ida ptinv_g+c.nei_east_noSO2.wrap96f_2018.ida milestone_smk_pt_051402.wrap_gc.ida commd_cntrl_smk_pt_2018_052302.wrap_other.ida commd_cntrl_smk_pt_2018_052302.wrap_t1.ida commd_cntrl_smk_pt_2018_052302.wrap_t2.ida ptinv_g+c.nei_east_SO2.wrap96f_2018.ida
			all other sources	same as 2018 CMAQ Base case wrap2018g
06/01/02	2018 CMAQ BART Point SO_2 sensitivity	wrap2018g_ ptSO2_ BART		Case w36g emissions with BART stationary source SO_2 controls in the WRAP, tier 1, and tier 2 states applied
			point	pt2018_wrap_noSO2_02112.ida ptinv_g+c.nei_east_noSO2.wrap96f_2018.ida commd_cntrl_smk_pt_2018_040302.wrap_other.ida ptinv_g+c.nei_east_SO2.wrap96f_2018.ida
			all other sources	same as 2018 CMAQ Base case wrap2018g
06/01/02	2018 CMAQ BART with Uncertainty Point SO_2 sensitivity	wrap2018g_ ptSO2_ BART Uncrty		Case w36g emissions with BART with uncertainty stationary source SO_2 controls in the 9 Grand Canyon states, and BART controls in the rest of the WRAP, tier 1, and Tier2 states applied
			point	pt2018_wrap_noSO2_0211-2.ida ptinv_g+c.nei_east_noSO2.wrap96f_2018.ida commd_cntrl_uncertainty_smk_pt_2018_052302.wrap_gc.ida commd_cntrl_smk_pt_2018_052302.wrap_other.ida commd_cntrl_smk_pt_2018_052302.wrap_t1.ida commd_cntrl_smk_pt_2018_052302.wrap_t2.ida ptinv_g+c.nei_east_SO2.wrap96f_2018.ida
			all other sources	same as 2018 CMAQ Base case wrap2018g
10/07/02	2018 CMAQ WRAP mobile sensitivity	wrap2018g_ NoGCMb		Case wrap2018g emissions with all on-road and nonroad mobile emissions in the 9 Grand Canyon states reduced to zero
			all sources$^+$	same as 2018 CMAQ Base case wrap2018g
10/07/02	2018 CMAQ CA mobile sensitivity	wrap2018g_ NoCAMb		Case wrap2018g emissions with all on-road and nonroad mobile emissions in California reduced to zero
			all sources$^+$	same as 2018 CMAQ Base case wrap2018g

Release Date	Simulation	Version Tag	Source category	Description (includes inventory files used in the simulation)
10/07/02	2018 CMAQ Phoenix mobile sensitivity	wrap2018g_ NoPhnxAZ Mb		Case wrap2018g emissions with all on-road and nonroad mobile emissions in Maricopa County, Arizona, reduced to zero
			all sources[+]	same as 2018 CMAQ Base case wrap2018g
10/07/02	2018 CMAQ Las Vegas mobile sensitivity	wrap2018g_ NoVegas Mb		Case wrap2018g emissions with all on-road and nonroad mobile emissions in Clark County, Nevada, reduced to zero
			all sources[+]	same as 2018 CMAQ Base case wrap2018g
12/03/02	2018 Grand Canyon point source NO$_x$ sensitivity	wrap2018g_ GCptNOx ctl		Case wrap2018g emissions with Grand Canyon state point sources emitting greater than 100 TPY NOx have their NOx emissions reduced by 50%
			all sources[‡]	same as 2018 CMAQ Base case wrap2018g
11/27/02	2018 Grand Canyon point source PM$_{10}$ sensitivity	wrap2018g_ GCptPM10 ctl		Case wrap2018g emissions with Grand Canyon state point sources emitting greater than 100 TPY PM10 have their PM10 emissions reduced by 50%
			all sources[‡]	same as 2018 CMAQ Base case wrap2018g
12/12/02	2018 Grand Canyon point source sensitivity	wrap2018g_ GCptNOx PMinc		Case wrap2018g emissions with all Grand Canyon state point source PM$_{10}$ and NO$_x$ increased by 25%
			all sources[‡]	same as 2018 CMAQ Base case wrap2018g
01/10/03	2018 All control sensitivity	wrap2018g_ P2all		Case wrap2018g emissions with Pollution Prevention (P2) point sources and optimal smoke management agricultural and prescribed fires
			point	pt2018_wrap_P2.112702.ida ptinv_g+c.nei_east_noSO2.wrap96f_2018.ida ptinv_g+c.nei_east_SO2.wrap96f_2018.ida
			agricultural fire	ptinv_wrap96.agosm.073102.{month}.ida ptday_agosm_073102.mod.{month}.ida pthour_agosm_073102.mod.{month}.ida (NOTE: fires dropped from optimal SMOKE management inadvertently from May 6-31)
			prescribed fire	ptinv_wrap96.rxosm.043002.{month}.ida ptday_rxosm_043002.mod.{month}.ida pthour_rxosm_043002.mod.{month}.ida
			all other sources	same as 2018 CMAQ Base case wrap2018g

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[*] Details on state and local control program assumptions for all WRAP emissions modeling scenarios are listed in Appendix A

[+] Mobile-source controls were applied to the SMOKE intermediate files; no manipulation of the raw inventories occurred.

[‡] Point-source controls were applied to the SMOKE intermediate files; no manipulation of the raw inventories occurred.

Emission Inventories

The WRAP provided modified versions of the National Emissions Inventory 1996 (NEI96) to MCNC for use in generating emissions for the CMAQ and REMSAD modeling. MCNC used the unmodified NEI96 to provide emissions data for the areas of the domain not covered by the WRAP inventories. The four major regions of the WRAP CMAQ modeling domain are:

Region	States
WRAP	AZ, CA, CO, ID, MT, NV, NM, ND, OR, SD, UT, WA, WY
Tier 1	KS, NE, OK, TX
Tier 2	AR, IA, LA, MN, MO
East US	IL, MI, MS, TN, WI

Table 12 lists the inventory data sources for the four regions of the WRAP modeling domain. "WRAP" refers to the modified WRAP inventories and "NEI96" refers to the unmodified National Emissions Inventory for 1996.

Table 1.2.1.2. Sources of emissions inventory data for the WRAP modeling domain regions

Year	Inventory	WRAP	Tier 1	Tier 2	East US
1996	Area	WRAP	WRAP	WRAP	NEI96
	Non-Road Mb	WRAP	NEI96	NEI96	NEI96
	On-Road Mb	WRAP	NEI96	NEI96	NEI96
	CA On-Road Mb	WRAP (CA)			
	Point	WRAP	WRAP	WRAP	NEI96
	Fire	WRAP			
2018	Area	WRAP	WRAP	WRAP	NEI96
	Road Dust	WRAP	WRAP	WRAP	WRAP
	Non-Road Mb	WRAP	NEI96	NEI96	NEI96
	On-Road Mb	WRAP	NEI96	NEI96	NEI96
	CA On-Road Mb	WRAP (CA)			
	Point	WRAP	WRAP	WRAP	NEI96
	Fire	WRAP			

Details on the exact nomenclature, creation dates, included pollutants, the number of records, and the name of the contractor who prepared the data for all of the emissions inventory files are tabulated in Appendix C of the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis contract (Houyoux, 2003). The files named in Appendix C are consistent with the files listed in Table 2 above.

Tables 1.2.1.3a-c through 1.2.1.4a-c contain pie charts of the 1996 and 2018 emissions by source category for all inventory pollutants for the WRAP modeling domain. Appendices F and G of the Final Report: WRAP Regional Modeling Center – Short-Term Modeling

Analysis contract (Houyoux, 2003) contain the annual inventory totals for 1996 and 2018 respectively for each of the major source categories.

Table 1.2.1.3a.1996 CO, NO_x, and VOC base emissions contributions by source category

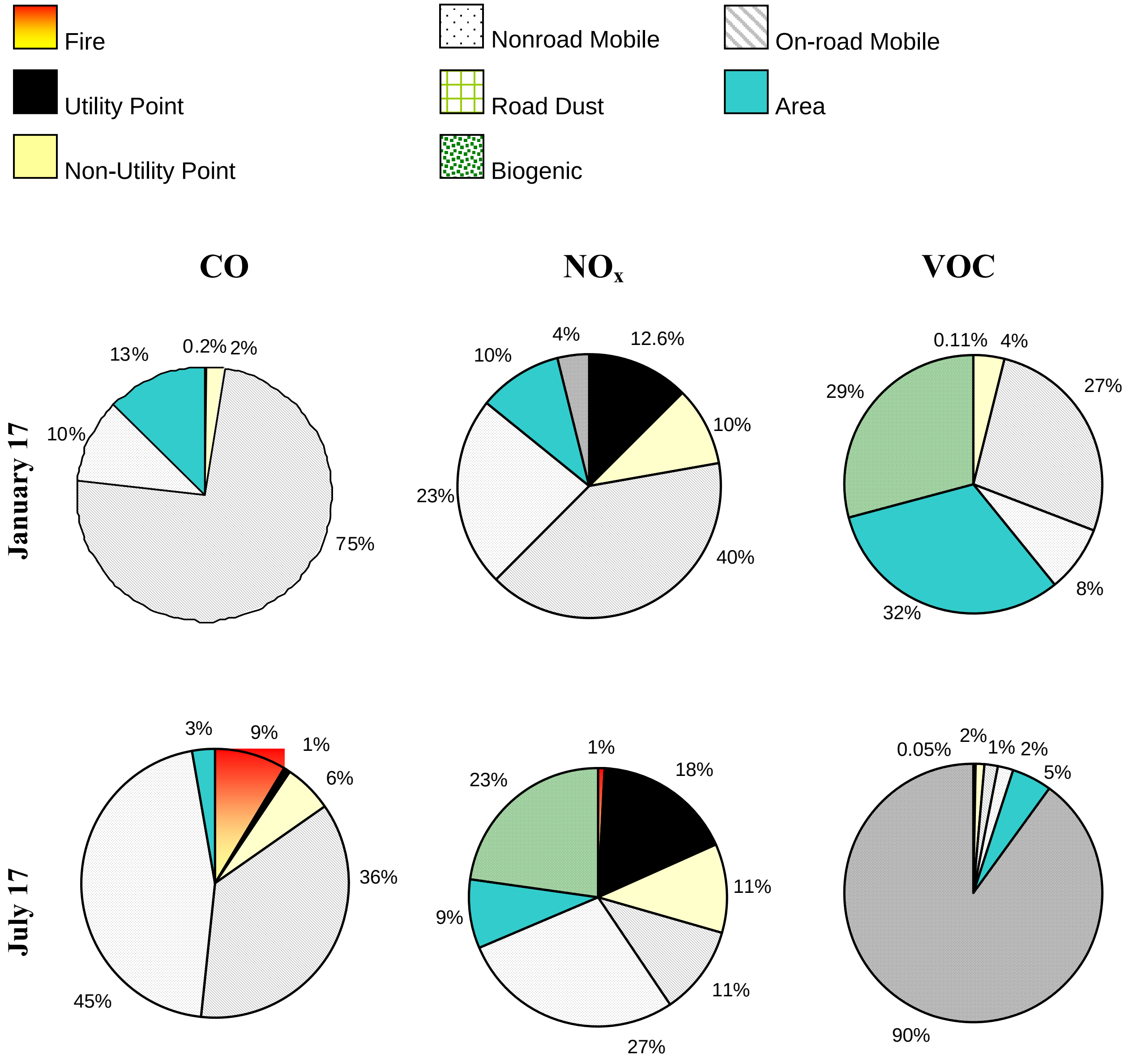


Table 1.2.1.3b.1996 PM_{10}, $PM_{2.5}$, and PMC base emissions contributions by source category

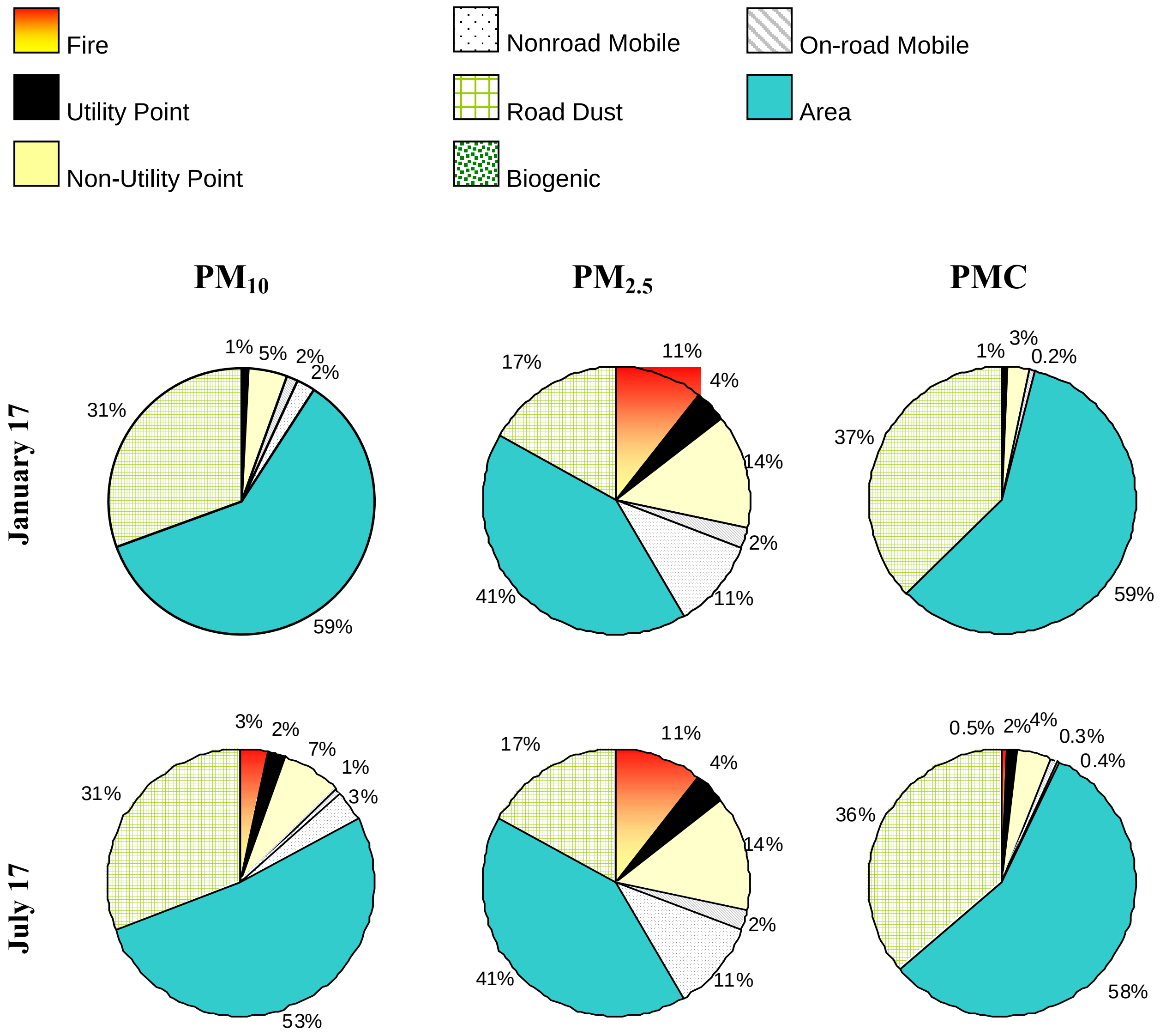


Table 1.2.1.3c.1996 NH_3 and SO_2 emissions contributions by source category

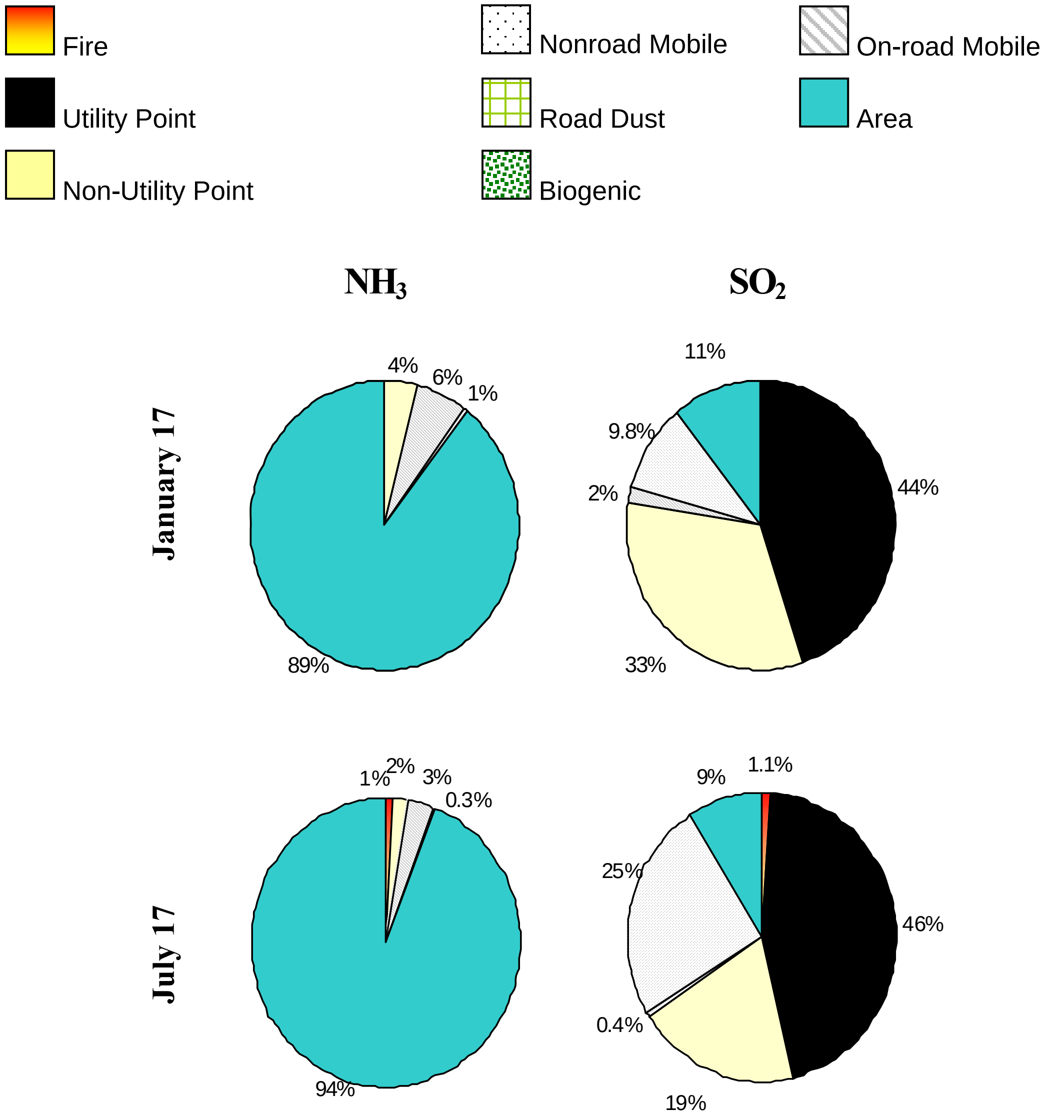


Table 1.2.1.4a.2018 CO, NO_x, and VOC base emissions contributions by source category

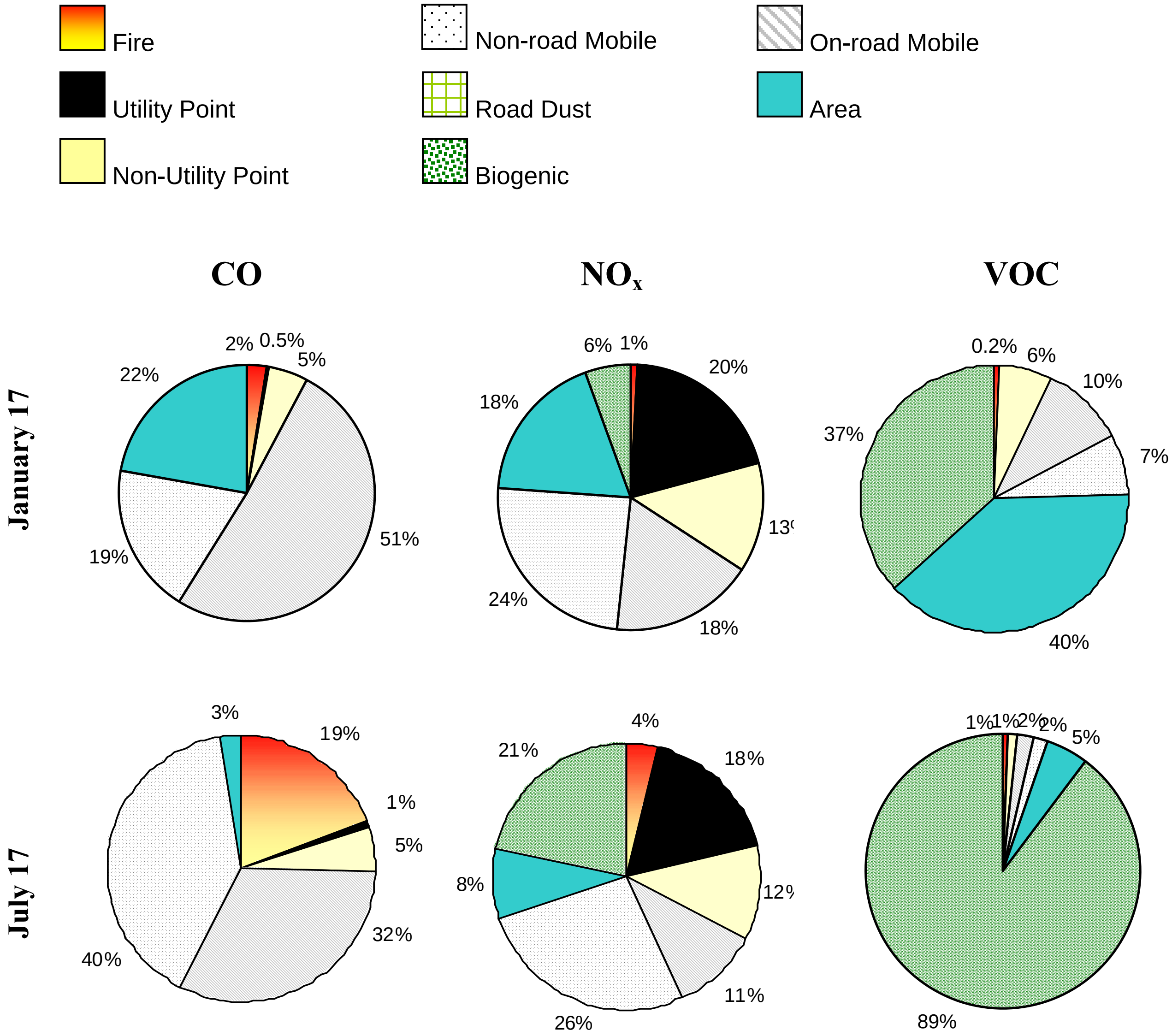


Table 1.2.1.4b.2018 PM_{10}, $PM_{2.5}$, and PMC base emissions contributions by source category

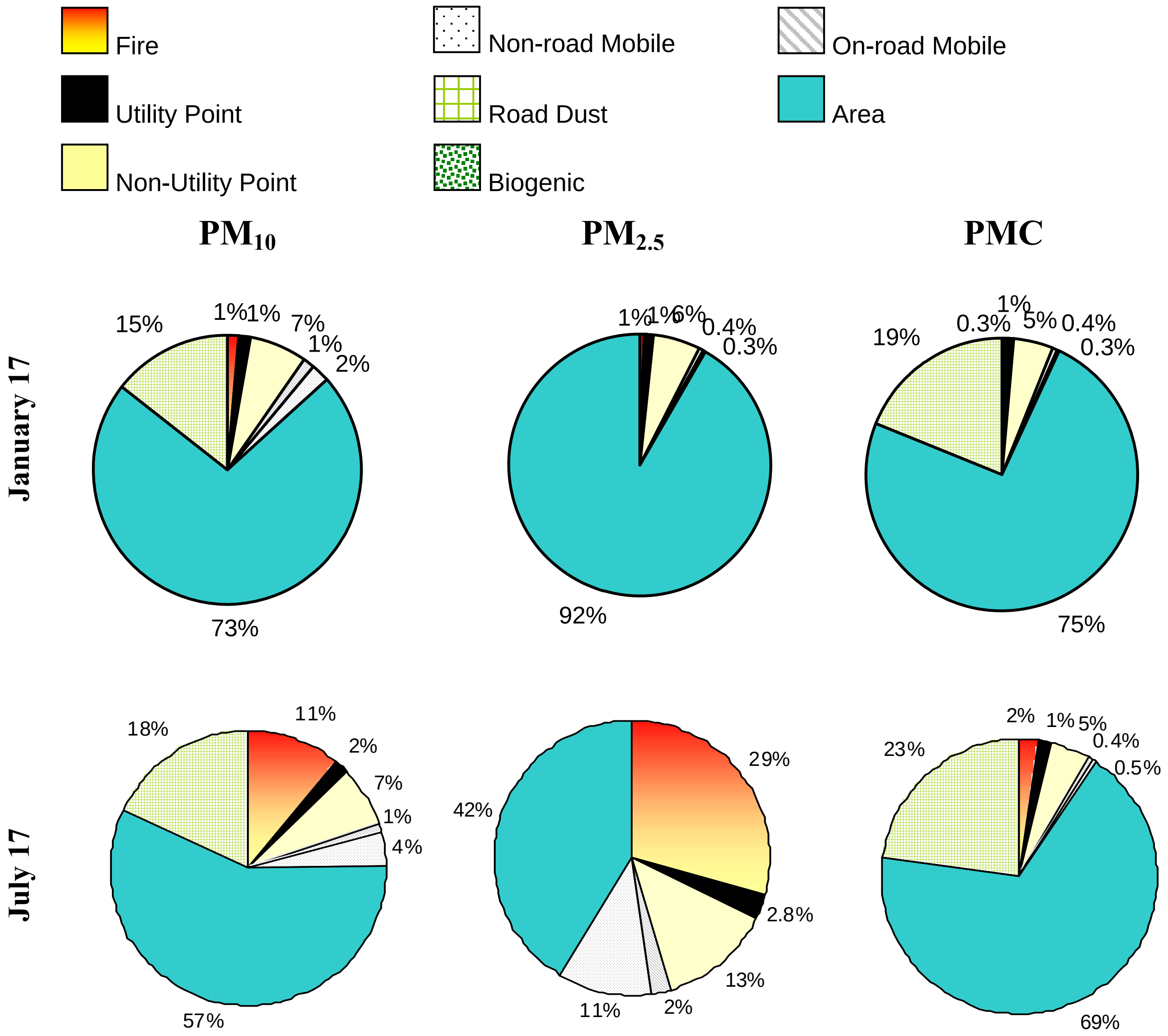
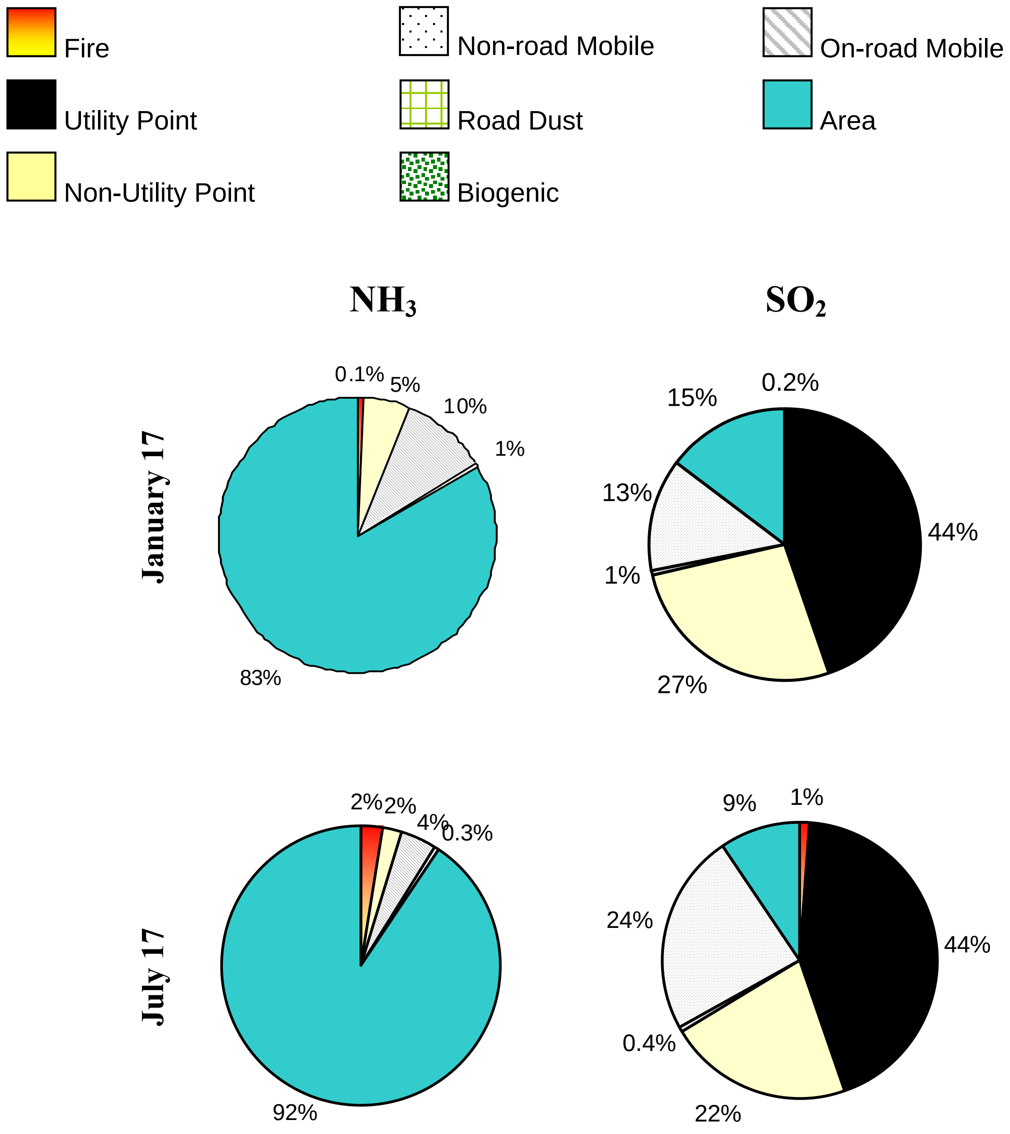


Table 1.2.1.4c.2018 NH_3 and SO_2 emissions contributions by source category



Processing with SMOKE

MCNC installed SMOKE at the WRAP RMC for large-scale batch processing. The operational scripts contained in the WRAP installation are organized by the number of times that each SMOKE program is used in creating an annual emissions data set. An alternative set-up is to organize the scripts by source category. The operational scripts reduce the interaction between the modeler and the software, thus automating more of the tasks and reducing the sources of human error. The following subsection provides details about each of the operational scripts used in creating the emissions datasets for WRAP modeling.

The base SMOKE installation directory for the scripts on the WRAP RMC system is:

/home/aqm2/edss/subsys/smokev1.3.2/scripts/run

Details on the exact SMOKE settings used in these scripts are included in Appendix H of the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis contract (Houyoux, 2003). Appendix I includes instructions on how to use the SMOKE scripts installed on the RMC computers to create an annual emissions dataset for CMAQ or REMSAD.

SMOKE Scripts

The scripts are the interface that emissions modelers use to run SMOKE, and are therefore the items of practical importance for anyone wanting to simply reproduce the work performed as part of this contract. For this project, we created many SMOKE scripts to run the required emissions modeling cases, which we describe in this subsection, and in the following table.

There are five types of scripts used in the SMOKE installation created for the WRAP RMC:

- Scripts that run programs once per model year
- Scripts that run programs once per month
- Scripts that run programs for each day
- Scripts that run programs for holidays
- Scripts that grow from 1996 to 2018

Table 1.2.1.5. Summary of SMOKE scripts

Year and case	**Source categories**	**Path under $SCRIPTS/ run**	**Script names**
1996 REMSAD Base, us36e	All	remsad	smkinven_wrap.remsad_us36.mole.cmd monthly_wrap.remsad_us36.mole.cmd daily_mrg_wrap.remsad_us36.cmd ptsrce_wrap96_remsad_us36.job
1996 CMAQ Base case f, w36f	All	base_96	smkinven_wrap96.cmaq_w36.mole.cmd monthly_wrap96.cmaq_w36.mole.cmd daily_mrg_wrap96.cmaq_w36.cmd In addition, the following scripts were derived from the base distribution files for processing specific inventory categories. They were created when we had to do reruns of some source categories. mobile/ monthly_mb_wrap96.cmaq_w36.mole.cmd

Year and case	Source categories	Path under $SCRIPTS/ run	Script names
			point/ smkinven_wrap96.cmaq_w36.mole.cmd_pt point/ monthly_pt_wrap1996.cmaq_w36.mole.cmd point/ daily_pt_wrap1996.cmaq_w36.cmd area/ smkinven_wrap96.cmaq_w36.mole.rpt_ar
2018 CMAQ Base, w36g	All	base_2018	smkinven_wrap2018.cmaq_w36.mole.cmd monthly_wrap2018.cmaq_w36.mole.cmd daily_wrap2018.cmaq_w36.mole.cmd
	stationary area, road dust, nonroad mobile	area	smkinven_ar_wrap2018.cmaq_w36.mole.cmd monthly_ar_wrap2018.cmaq_w36.mole.cmd daily_ar_wrap2018.cmaq_w36.cmd smkinven_ar_wrap2018.cmaq_w36.mole.rpt
	on-road mobile	mobile	monthly_mb_wrap2018.cmaq_w36.mole.cmd daily_mb_wrap2018.cmaq_w36.cmd
	point sources, SO$_2$ and no-SO$_2$ files	point	smkinven_pt_wrap2018.cmaq_w36.mole.cmd monthly_pt_wrap2018.cmaq_w36.mole.cmd daily_pt_wrap2018.cmaq_w36.cmd smkinven_pt_wrap2018.cmaq_w36.mole.rpt
	wildfire, agricultural fire, prescribed fire	FireScens	smkinven_agbsm_wrap2018.cmaq_w36.mole.cmd smkinven_agosm_wrap2018.cmaq_w36.mole.cmd smkinven_rxbsm_wrap2018.cmaq_w36.mole.cmd smkinven_rxosm_wrap2018.cmaq_w36.mole.cmd smkinven_wf_wrap2018.cmaq_w36.mole.cmd daily_pt_wrap2018.cmaq_w36.cmd.agbsm daily_pt_wrap2018.cmaq_w36.cmd.agosm daily_pt_wrap2018.cmaq_w36.cmd.rxbsm daily_pt_wrap2018.cmaq_w36.cmd.rxosm daily_pt_wrap2018.cmaq_w36.cmd.wf daily_mrggrid_wrap2018.cmaq_w36.bsm daily_mrggrid_wrap2018.cmaq_w36.osm
2018 w36g_ptSO2_ milestone	Point	PtControls	smkinven_wrap2018.cmaq_w36.mole.cmd_milestone monthly_wrap2018.cmaq_w36.mole.cmd_milestone daily_merge_wrap2018.cmaq_w36.milestone (Smkmerge) daily_mrggrid_wrap2018.cmaq_w36.milestone (Mrggrid)
2018 w36g_ptSO2_ BART	Point	PtControls	smkinven_wrap2018.cmaq_w36.mole.cmd_BART monthly_wrap2018.cmaq_w36.mole.cmd_BART daily_merge_wrap2018.cmaq_w36.BART daily_mrggrid_wrap2018.cmaq_w36.BART
2018 w36g_ptSO2_ BART Uncrty	Point	PtControls	smkinven_wrap2018.cmaq_w36.mole.cmd_BARTwUncrty monthly_wrap2018.cmaq_w36.mole.cmd_BARTwUncrty daily_merge_wrap2018.cmaq_w36.BARTwUncrty daily_mrggrid_wrap2018.cmaq_w36.BARTwUncrty
2018 w36g_NoGCMb	Mobile	MbControls	smkinven_wrap2018.cmaq_w36.mole.cmd_noGCMb monthly_wrap.cmaq_w36.mole.cmd_noGCMb daily_wrap2018.cmaq_w36.cmd_noGCMb daily_mrggrid_wrap2018.cmaq_w36.base_noGCMb

Year and case	Source categories	Path under $SCRIPTS/ run	Script names
2018 w36g_NoCAMb	Mobile	MbControls	smkinven_wrap2018.cmaq_w36.mole.cmd_noCAMb monthly_wrap.cmaq_w36.mole.cmd_noCAMb daily_wrap2018.cmaq_w36.cmd_noCAMb daily_mrggrid_wrap2018.cmaq_w36.base_noCAMb
2018 w36g_NoPhnxAZMb	Mobile	MbControls	smkinven_wrap2018.cmaq_w36.mole.cmd_NoPhnxAZMb monthly_wrap.cmaq_w36.mole.cmd_ NoPhnxAZMb daily_wrap2018.cmaq_w36.cmd_ NoPhnxAZMb daily_mrggrid_wrap2018.cmaq_w36.base_ NoPhnxAZMb
2018 w36g_NoVegasMb	Mobile	MbControls	smkinven_wrap2018.cmaq_w36.mole.cmd_NoVegasMb monthly_wrap.cmaq_w36.mole.cmd_ NoVegasMb daily_wrap2018.cmaq_w36.cmd_ NoVegasMb daily_mrggrid_wrap2018.cmaq_w36.base_ NoVegasMb
2018 w36g_GCNOxCtl	Point	PtControls	smkinven_wrap2018.cmaq_w36.mole.cmd_GCNOxCtl monthly_wrap2018.cmaq_w36.mole.cmd_GCNOxCtl daily_merge_wrap2018.cmaq_w36.GCNOxCtl daily_mrggrid_wrap2018.cmaq_w36.GCNOxCtl
2018 w36g_GCPM10Ctl	Point	PtControls	smkinven_wrap2018.cmaq_w36.mole.cmd_GCPM10Ctl monthly_wrap2018.cmaq_w36.mole.cmd_GCPM10Ctl daily_merge_wrap2018.cmaq_w36.GCPM10Ctl daily_mrggrid_wrap2018.cmaq_w36.GCPM10Ctl
2018 w36g_GCNOxPMinc	Point	PtControls	smkinven_wrap2018.cmaq_w36.mole.cmd_GCNOxPMinc monthly_wrap2018.cmaq_w36.mole.cmd_GCNOxPMinc daily_merge_wrap2018.cmaq_w36.GCNOxPMinc daily_mrggrid_wrap2018.cmaq_w36.GCNOxPMinc
20918 w36g_P2	Point	P2	smkinven_wrap2018.cmaq_w36.mole.cmd_P2 monthly_pt_wrap2018.cmaq_w36.mole.cmd.P2 daily_pt_wrap2018.cmaq_w36.cmd.P2 daily_mrggrid_wrap2018.cmaq_w36.cmd_cntl_all

The following section explains the four types of scripts in more detail. The scripts are presented in the order in which they should be run. For more details on how to use these scripts, please refer to Appendix J.

Scripts that run programs once per model year

The scripts in Table 15 with names starting with "smkinven" run SMOKE processing steps that are needed only once per model year. These scripts run the following processing steps:

- Import the raw stationary area, nonroad mobile, and/or point inventories (uses Smkinven program)
- Import the biogenic land use (for 1996 base case only) (uses Rawbio program)
- Compute matrices for chemical speciation (program Spcmat) and gridding (program Grdmat) for stationary area, nonroad mobile, and point sources

- Create import QA reports to summarize inventories by state, county, SCC, and various other combinations (uses Smkreport program)
- For 2018 cases, compute matrices for growth and controls (uses Cntlmat and Grwinven programs)

Scripts that run programs once per month

The scripts in Table 1.2.1.5 with names starting with “monthly” run SMOKE processing steps, which need to be run once per model month. These scripts run the following processing steps:

- Import the raw on-road mobile-source precomputed emissions inventory and VMT (uses Smkinven program)
- Import any fire data for each month (only for scripts that include fire processing) (uses Smkinven program)
- Compute matrices for chemical speciation (Spcmat program) and gridding (Grdmat program) for on-road precomputed emissions mobile sources
- Compute matrices for chemical speciation (Spcmat program) and gridding (Grdmat program) for fire data (only for scripts that include fire processing)
- Calculate hourly emissions for representative Mondays, weekdays, Saturdays, and Sundays for stationary area, nonroad mobile, and point sources; Table 16 lists the Julian dates in each month used as representative days (uses Temporal program)
- Create import QA reports to summarize the on-road mobile precomputed emissions inventory by state, county, SCC, and various other combinations (uses Smkreport program)
- Create additional QA reports of hourly emissions for stationary area, nonroad mobile, on-road mobile, and point sources for representative Mondays, weekdays, Saturdays, and Sundays; these reports include inventory summaries by state, county, SCC and other combinations (uses Smkreport program).

Table 1.2.1.6. Julian dates of representative Saturday, Sunday, Weekday, Monday days

Month	Saturday	Sunday	Weekday	Monday
January	1996006	1996007	1996005	1996008
February	1996034	1996035	1996037	1996036
March	1996062	1996063	1996065	1996064
April	1996097	1996098	1996094	1996093
May	1996125	1996126	1996128	1996127
June	1996160	1996161	1996156	1996155
July	1996188	1996189	1996185	1996190
August	1996216	1996217	1996219	1996218
September	1996252	1996252	1996254	1996253
October	1996279	1996280	1996282	1996281
November	1996307	1996308	1996310	1996309
December	1996342	1996343	1996345	1996344

Scripts that run programs for each day

There are two types of scripts that run SMOKE programs for each day. These all start with the name “daily”. The daily scripts other than those starting with “daily_mrggrid” (which are a special case, described below the bulleted list) run the following processing steps:

- Compute hourly on-road emissions for every day for precomputed emissions and VMT (uses Premobl, Emisfac, and Temporal programs)
- Compute hourly fire emissions (for fire-specific scripts only) (uses Temporal program)
- Compute point-source plume rise for point sources and fire sources (uses Laypoint program)
- Combine hourly emissions with matrices to create hourly, gridded, and chemically speciated emissions; a separate file is created for each day and source category for stationary area, nonroad mobile, on-road mobile, point, and all fire sources (uses Smkmerge program)
- Calculate hourly, gridded, and chemically speciated biogenic emissions based on previously imported land use data and meteorology data (base year only) (uses Tmpbio program of SMOKE/BEIS2)

Once all of the hourly, gridded, and chemically speciated files have been created for either CMAQ or REMSAD, the “daily_mrggrid” script performs the following step:

- Combine separate hourly, gridded, and chemically speciated emissions files for each source category into the single 3-D file needed for CMAQ or the low-level emissions and ASCII point source elevated file needed for REMSAD

Scripts that run programs for holidays

Because we are using a Monday-weekday-Saturday-Sunday approach, we must also make sure to run holidays separately. This is because the holidays are assigned Sunday diurnal profiles, regardless of the day of the week on which the holiday falls. Because our inventory covers five time zones but all output uses the same GMT time zone, we must also run for the day *after* each holidays to capture those holiday emissions at the end of the holiday in the local time zone that appear in the next day's model input file in GMT. Holidays must be run for all cases that use the MWDSS approach, which excludes only biogenic sources. On-road mobile sources that use MOBILE5b (or MOBILE6 in newer versions of SMOKE) are also excluded from this step.

The holiday script needs to be run only once to allocate holiday emissions to Sunday temporal profiles because it runs the necessary SMOKE programs for all of the holiday days.

Table 1.2.1.7. 1996 holidays for Task 3

Holiday	Dates	Julian Dates
New Year's Day	January 1	1996001
Good Friday	April 14	1996096
Memorial Day	May 29	1996148
Independence Day	July 4	1996186
Labor Day	September 4	1996246
Thanksgiving Weekend	November 23, 24	1996333, 1996334
Christmas Eve	December 24	1996359
Christmas	December 25	1996360

SMOKE Ancillary Inputs

Appendix D of the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003) lists the final set of ancillary input files used to create the CMAQ and REMSAD emissions with SMOKE. We started with SMOKE version 1.3 ancillary files, and made some modifications based on (1) changes requested by the WRAP Modeling Forum or required because of the needs of the modeling effort, and (2) errors found in the files. Some of these files went through several versions before the creation of the final file. Other than some modifications to the files to accommodate new inventory sources (e.g., fires), we maintained consistency in the ancillary files throughout all of the emissions modeling.

In this subsection, we provide further description of changes that we made to SMOKE version 1.3 files. We document how the spatial surrogates were provided by EMC, and how we updated the temporal assignments and speciation assignments. In addition, we also identify files that we did not update after errors had been found because the files had already been used in the base case modeling and needed to continue to be used "as is" for the sake of consistency with all of the modeling runs.

MCNC created the SMOKE spatial surrogates for specific parts of the domain for both the REMSAD and CMAQ emissions modeling. For the REMSAD domain, we used a Geographic Information System (GIS)-based tool to overlay a 36-km resolution grid over the map of the WRAP region and assign the 20-category Models-3 spatial surrogate fractions to the grid. The table below lists the data sources that we used to obtain GIS shape files for deriving the SMOKE surrogate data. We created spatial surrogates for Canada and Mexico from the same database, but used only a single surrogate, population, to spatially allocate these emissions. The spatial surrogate names, codes, and data sources are available in the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003).

We modified the spatial cross-reference file for the California on-road mobile inventory. Since the inventory does not include road types as part of the identification of emissions, and since the default SMOKE spatial cross-reference assigns surrogates based on road type, we had to add entries so that the emissions would not be dropped. Population was the only available surrogate that we could use to assign on-road mobile emissions that are defined only by their vehicle type. Had road class been a part of the emissions inventory, we could have used the road-class-specific surrogates, which would certainly have provided a more robust spatial allocation approach for California on-road emissions.

MCNC added information to the EPA temporal allocation cross-reference and profile files to accommodate the WRAP inventories. Temporal information for Canada, in the form of region-specific profiles, was added to the files. We used Canadian profile data developed by the EPA for the CMAQ Proof-of-Concept modeling study (EPA, 2000). The WRAP Fire Forum supplied daily temporal profiles for wildfires, agricultural fires, and prescribed fire sources that capture the differences in the diurnal distribution of emissions for the three types of fires. We added these fire profiles to the SMOKE temporal input files. The profiles can be found in the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003).

For the seasonal mobile inventories, the cross-references for several on-road and nonroad mobile SCCs for the WRAP states were converted to uniform monthly profiles to account for the inherent seasonality in the inventories. The Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003) lists the on-road and nonroad mobile SCCs for the WRAP states that received uniform monthly profiles. We did this because it is unnecessary to apply a monthly profile to these emissions when the emissions are already being provided for each month or season.

On July 10, 2002, MCNC was notified of a bug in the temporal profiles used for the WRAP modeling that affects the monthly allocation of stationary point source emissions. The temporal profiles used in the WRAP modeling contain incorrect monthly profile codes for some point source SCCs. These incorrect codes affect the seasonal and monthly allocation of the emissions from some point sources. The magnitude of the effects from this bug by SCC is available on the website for the Community Modeling and Analysis System (CMAS) center at http://www.emc.mcnc.org/product_qa/bugzilla/show_bug.cgi?id=403. The “bug report 403” attachment can be downloaded for review by interested parties.

In addition, MCNC modified the chemical allocation profiles to account for the information contained in the WRAP inventories. Since the WRAP on-road mobile inventories used prespeciated $PM_{2.5}$ emissions, the chemical allocation profiles for both CMAQ and REMSAD had to be modified to speciate these emissions correctly. Table 1.2.1.8 lists the pollutants contained in the prespeciated mobile inventories and the CMAQ and REMSAD input pollutants to which they were mapped. Based on recommendations from the Fire Forum, EMC also slightly modified the $PM_{2.5}$ chemical profiles for fire sources. Table 1.2.1.9 presents the chemical allocation profiles used for fire sources in the WRAP Jumpstart modeling.

Table 1.2.1.8. WRAP mobile-source PM chemical species

Nonspeciated Pollutant	WRAP Mobile PM Pollutant	CMAQ Input Pollutant	Nonspeciated Pollutant
PMC (PM10-PM2_5)	PMC_PRE	PMC	PMCOARS
PM2_5	EC2_5	PEC	PEC
	OC2_5	POA	POA
	SO4_2_5	PSO4	GSO4
	OTHER2_5	PMFINE	PMFINE

Table 1.2.1.9. WRAP fire-source PM chemical profiles

Source	Profile #	PEC	PMFINE	PNO3	POA	PSO4
Agricultural Fire	22070	0.09	0.274	0	0.636	0
Wildfire/Prescribed Fire	22080	0.262	0.2663	0.0063	0.45	0.0154

General processing issues

SMOKE has four different processing approaches: processing for area, on-road mobile, point, and biogenic sources. The WRAP source categories map to these processing approaches is shown next.

Table 1.2.1.10. WRAP source categories mapped to processing approaches in SMOKE

WRAP Source category	SMOKE processing approach
Stationary area	Area
Nonroad mobile	Area
Road dust	Area

On-road mobile	On-road mobile
Point	Point
Fire (wildfire, agricultural fire, and prescribed fire)	Point
Biogenics	Biogenics

Each SMOKE processing approach is for a specific SMOKE source category, which has its own source characteristics. These correspond to the identifiers used in creating the emission inventory (e.g. state/county FIPS code and SCC). The source categories also have source attributes, which are the other useful data in the emission inventories that SMOKE uses for processing them (e.g., point-source flue gas exit height and temperature). Source characteristics *define* the sources as area, mobile, or point sources for SMOKE processing and also distinguish one source in the inventory from another. Source attributes are additional data about the source that do not contribute to the source's uniqueness in SMOKE.

In SMOKE, each source category is defined by source characteristics, as follows:

- **Area sources** are defined by (1) country, state, and county codes, (2) SCC codes, or optionally (3) grid cell only.
- **On-road mobile sources** are defined by (1) country, state, and county codes, (2) SCC codes, and optionally (3) link codes.
- **Point sources** are defined by (1) country, state, and county codes, (2) plant codes, and (3) characteristics 1 through 5, one of which should be the SCC code.
- **Biogenic sources** are defined differently depending on the type of processing that you are using. They can be defined either by (1) country, state, and county codes and (2) land use code, or by (1) grid cell and (2) land use code.

In the following subsections, we describe the processing that we performed for each of the WRAP source categories. A great deal of additional information on the processing for each of these source categories is available in the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003). This additional information includes a list of all scripts, the major steps taken during processing, and figures describing the connections between SMOKE programs and files.

Area source emissions processing

MCNC divided the stationary area source inventory into area sources, road dust sources, and Mexico sources to facilitate the creation of emissions sensitivities by the WRAP. The area source inventory contains US area sources and Canadian area, non-road, and on-road mobile sources. WRAP inventory contractors supplied area inventories for the WRAP, Tier 1, and Tier 2 states. MCNC used the NEI96 for the inventories in the Eastern US tier of states. The road dust inventory being used in the final modeling is the fourth version of the inventory and is composed of paved and unpaved road emissions. An improvement over the default road dust emissions of the NEI96, the WRAP road dust inventory uses a more robust method to account for the transportable fraction of the emissions as compared to the flat 75% reduction used for the NEI96 (ENVIRON, 2002). WRAP inventory contractors supplied the road dust inventory for the entire WRAP domain. The Mexico inventory is a combination of stationary, area, nonroad, and on-road mobile sources for the three northwestern Mexican states, Chihuahua, Baja Norte, and Sonora. All of these area source components are combined at the final step in the processing to represent the WRAP area source emissions.

Nonroad mobile source emissions processing

Consistent with the technique of dividing the area source inventory into several specific inventories, MCNC processed the non-road mobile inventory as a stand-alone inventory component. The WRAP mobile source inventory contractor supplied seasonal, non-road emissions for the 13 WRAP states; MCNC used the NEI96 to represent the inventory for the rest of the domain. The inventory developed by the inventory contractor contained 4-digit SCCs for the non-road sources, rather than the standard 10-digit SCCs normally used. While the 4-digit SCCs capture the engine types (i.e. 4-stroke vs. 2-stroke) of the non-road sources, they do not capture the specific vehicle types (i.e. motorcycles vs. snowmobiles). Before processing the non-road mobile inventory, MCNC explored the effects of using general, 4-digit SCC descriptions of the non-road sources. It was determined and documented in the email titled “WRAP NONROAD emissions, 2-stroke versus 4-stroke speciation” sent on February 13, 2002 by Marc Houyoux, that the effects of the 4-digit SCCs are of less concern on speciation and temporal allocation than are the effects of using antiquated modeling profiles. Although prespeciated, particulate, nonroad mobile data were provided by the nonroad mobile contractor, we are using the non-prespeciated data only with speciation profiles. Future configurations should consider using the prespeciated particulate emissions data as is done with on-road mobile sources.

On-road mobile source emissions processing

MCNC received monthly on-road mobile inventories from the WRAP inventory contractor for the 13 WRAP states. The inventory contained two files per season, a California-only inventory and an inventory for the “other-12” WRAP states. The California inventory does not associate road-types with vehicle classes while the “other-12” on-road inventory does. MCNC combined these WRAP inventories with monthly NEI96 heavy-duty diesel inventories for the Tier 1, Tier 2, and Eastern US states to get coverage for the entire WRAP domain. The WRAP on-road mobile PM inventory differed from the rest of the inventories by containing pre-speciated $PM_{2.5}$ emissions. MCNC created a new set of speciation profiles that simply mapped the pre-speciated emissions directly to CMAQ-ready pollutants. MCNC hybridized both the temporal and chemical allocation profiles to account for the combination of the WRAP and NEI inventories. The application of uniform monthly temporal profiles accounted for the inherent temporal variability contained in the seasonal and monthly inventories. MCNC created new speciation profiles that combined the standard $PM_{2.5}$ profiles with the pre-speciated $PM_{2.5}$ mapping.

Point source emissions processing including utilities

Point-source processing for the WRAP includes emissions for the point-source inventory, wildfire inventory, prescribed (Rx) burning inventory, and agricultural (ag) burning inventory. The point-source inventory included Mexican point sources but no Canadian point sources. The processing approaches differed for 1996 and 2018; below we describe the 1996 approach, then the 2018 approach.

For 1996, the approach and data changed as we proceeded. Initially, we processed all point sources and wildfire sources together in a single run. These wildfires were a 1996-specific set of fires, and the other fire sources were not available. By the end of the project, we separated the point inventories from the fire processing, so that is what we present here; this is the 1996 “base g” case. This case uses the 1996 point sources, the “typical year” wildfires provided in April 2002, the Base Smoke Management (BSM) agricultural fires, and BSM prescribed fires. The files and processing approaches are described in further detail in the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, M., 2003).

For the many point-source control strategies, we configured the point-source processing in many groups to facilitate reusing as much previous work as possible in creating the controlled inventories.

In SMOKE, one of the major factors distinguishing stationary-source inventory processing from the other source categories is the calculation by SMOKE of plume rise and subsequent allocation of the emissions vertically. In addition, point-source processing can include day-specific and hour-specific emission inventories and hour-specific precomputed plume rise. Also, the elevated point sources are treated differently for CMAQ and REMSAD processing.

Fire emissions processing

MCNC instrumented SMOKE to treat fire emissions as point sources. The technique developed for the WRAP modeling differs from the traditional fire emissions processing methods of treating fires in the area source inventory. The new method locates the fires using a latitude-longitude coordinate and imports pre-computed plume rise information to determine the vertical allocation of the fire emissions. SMOKE uses daily fire inventory data and newly developed hourly temporal profiles to model the fires. In addition, hourly plume rise information, supplied to MCNC by the fire inventory contractor, provides data for allocating the emissions to the different vertical model layers. There were a few issues that MCNC resolved with the fire inventories and ancillary input data before the final set of fire emissions was created.

Biogenic emissions processing

Please refer to the earlier section about the biogenic emission inventory development, which covers the methods for processing the data.

Emissions processing quality assurance

The two primary areas of focus in the emissions QA process are the input data and the emissions software. We employed three types of QA checks throughout the emissions generation process for the WRAP Jumpstart modeling to address these areas:

- *Qualitative analyses* of different visualizations of spatially and temporally allocated pollutants are useful in determining whether there were problems with the input data. The location of urban centers and highways, temporal profiles for the different source categories, and the omission of areas within the domain are all checked in this analysis.
- *Quantitative analyses* of the inventory reports confirm that SMOKE correctly processed the information contained in the raw inventories. Comparisons of the inventory reports with the reports generated by the Smkreport module allow QA checks of the emissions generation process from the SCC level up to the level of fully merged emissions for the entire domain.
- *Random and frequent checks* of the SMOKE log files can uncover problems with the SMOKE inputs, the processing, and scripting.

The Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis WRAP Jumpstart (Houyoux, 2003) discusses these steps in more detail. The proper combination of the three steps leads to a high-quality emissions data set in the context of SMOKE processing. While errors in the raw inventory and/or SMOKE inputs may manifest themselves in the CMAQ-ready emissions, thoroughly performing these steps will ensure that SMOKE correctly processed the inventory information and reproduced the input data.

Qualitative Analysis

Importing the model-ready emissions into the Package for Analysis and Visualization of Environmental data (PAVE) and looking at both the spatial and temporal distributions of the emissions provides insight into the quality and accuracy of the emissions inputs. By visualizing the model-ready emissions with the scale on the plots set to a very low value, one can determine whether data for sections of the modeling domain are omitted from the raw inventory. Checking for point, area, and biogenic emissions over water cells, and confirming the presence of elevated emissions over urban areas, are checks for correct spatial allocation of the emissions. Comparing pollutant time-series in different source categories for different days of the week and different months checks the accuracy of the diurnal, weekend/weekday, and seasonal temporal allocation in the emissions. Several QA analyses based on visualizations of the emissions are possible, but as we were concerned more with the accuracy of SMOKE than with the accuracy of the input data, we performed only cursory qualitative checks using PAVE visualizations.

Quantitative Analysis

Throughout the §309 modeling effort, the WRAP inventory contractors supplied us with reports summarizing the raw inventories from which SMOKE generated the CMAQ-ready emissions. We used the state totals in these reports to check how accurately SMOKE reproduced the inventories. By comparing these totals to the Smkreport outputs after each step in the emissions generation process, we tracked the performance of SMOKE and were able to discover problems as they arose. We are confident that SMOKE imported the raw inventory correctly. Additionally, we are confident that the temporal, spatial, and chemical allocation occurred in conjunction with the SMOKE input files used in the Section 309 modeling. Our standard quantitative QA procedures described above do not cover the allocation of point-source emissions to the vertical model layers. As this step in the emissions modeling process introduced errors in the model-ready emissions, it has now been added to the standard QA package.

The Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003) contains examples of QA plots that represent the products that we used to check that SMOKE correctly processed the raw emissions inventories. SMOKE generates reports following each major step in the process of converting annual average emissions inventories to temporally, chemically, and spatially allocated model-ready emissions. These reports are compared back to the inventory contractor totals qualitatively through normalized differences using graphical plots. Creating these plots for every pollutant for each new inventory quickly helps to ensure that SMOKE correctly processes the inventory data and the corresponding input files.

SMOKE Log Files

The first step in troubleshooting problems encountered while creating model-ready emissions with SMOKE is to inspect the log files generated during each step in the process. If any step in the SMOKE processing fails, the log files contain the information needed to track down the reasons for the failure. The warnings and errors printed in the SMOKE log files offer a wealth of information for determining the causes of most problems encountered during SMOKE processing.

Errors in SMOKE processing occur as both “show-stoppers”, problems that prevent SMOKE from completing successfully, and as the assimilation of incorrect input files. SMOKE handles showstoppers by printing out detailed descriptions of the cause of the errors in the log files. Unexpected results in SMOKE outputs are often due to either lack of information in the SMOKE input files and the subsequent assignment of default profiles, or the assignment of wrong input files. For example, after adding the new set of temporal profiles for wildfire sources to the SMOKE temporal allocation inputs and reprocessing the fire sources, the temporal profile for wildfires did not change in the applicable grid cells. Inspection of the log files uncovered that the revised temporal allocation file had not been applied. We corrected this problem by updating the setting for the point-source temporal allocation inputs and rerunning SMOKE. This last type of QA check is not as specific as the qualitative and quantitative checks and is most often used in determining the cause of run-time errors. There are times, however, when it becomes necessary to confirm that we used the correct input files to generate of a set of emissions. The SMOKE log files present a concise summary of the entire set of information used to create the model-ready emissions.

WRAP Emissions QA

Appendices E and F of the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003) list the annual totals for all of the states in the WRAP domain for each of the following base inventory scenarios:

- 1996 Base scenario point, area, on-road mobile, non-road mobile, road dust
- 2018 Base scenario point, area, on-road mobile, non-road mobile, road dust

Appendix G of the same report lists the annual totals for all of the states in the WRAP domain for each of the following sensitivity inventory scenarios:

- 2018 SO_2 Milestone/Annex scenario point
- 2018 BART scenario point
- 2018 BART with Uncertainty scenario point
- 2018 Zero Grand Canyon States Mobile scenario on-road and nonroad mobile
- 2018 Zero California Mobile scenario on-road and nonroad mobile
- 2018 Zero Phoenix, AZ, MSA Mobile scenario on-road and nonroad mobile
- 2018 Zero Las Vegas, NV, MSA Mobile scenario on-road and nonroad mobile
- 2018 Stationary source 50% NO_x reductions
- 2018 Stationary source 50% PM_{10} reductions
- 2018 Stationary source 25% NO_x + PM_{10} increases
- 2018 Pollution Prevention point

We used the inventory summaries in Appendices E through G to generate regression plots for checking that SMOKE processed these inventories correctly.

Appendix H of the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis contract (Houyoux, 2003) contains emissions density plots. These plots are best viewed in color.

Problems encountered and remaining processing issues

The emissions processing required for this project has been the most complicated effort performed by the authors to date. The complexity arose from the necessity of having to merge several different inventories (e.g., WRAP, NEI, California) provided by several different sources (e.g., PES, Pechan, ENVIRON, EPA) at several different time resolutions (e.g., day-specific, hour-specific, annual, seasonal, and monthly). Furthermore, the inventories were frequently in error themselves, were provided at different times and in numerous different versions, and were often provided without detailed descriptions of what the inventories contained or how the inventories were intended to be different from previous versions. In some cases, the formats of the inputs were not acceptable, requiring our having to reformat them before using them.

Needless to say, such unprecedented complexity resulted in discovery of many shortcomings with our emissions processing system and quality assurance techniques. These problems resulted in wasted modeling and analysis time when it was discovered, for example, that the emissions data being used in CMAQ were invalid for a critical case. In this subsection, we document the critical problems that we encountered as well as problems remaining at the end of the modeling effort.

A number of problems were found and resolved as part of the modeling effort. These are documented in Section 3.4.1 of the Final Report: WRAP Regional Modeling Center – Short-Term Modeling Analysis (Houyoux, 2003). In addition, some of the problems found were not resolved by the completion of the Jumpstart project, and these are documented in Section 3.4.2 of that same report. It is important for future WRAP modeling efforts that these issues be considered and addressed.

1.2.2. MM5/MCIP meteorological processing

Models-3 Community Multiscale Air Quality (CMAQ) modeling system is designed to simulate multiscale (urban and regional) and multi-pollutant (oxidants, acid deposition, and particulates) air quality problems. Before running the CMAQ Chemical Transport Model (CCTM), information about the coordinates and grid as well as the meteorological data has to be processed and provided. In addition, CCTM-ready meteorological data are needed to process emissions files.

The Regional Modeling Center (RMC) uses the Meteorology-Chemistry Interface Processor (MCIP) version 1 provided in the CMAQ modeling system to link Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Modeling System Generation 5 (MM5) with CCTM to provide a complete set of meteorological data needed for air quality simulation. Some other necessary parameters not available from the meteorological model are estimated with appropriate diagnostic algorithms in the MCIP processor. The key functions of MCIP include:

1. Reading in meteorological model (MM5) output files
2. Extracting meteorological data for CCTM window domain
3. Collapsing of meteorological profile data if coarse vertical resolution data is requested
4. Computation or passing through surface and PBL parameters
5. Diagnosing of cloud parameters
6. Computation of species-specific dry deposition velocities
7. Generation of coordinate dependent meteorological data for the generalized coordinate CCTM simulation
8. Output meteorological data in Models-3 I/O API format which is required for operations of Models-3 CMAQ processors

MM5

The dynamic meteorology model selected with the Community Multiscale Air Quality (CMAQ) Model is the Fifth-Generation Pennsylvania State University/National Center for Atmospheric Research (NCAR) Mesoscale Model (Grell et. al., 1994). The MM5 is a three-dimensional prognostic meteorological model available not only for meteorology studies but also for air quality studies. The MM5 was originally developed in the early 70's and has undergone many changes to increase and broaden its capabilities. It was used to simulate meteorology at 108-km and 36-km resolutions for calendar year 1996 over the entire continental United States and portions of Canada, Mexico, and the Atlantic and Pacific Oceans (Olerud et al., 1999).

The version of MM5 used to simulate the 1996 meteorology is MM5 version 2.12 with modifications to allow the output of vertical exchange coefficient (Kv) for use in air quality models. The domain for MM5 covers the entire United States at 108-km and 36-km resolutions, and the western half of the United States at 12-km resolution. Some of the physics used in the simulation include one-way nesting; nonhydrostatic dynamics; four-dimensional data assimilation of wind, temperature, and mixing ratio; explicit treatment of moisture; cumulus subgrid cloud parameterization with Anthes-Kuo scheme in the 108-km grid and Kain-Fritsch scheme in the 36-km grid; vertical mixing of momentum in the mixed layer; planetary boundary layer (PBL) parameterization; atmospheric radiation; sea ice treatment; and snow cover. Atmospheric radiation was adjusted for cloud effects.

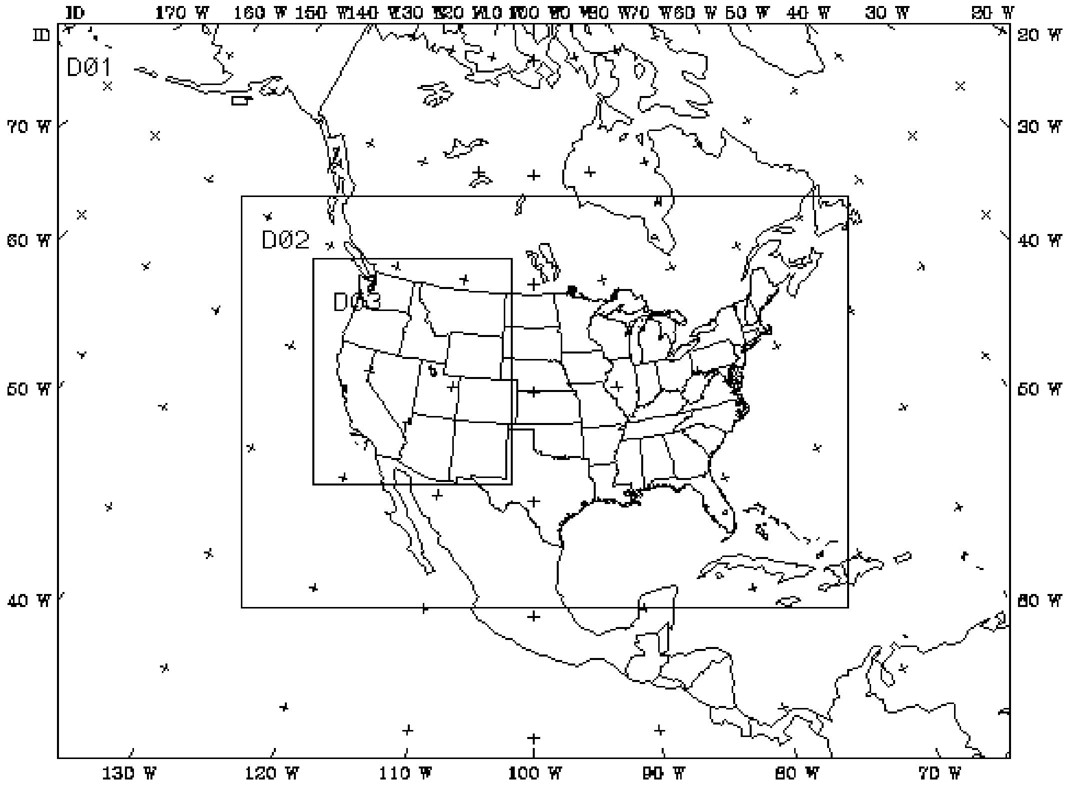
The MM5 version 2-12 was run to generate a set of annual meteorological data for 1996. The simulations consisted of multiple nested domains of 108-km and 36-km horizontal resolution on a Lambert Conformal Projection (LCP) coordinate system with 23 vertical sigma layers extending from the surface to the 100 mb pressure level (Table 21). In addition to the standard MM5 output, a supplemental output data file was generated providing the Planetary Boundary Layer (PBL) heights and the vertical exchange coefficients, for both heat and momentum. The total file size for 1996 MM5 36-km horizontal resolution output files are 195 Gb. The extent of the MM5 36-km resolution domain is shown below (domain D02). This MM5 36-km domain is configured using a grid with 168 columns and 114 rows.

Table 1.2.2.1. Vertical structure of the MM5 modeling system

Level	Sigma	Height (m)	Pressure (mb)	Thickness (m)
0	1.000	0.0	1000.0	0.0
1	0.995	38.0	995.5	38.0
2	0.988	91.5	989.2	53.5
3	0.980	152.9	982.0	61.4
4	0.970	230.3	973.0	77.3
5	0.956	339.5	960.4	109.2
6	0.938	481.6	944.2	142.1
7	0.916	658.1	924.4	176.4
8	0.893	845.8	903.7	187.8
9	0.868	1053.9	881.2	208.1
10	0.839	1300.7	855.1	246.8
11	0.808	1571.4	827.2	270.7
12	0.777	1849.6	799.3	278.2
13	0.744	2154.5	769.6	304.9
14	0.702	2556.6	731.8	402.1
15	0.648	3099.0	683.2	542.4

Level	Sigma	Height (m)	Pressure (mb)	Thickness (m)
16	0.582	3805.8	623.8	706.8
17	0.500	4763.7	550.0	957.9
18	0.400	6082.5	460.0	1318.8
19	0.300	7627.9	370.0	1545.5
20	0.200	9510.5	280.0	1882.6
21	0.120	11465.1	208.0	1954.6
22	0.052	13750.2	146.0	2285.1
23	0.000	16262.4	100.0	2512.1

Figure 1.2.2.1. MM5 domains for the 1996 simulations



After the simulation was completed, statistical measures of surface variables for the entire analysis domain were examined. Point-specific performance using time series was also examined. Overall, for the entire year, MM5 performed reasonably well. It does a good job in replicating the mean flow on a cell-to-cell basis. However, the 36-km resolution used in this modeling is clearly insufficient to resolve the complicated orographically-induced flows near the surface over the western United States. The wind fields aloft are modeled well everywhere. The surface moisture fields are modeled exceptionally well. Major synoptic features were captured, and only a couple errors stood out (Olerud et al., 1999). Finally, because MM5 is not built for air quality modeling purposes, MCIP processor was used to provide a complete set of meteorological data needed for air quality simulations.

CCTM-ready Meteorological Data Preparation

The RMC uses the Meteorology-Chemical Interface Processor (MCIP) to derive the CCTM-ready meteorological data for the WRAP domain for the entire year of 1996. The CCTM-ready meteorological input files were derived from the Penn State/NCAR Mesoscale Meteorological Model (MM5) runs developed by the EPA. In running MCIP, offsets for the CMAQ domain relative to the MM5 domain (in terms of number of columns and rows) are specified to be 11 columns and 21 rows. (It is desirable that the offsets be at least 4-6 grid cells to avoid any boundary interferences.) The WRAP modeling domain is large enough to address the needs of stakeholders and consists of 85 columns and 95 rows. The WRAP CMAQ modeling domain is limited by the extent of the MM5 modeling domain.

The CCTM-ready meteorological input files derived from the MM5 data include three-dimensional gridded fields of u- and v-wind components, temperatures, water vapor, cloud water content, rain water content and vertical exchange coefficients. The MCIP processor also developed two-dimensional gridded fields of terrain and land use information, surface temperatures and pressures as well as rainfall rates.

The vertical domain used in the MM5 extends from the surface to the 100-mb pressure surface and is discretized using 23 layers of variable thickness. The first layer has a thickness of approximately 38 m. The vertical structure is described below in further detail, where the heights are calculated using standard atmospheric conditions.

Table 1.2.2.2. Vertical Layer Structure – Sigma Coordinates and Layer Thickness

	Sigma Coordinates		Layer Thickness (m)	
Layers	**Layer_23**	**Layer_18**	**Layer_23**	**Layer_18**
23	0	0	16262.4	16262.4
22	0.052		13750.2	
21	0.12		11465.1	
20	0.2	0.2	9510.5	9510.5
19	0.3		7627.9	
18	0.4		6082.5	
17	0.5	0.5	4763.7	4763.7
16	0.582		3805.8	
15	0.648	0.648	3099	3099
14	0.702	0.702	2556.6	2556.6
13	0.744	0.744	2154.5	2154.5
12	0.777	0.777	1849.6	1849.6
11	0.808	0.808	1571.4	1571.4
10	0.839	0.839	1300.7	1300.7

9	0.868	0.868	1053.9	1053.9
8	0.893	0.893	845.8	845.8
7	0.916	0.916	658.1	658.1
6	0.938	0.938	481.6	481.6
5	0.956	0.956	339.5	339.5
4	0.97	0.97	230.3	230.3
3	0.98	0.98	152.9	152.9
2	0.988	0.988	91.5	91.5
1	0.995	0.995	38	38
0	1	1	0	0

Vertical layer collapsing has been used in a number of modeling studies to reduce computational costs associated with using larger number of vertical layers. However, as meteorological data from various layers are collapsed into a single layer, consistency problems may occur for the resulting profile and the model results will vary considerably. While the layer collapsing procedure raises data quality issues such as different cloud parameterization, change in vertical distribution of emissions, and different plume rise from point sources, RMC understands the need for compromises, given the stringent timelines and budget for this study. The WRAP Modeling Forum has suggested collapsing the data from 23 layers to 16 layers. The RMC had conducted a total of seven sensitivity studies to examine the impact on layer collapsing to model simulations. The entire month of July was simulated in each sensitivity study. The seven sensitivity studies include collapsing the 23 MM5 layers into 8, 12, 16 (two different configurations), 17 18, and 23 CMAQ layers. The CMAQ emissions input files are processed according to each layer structure.

The RMC compared the differences of the CCTM results from the various vertical layer structures and looked at differences in tile plots and four statistical measurements including the maximum, minimum, mean, and standard deviation of the differences of each grid cell in the surface layer. We also examined the mean normalized bias error and the mean normalized gross error. Based upon the results from the seven sensitivity runs, the RMC has chosen a 18-layer structure (Table 1.2.2.3) capable of adequately resolving diurnal variations in boundary layer growth and mixing processes therein, wind shear, as well as transport to and from the free troposphere and consequent effects of long-range transport processes. The 18-layer structure also gives us good model simulation results (compared with 23-layer structure) with less computation time required.

Table 1.2.2.3. Vertical Layer Structure – Sigma Coordinates and Layer Thickness

	Sigma Coordinates		**Layer Thickness (m)**	
Layers	**Layer_23**	**Layer_18**	**Layer_23**	**Layer_18**
23	0	0	16262.4	16262.4
22	0.052		13750.2	
21	0.12		11465.1	
20	0.2	0.2	9510.5	9510.5
19	0.3		7627.9	
18	0.4		6082.5	
17	0.5	0.5	4763.7	4763.7
16	0.582		3805.8	
15	0.648	0.648	3099	3099
14	0.702	0.702	2556.6	2556.6
13	0.744	0.744	2154.5	2154.5
12	0.777	0.777	1849.6	1849.6
11	0.808	0.808	1571.4	1571.4
10	0.839	0.839	1300.7	1300.7
9	0.868	0.868	1053.9	1053.9
8	0.893	0.893	845.8	845.8
7	0.916	0.916	658.1	658.1
6	0.938	0.938	481.6	481.6
5	0.956	0.956	339.5	339.5
4	0.97	0.97	230.3	230.3
3	0.98	0.98	152.9	152.9
2	0.988	0.988	91.5	91.5
1	0.995	0.995	38	38
0	1	1	0	0

Recently, EPA has announced that various algorithmic bugs had been discovered in the MCIP versions 1 and 2. The most severe problem is the incorrect layer collapsing for UHAT_S and VHAT_T (horizontal wind components coupled with map-scaled factors on the Arakawa-C grid). In MCIP v.1 that the RMC used to process MM5 files and MCIP v.2 that EPA released well after the WRAP modeling is under way, the two fields were inadvertently filled directly from the lowest NLAYS layers of the input met data set without collapsing (ftp://falcon.emc.mcnc.org/MODELS/MCIP/RELEASE_NOTES). By conducting the seven vertical layer collapsing sensitivity studies prior to select the final vertical structure for WRAP CMAQ modeling, the RMC was able to avoid the impacts of the bugs.

By collapsing the vertical structure from 23 into 18 layers, the computation costs for CCTM (per day) are reduced from approximately 4 hour (23-layers) to 3.5 hours (18-layers). The half an hour reduction for each model day may not seem significant, but it translates into 7.6 calendar days (183 hours) when the RMC runs CCTM for a whole year. The total file size for 1996 CCTM-ready meteorology files (entire year) is about 133 Gb.

MCIP Configurations

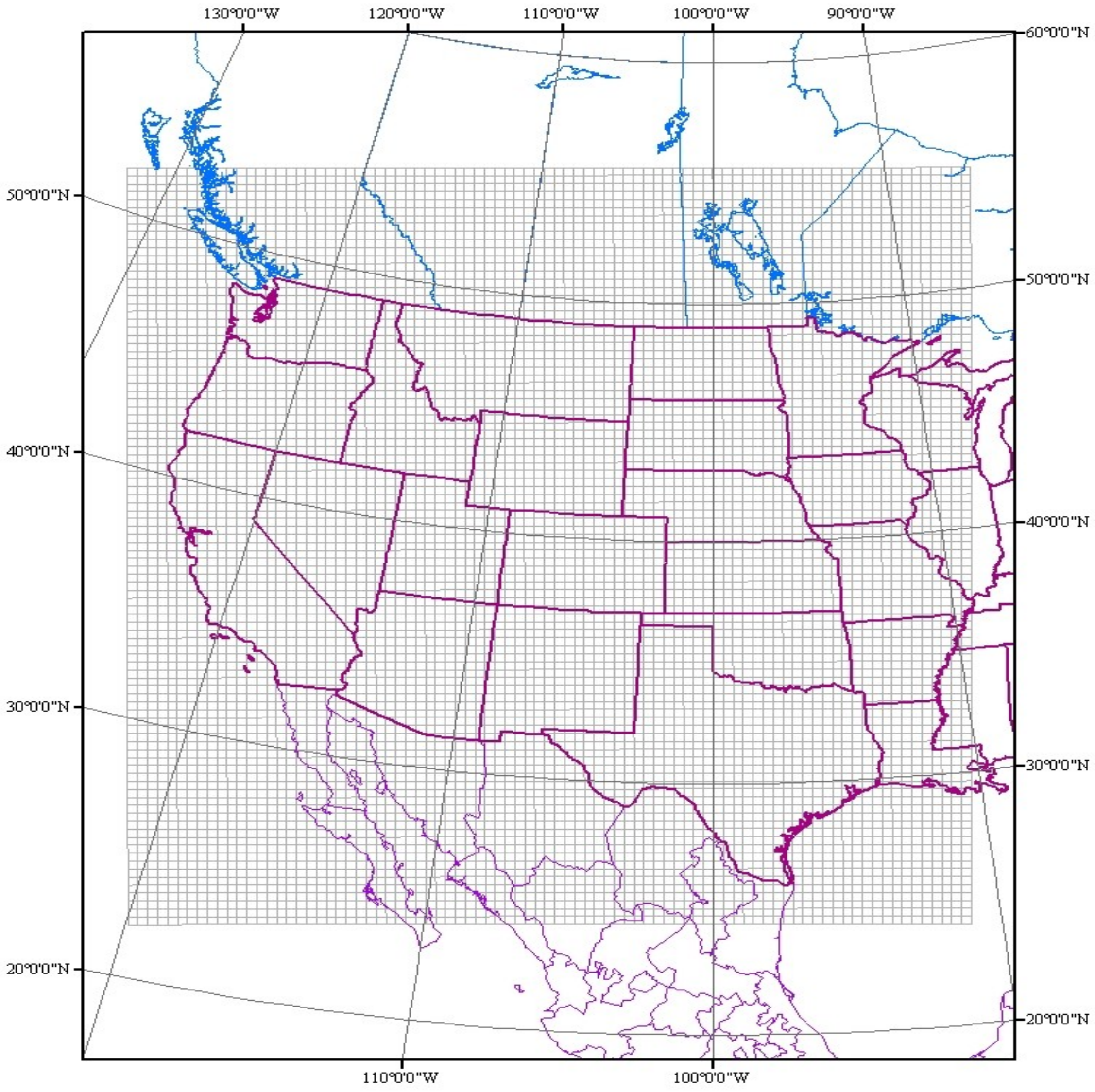
The default configuration was used for MCIP (Table 1.2.2.4), which comes with the February 1, 2001 released version of CMAQ. We also configured MCIP to be consistent with the CMAQ grid, vertical layer structure, and episode. Table 24 also lists the other MCIP processor options used in preparing CCTM-ready meteorological files.

Table 1.2.2.4. MCIP default configuration

Module or option	**Values or setting**	**Additional Information**
Land use module	RADM	Currently the only module available
PBL module	Models-3	Currently the only module available
Dry deposition module	RADM	Currently the only module available
Convective cloud module	RADM/Kuo	Currently the only module available
Cloud cover, solar radiation and other cloud parameters module	MM5-PX	Includes cloud cover and radiation parameters as output
PBL value computation option	Yes	Do not use MM5 PBL
Similarity algorithm option	PBL	
Dry deposition option	RADM	
Cloud computation option	Yes	Do not use MM5 clouds
Land use input option	MM5 direct	
Hydrostatic conversion option	No	Do not convert from nonhydrostatic to hydrostatic
Check output parameter range option	Yes	
Number of iterations for vertical wind field correction	0	No correction will be made to the vertical wind fields
I/O API output file type	Time-dependent	
Maximum boost rate for urban area	2	Will treat a cell with any urban component as all urban
Number of deposition layers	1	
Check I/O API file headers?	No	

Modeling Domain

Figure 1.2.2.2. 36 km grid cell modeling domain used for the §309 modeling.



1.2.3. Use of CMAQ for §309 Visibility Modeling

Regional haze and poor visibility are caused by particulate matter (PM) in the atmosphere, which scatters and absorbs light. PM can be classified as fine particulate matter with aerodynamic diameter of less than 2.5 micrometers ($PM_{2.5}$) and coarser particles with aerodynamic diameter of less than 10 micrometers (PM_{10}). Particulates can also be classified by formation mechanism; either by primary emissions or by secondary production from chemical conversion of gas phase precursors and subsequent mass transfer to the aerosol phase. Sources of primary particulate emissions in the coarse size mode include geological processes such as wind-blown dust and sea salt particles. Combustion processes produce primary emissions of soot or elemental carbon (EC) in the $PM_{2.5}$ size mode. Formation of secondary particulates begins with chemical conversion of NO_x, SO_x, NH_3 and VOC to ammonium nitrate and sulfates and low volatility organic compounds. Transfer from the gas phase to particulate phase can occur by nucleation of new particles when gas phase concentrations exceed their saturation vapor pressure or by absorption of the gas phase to existing particles. Particulates also undergo a number of dynamic processes including coagulation or aggregation of small particulates to former larger particulates, deposition to surfaces, and fine particulates act as sites for cloud condensation.

The rate of formation and the fate of secondary $PM_{2.5}$ are non-linear functions of the rate of precursor emissions, complex chemical transformations, and meteorological parameters. Thus, sophisticated numerical simulation models must be used to represent the formation of $PM_{2.5}$ and the transport and fate of both $PM_{2.5}$ and PM_{10}. Typically, air quality models are used to simulate an historical air pollution episode, and, after the model has been validated for the historical episode, it is used to predict the effects of emissions changes in future scenarios. For the case of the WRAP §309 modeling, out historical episode was calendar year 1996, and we then simulated future emissions and controls strategies for calendar year 2018. This section discusses the science components and the model performance validation of the air quality modeling including the following topics:

- Model setup for 1996 base case and 2018 control case simulations
- 1996 model performance evaluation
- Overview for 2018 projection cases
- Table of control strategies and SMOKE emissions files applied in each model run.
- QA for each model run
- Use of relative reduction factors using EPA guidance

CMAQ Model Configuration Description

The Models-3 Community Multiscale Air Quality (CMAQ; USEPA, 1999) model was used for all §309 modeling. CMAQ is a state-of-the-art "one atmosphere" Eulerian photochemical air quality modeling system (Dennis et al., 1998). The system is described as "one atmosphere" because it is designed to address all atmospheric pollutants of interest including O_3, PM, regional haze, and air toxics. It is described as a "modeling system" because CMAQ includes several different models or preprocessors, which must be operated together to simulate air quality. The components of CMAQ include the following:

- **ICON** A preprocessor for creating a model input data for initial conditions;
- **BCON** A preprocessor for creating a model input data for boundary conditions;
- **JPROC** A preprocessor for creating a look up tables of photolysis rates;
- **MCIP** The meteorological preprocessor for converting MM5 files into CMAQ model ready input files.
- **SMOKE** Preprocessor for preparing emissions inventories.

- **CCTM** The CMAQ Chemical Transport Model used for predicting 3-dimensional concentration fields of trace gas and aerosol species and extinction coefficients.

Each of these interface processors incorporates raw data into CMAQ and performs functions such as calculating parameters and interpolating or converting data. CMAQ's CCTM has a modular design such that the user can select from alternative science algorithms by selecting the appropriate module when compiling the executable program. This also facilitates the incorporation of new or alternative science algorithms into the modeling system. Currently, nine science modules are included:

- **DRIVER** controls model data flows and synchronizes fractional time steps;
- **HADV** computes the effects of horizontal advection;
- **VADV** computes the effects of vertical advection;
- **ADJCON** adjusts mixing ratio conservation property of advection processes;
- **HDIFF** computes the effects of horizontal diffusion;
- **VDIFF** computes the effects of vertical diffusion and deposition;
- **CHEM** computes the effects of gas-phase chemical reactions;
- **CLOUD** computes the effects of aqueous-phase reactions and cloud mixing;
- **AERO** computes aerosol dynamics and size distributions; and
- **PING** computes the effects of plume chemistry.

The default options for each module are summarized in Table 1.2.3.1. CMAQ also uses the concurrent versions system (CVS) software to manage the source code. Although the use of modular structure and CVS software increases the complexity of compiling and running the air quality model, this approach provides several convenient features that are not available in other modeling systems including code management and archiving capabilities.

Table 1.2.3.1. CMAQ CCTM Science Module Options (Default)

Module Name	**Process Description**	**Algorithm Used in Default Configuration**
Driver	Chemistry-transport coupling control execution	Chemical Tracer Model (CTM)
Hadv	Horizontal advection	Piece-wise parabolic method (PPM)
Vadv	Vertical advection	Piece-wise parabolic method (PPM)
ADJc	Mass conservation/adjustment	Density adjustment to ensure mass conservation in vertical advection solver
Hdiff	Horizontal diffusion	K-theory, Uniform
Vdiff	Vertical diffusion	K-theory, Blackadar scheme
Chem	Chemical mechanism	CB4 w/ aerosol version 2 and aqueous species
Chem	Photolysis rate calculation	Table look-up (from JPROC)
Chem	Gas-phase chemical solver	Modified Euler Backward Integration (MEBI)
PinG	Plume-in-grid	No
Cloud	Convective / nonconvective cloud mixing schemes	RADM-Kuo / resolvable-scale clouds
Cloud	Scavenging / wet deposition	Henry's Law for washout; RADM scheme for rainout; aerosols scavenged according to Binkowski and Shankar [1994], and Shankar and Binkowski [1994]
Cloud	Aqueous chemistry	Walcek and Taylor [1986]
Aero2	Speciation	Speciated $PM_{2.5}$ from emissions
Aero2	Thermodynamics	RPMARES
Aero2	Aerosol dynamics	Whitby's Modal Aerosol Dynamics size distribution formulation (RPM)
Aero2	Secondary Organic Aerosols	Pandis et al. [1992] methods for secondary organic aerosol formation (SOA) formation
Aero2	Visibility	IMPROVE algorithm
Adepv	Deposition velocities	Surface-layer resistance method (RPM) based on approach used in RADM

Treatment of Aerosols

The approach used to treat aerosol size and dynamics is of special importance to visibility modeling. Particulate matter can be classified by particle size or diameter. For example, in the CMAQ model, particulates are classified in 3 different size modes (with approximate size range shown in parentheses) as follows

- Aitken nuclei (0.03 to 0.5 µm)
- Accumulation mode (0.5 to 2.5 µm)
- Coarse mode (greater than 2.5 µm)

Accurate simulation of aerosol physics and the prediction of visibility impairment require that the model must represent the full range of particle sizes from 0.03 to 10 µm. Two common approaches have been employed to represent aerosol size distributions: a sectional approach in which particles are represented by a finite number of discrete bin sizes, and a modal approach in which size distributions are represented as the moments of log normal distributions. The advantage of the sectional approach is its inherent simplicity, but its computational cost increases rapidly as the number of bins is increased to improve particle size resolution and to achieve greater accuracy. The advantage of the modal approach is that it provides a representation of the entire particle size distribution. The CMAQ model adopts the modal approach in which distributions of particle number, diameter, and mass are represented for the Aitken nuclei, the accumulation mode and the coarse mode, while the REMSAD adopts a sectional approach.

The aerosol modal size distributions are also used in the calculation of dynamic processes include coagulation of particles within and between the modes, binary nucleation of sulfuric acid and water, and condensation and evaporation of condensable vapor on/off particles, as well as size-dependent wet and dry removal and in-cloud scavenging of interstitial aerosol. CMAQ includes an alternative approach to the IMPROVE visibility algorithm involving a size-dependent and computationally efficient Mie-based algorithm.

Chemical Mechanism and Species Treatment

All major regulatory modeling studies employ condensed photochemical mechanisms that use a small set of artificial surrogate species to represent the complex mixture of ambient VOC (Dodge, 2000). In particular, three different condensed, gas phase chemical mechanisms are widely used in air quality modeling. These include the Carbon Bond Mechanisms IV (CB4, Gery et al., 1989), the Regional Acid Deposition Mechanism (RADM2, Stockwell et al., 1990), and the SAPRC99 mechanism (Carter, 2000). The CB4 mechanism was used in the WRAP §309 modeling because it provides the greatest computational efficiency. The CB4 was developed for high NO_x, typically urban conditions, but a number of "patches" have been made to the CB4 over the years to attempt to address the concern for regional, low NO_x modeling. Both the RADM2 and SAPRC99 gas phase mechanisms were specifically developed for regional, low NO_x conditions and therefore these mechanisms include a more detailed representation of the fate of NO_x and of the chemistry of peroxyl radical species. The errors introduced by the use of the CB4 are expected to be considerably less than other errors or uncertainties associated with the emissions and meteorology inputs. The errors in CB4 are most likely to affect SOA formation due to CB4's more condensed representation of organic intermediates.

Secondary Organic Aerosol (SOA) Treatment

There are two SOA algorithms implemented in CMAQ that are based on the methods of Pandis et al. (1992) and Odum et al. (1996). The Pandis approach is the default and current choice in CMAQ for calculating SOA yields in the 2001 CMAQ release. The CMAQ chemical mechanism includes OH, NO_3, and O_3 oxidation reactions for six lumped VOC groups, which lead to SOA production. These are (1) the C8 and higher alkanes, (2) anthropogenic internal alkenes, (3) xylenes, (4) toluene, (5) cresols, and (6) monoterpenes. Also, through a user-defined option, CMAQ can use the alternative Odum et al. [1996]

approach to provide a more detailed dependence of aerosol yields on the existing organic aerosol mass.

Operating System

CMAQ has been ported and operated successfully on a LINUX platform, providing more reliability, easy accessibility and much less computational expense than other operating systems.

Model Predictions of Visibility Impairment

Impairment of visibility can occur both by scattering and absorption of light, where these effects can be represented as a scattering coefficient and an absorption coefficient. The sum of these is defined as the extinction coefficient (β_{ext}). In a clean atmosphere, the extinction coefficient from Rayleigh scattering by gas molecules provides an upper limit for maximum visibility, where a standard value of Rayleigh scattering is defined as: β_0 = 1/(100 km).

Several different metrics are used to describe visibility. These include visual range, extinction coefficient, and a haziness scale defined in units of *deciviews* (Pitchford and Malm, 1994). Visual range is intuitively simple and is a useful measure for applications such as air operations and recreational activities. Extinction coefficients are a useful measure for scientists in performing budget analysis of the contribution of atmospheric constituents to haziness. However, neither visual range nor extinction coefficients have a linear relationship to perceived haziness and therefore are not easily used for analyzing changes in visibility. For example, the effect of a change in visibility of 1 km can only be meaningfully interpreted in references to a base case: a reduction from 50 km to 49 km would be insignificant, while a reduction from 2 km to 1 km would be of great importance. For this reason, Pitchford and Malm (1994) recommend a haziness scale defined in units of deciviews that provides a linear measure of perceived changes in visibility.

The deciview scale is defined in terms of a relationship of the visibility to a perfectly clean atmosphere, where this is calculated as:

$$deciview = 10\ln\left(\frac{\beta_{ext}}{\beta_0}\right)$$

where β_{ext} is the extinction coefficient of ambient air, and this is calculated as a function of the total particulate load, its size distribution, and the refractive index of the particles. The Regional Haze Rule requires that calculations of baseline and natural visibility conditions must be expressed in units of deciviews.

1996 model performance evaluation case

This section describes the procedures used to evaluate the performance of CMAQ using 1996 base case study. As part of the WRAP regional visibility modeling using the Models-

3/CMAQ model, the observed PM concentrations collected at the IMPROVE monitors were matched up with the model predictions as part of the model performance evaluation. The RMC and the jumpstart team engaged in a review process with members of WRAP modeling forum to select the mapping of ambient data to the model predicted species. The RMC also developed software tools available for performing model evaluation.

Ambient Data used for Evaluation

Model simulations were evaluated by comparing with ambient monitoring data for PM from the IMPROVE sites and from the CASTNET sites. Approximately 60 IMPROVE sites were available in the western US domain during 1996. Data were collected at the IMPROVE sites every 3rd day, and approximately 100 days of PM data were available for the evaluation. IMPROVE data are reported as the 24 hour average. The species measured at the IMPROVE sites do not correspond exactly with the species as represented in the CMAQ model. We used the groupings of model species shown in Table 26 to compare the model to the monitored species. CASTNet data are reported as 7-day averages, and we used the groupings shown in the following table to compare the model species with the CASTNet data. Detailed plots showing the comparison of model to data for each monitoring site are available at the project website (www.cert.ucr.edu/rmc) as described below.

Table 1.2.3.2. Mapping of CMAQ species to IMPROVE species.

Compound	IMPROVE Species	CMAQ Mapping
SO4	SO4	ASO4J + ASO4I
NO3	NO3	ANO3J + ANO3I
OC	1.4*(OC1+OC2+OC3+OC4+OP)	AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI
EC	EC1+EC2+EC3-OP	AECJ + AECI
SOIL	2.2*Al + 2.49*Si + 1.63*Ca + 2.42*Fe + 1.94*Ti	A25I +A25J
CM	MT – FM	ACORS + ASEAS + ASOIL
PM25[a]	FM	1.375*(ASO4J + ASO4I) + 1.29*(ANO3J + ANO3I) + AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI + AECJ + AECI + A25J + A25I
RCFM	1.375*SO4 + 1.29*NO3 + **EC** + **OC** + **SOIL**	Same for PM25

PM10	MT	1.375*(ASO4J + ASO4I) + 1.29*(ANO3J + ANO3I) + AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI + AECJ + AECI + A25J + A25I + ACORS + ASEAS + ASOIL
Bext_Recon (1/Mm)	10[b] + 3*f(RH)[c](1.375*SO4 + 1.29*NO3) + 4***OC** + 10***EC** + **SOIL** + 0.6***CM**	10[b] + 3*f(RH)[c][1.375*(ASO4J + ASO4I) + 1.29*(ANO3J + ANO3I)] + 4*1.4*(AORGAJ + AORGAI + AORGPAJ + AORGPAI + AORGBJ + AORGBI) + 10*(AECJ + AECI) + 1*(A25J + A25I) + 0.6*(ACORS + ASEAS + ASOIL)

[a] Measured; [b] Rayleigh scattering correction; [c] f(RH), monthly relative humidity

Although O_3 does not affect visibility directly, O_3 play a central role in the oxidation of precursors that form PM and affect visibility. In particular, concentration of O_3 and related oxidants (NO_3, OH, and HO_2) affect the rate of formation of nitric acid, sulfuric acid and low volatility organics. We performed a limited comparison of model predictions to O_3 monitoring data for the month of July 1996. We did not expect good model performance for O_3 in urban areas because of the coarse (36 km) grid resolution is unable to resolve major point source plumes and urban NO_x and VOC gradients. Indeed, the model typically underestimates peak O_3 levels in southern CA by 10 to 30 ppb. The model generally compared well with O_3 data in central CA and in other parts of the domain, typically within 10 to 20 ppb of observed O_3. Increased attention to model performance evaluations for O_3 will be a high priority as we attempt to improve model performance for future §308 modeling.

Development of model evaluation tools

This section discusses the approach for matching up the CMAQ model estimates with the IMPROVE PM data. CMAQ treats particles, based on their size distributions, as the superposition of three lognormal subdistributions, called modes. The three modes are:

1. fine particle mode, the *i*-mode, representing the smaller (nuclei or Aitken) particles from nucleation or from direct emission with diameters < 0.1 µm;
2. larger particle mode, the *j*-mode, representing particles with diameters between 0.1 µm and 1-2 µm, known as the accumulation range; and
3. coarse particles, representing the difference between the masses in PM_{10} and $PM_{2.5}$.

While the first two modes, *i*- and *j*- mode, are two interacting modes treated as two subdistributions in $PM_{2.5}$, the addition of coarse particles makes up the total amount of PM_{10}. The chemical species treated in the aerosol component of CMAQ are listed in the next table. Among them, the fine particle species include sulfates, nitrates, ammonium, water, anthropogenic and biogenic organic carbon. The coarse mode species include sea salt, wind-blown dust, and other unspecified material of anthropogenic origin.

Table 1.2.3.3. CMAQ aerosol species list. All units are in mass concentration $\mu g\ m^{-3}$.

CMAQ Species Name	Description
ASO4J	Accumulation mode sulfate mass
ASO4I	Aitken mode sulfate mass
ANH4J	Accumulation mode ammonium mass
ANH4I	Aitken mode ammonium mass
ANO3J	Accumulation mode nitrate mass
ANO3I	Aitken mode aerosol nitrate mass
AORGAJ	Accumulation mode anthropogenic secondary organic mass
AORGAI	Aitken mode anthropogenic secondary organic mass
AORGPAJ	Accumulation mode primary organic mass
AORGPAI	Aitken mode primary organic mass
AORGBJ	Accumulation mode secondary biogenic organic mass
AORGBI	Aitken mode secondary biogenic organic mass
AECJ	Accumulation mode elemental carbon mass
AECI	Aitken mode elemental carbon mass
A25J	Accumulation mode unspecified anthropogenic mass
A25I	Aitken mode unspecified anthropogenic mass
ACORS	Coarse mode unspecified anthropogenic mass
ASEAS	Coarse mode marine mass
ASOIL	Coarse mode soil-derived mass
AH2OJ	Accumulation mode water mass
AH2OI	Aitken mode water mass

The IMPROVE monitoring network (http://vista.cira.colostate.edu/improve) reports detailed chemical species (raw database) in its measurements of visibility-reducing aerosol species on a twice-a-week basis. Next are the PM fine mass species being used in the evaluation :

- Sulfates (SO_4), as sulfate ion;
- Nitrates (NO_3), as nitrate ion;
- Organic carbon (OC), as organic carbon mass;
- Elemental carbon (EC), as light absorbing carbon or carbon soot;
- Soil (SOIL), as fine soil and is sum of several inorganic elements such as Al, Si, Ca, Fe and Ti.

These species are all measured using a 2.5-micron cut point inlet. The IMPROVE monitors also measure total PM_{10} and $PM_{2.5}$ mass. These values are reported as the $PM_{2.5}$ fine matter (FM) portion of the mass and the coarse matter (CM) portion, as PM_{10} - $PM_{2.5}$. The mapping of the CMAQ species to the IMPROVE species counterparts is summarized in Table 24, above. Note that in CMAQ water as fine particle species is not included among the mapping of IMPROVE species, because IMPROVE measures only dry particles. In addition, IMPROVE defines SOIL as fine soil concentration, which is the sum concentrations of several inorganic species. Although fine soil is not specifically defined in CMAQ, it is taken as unspeciated portion of $PM_{2.5}$ emitted species. Therefore, model species, A25J+A25I, are used as surrogates for the IMPROVE fine soil concentration.

For the visibility comparisons of CMAQ model predictions and IMPROVE measurements, IMPROVE network uses either direct transmissometer measurement or reconstructed light extinction from aerosol species measurements, while CMAQ uses two approaches to calculation light extinction coefficient. The first is based on theoretical calculation (known as Mie theory) of extinction coefficient from the sum of scattering and absorption coefficients. The second approach is based on modified aerosol species mass concentrations known as reconstructed extinction. This is an empirical approach and uses the similar equation used in the IMPROVE measurement for visibility calculation:

$$\begin{aligned}\beta\text{ext}(1/\text{Mm}) = \;& 3*f(rh)*([\text{ammonium sulfate}]+[\text{ammonium nitrate}]) + \\ & 4*[\text{organic mass}] + 10*[\text{light absorbing carbon}] + \\ & 1*[\text{fine soil}] + 0.6*[\text{coarse mass}] \quad + \beta_{Rayleigh} \qquad \text{Eq (1)}\end{aligned}$$

where f(rh) is relative humidity correction factor, and $\beta_{Rayleigh}$ is the extinction for Rayleigh scattering with a value of 10 Mm^{-1} for clean background environment. In CMAQ, the relative humidity factor, f(rh), is obtained from a table of corrections with entries at one-percent intervals (CMAQ protocol), whereas in IMPROVE measurement it is based on monthly site-specific relative humidity adjustment factors obtained from the document -- “Draft Guidance for Tracking Progress Under the Regional Haze Program”. For model evaluation, however, monthly site-specific relative humidity factors are used to calculate the extinction coefficients both in CMAQ and IMPROVE ambient measurement (Table 24).

The RMC has developed a software package capable of producing model versus observation graphs in an automated process to help model evaluation. The programs in this package extract information from both CMAQ outputs and IMPROVE observation data sets and combine which with proper species mappings, and produce the following graphs:

- Example scatter plots for CMAQ seasonal performance evaluation for all sites and all days (see Figures 1.2.3.1 through 1.2.3.5)
- Example scatter plots of all days at one site (see Figure 1.2.3.6)
- Example scatter plots of all sites for one day (see Figure 1.2.3.7)
- Example time series plots at a given site (see Figure 1.2.3.8)

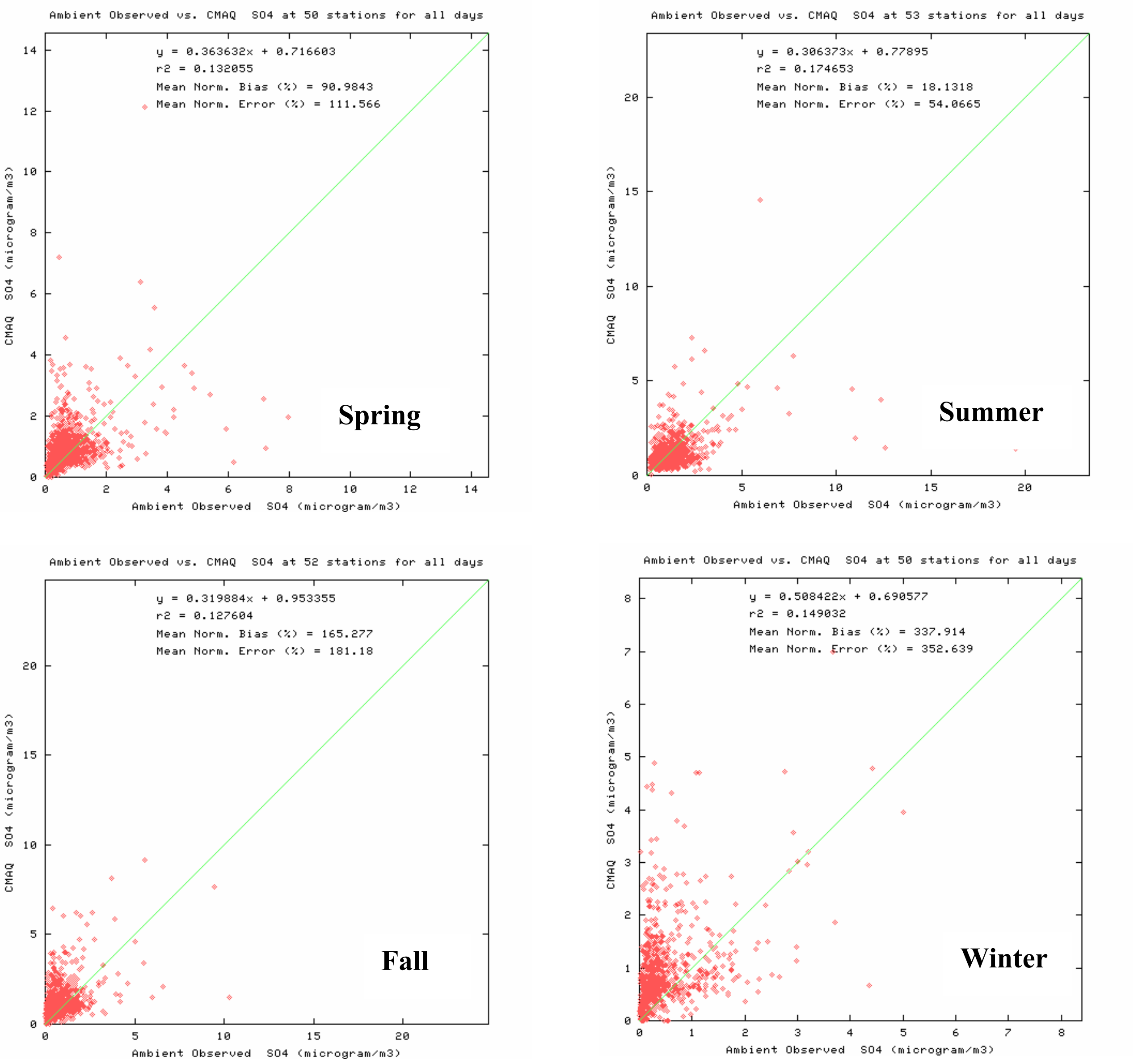


Figure 1.2.3.1. Seasonal comparison plots of model predictions versus all available observation data in all monitoring sites within modeling domain for SO_4.

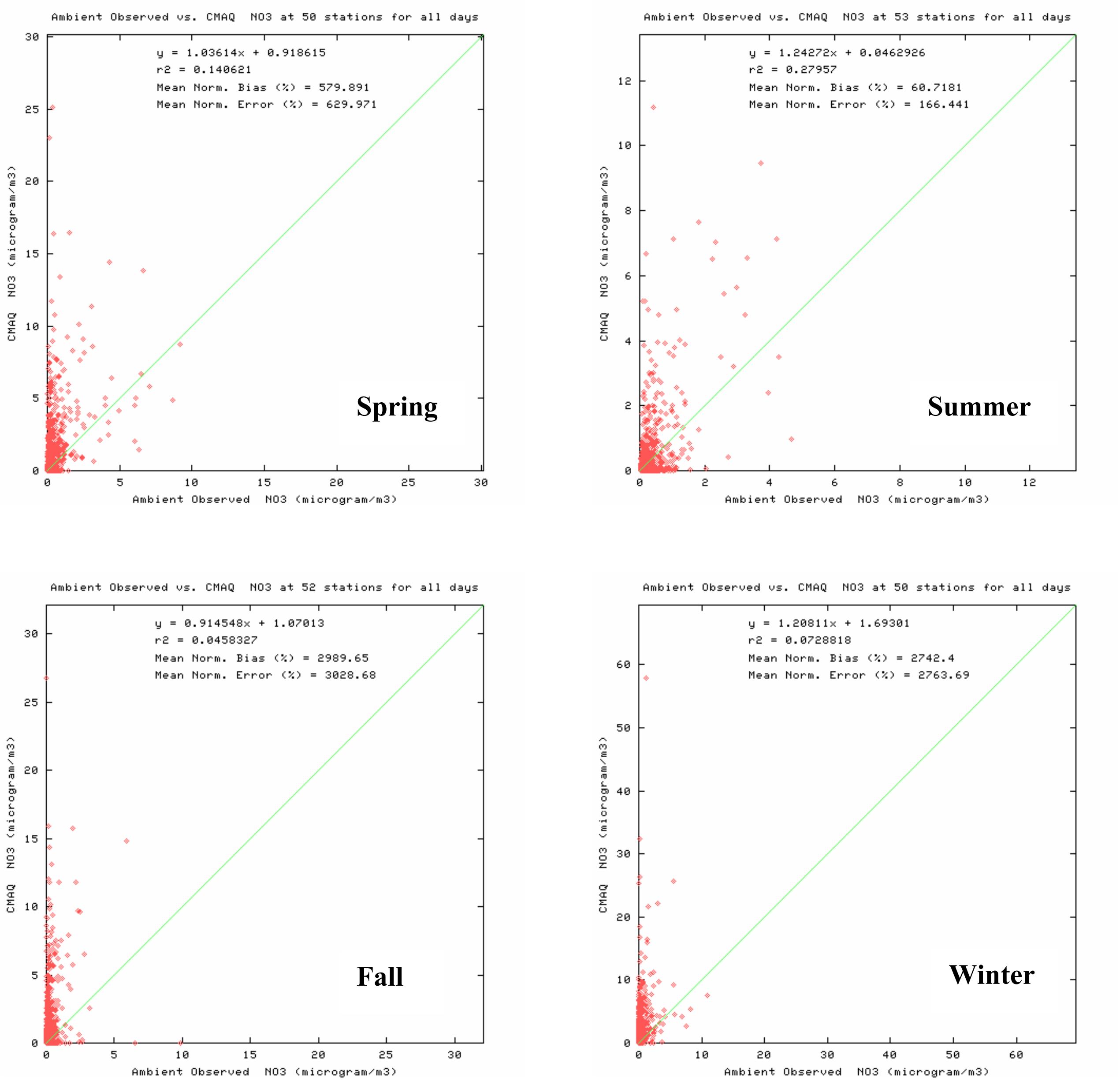


Figure 1.2.3.2. Seasonal comparison plots of model predictions versus all available observation data in all monitoring sites within modeling domain for NO_3.

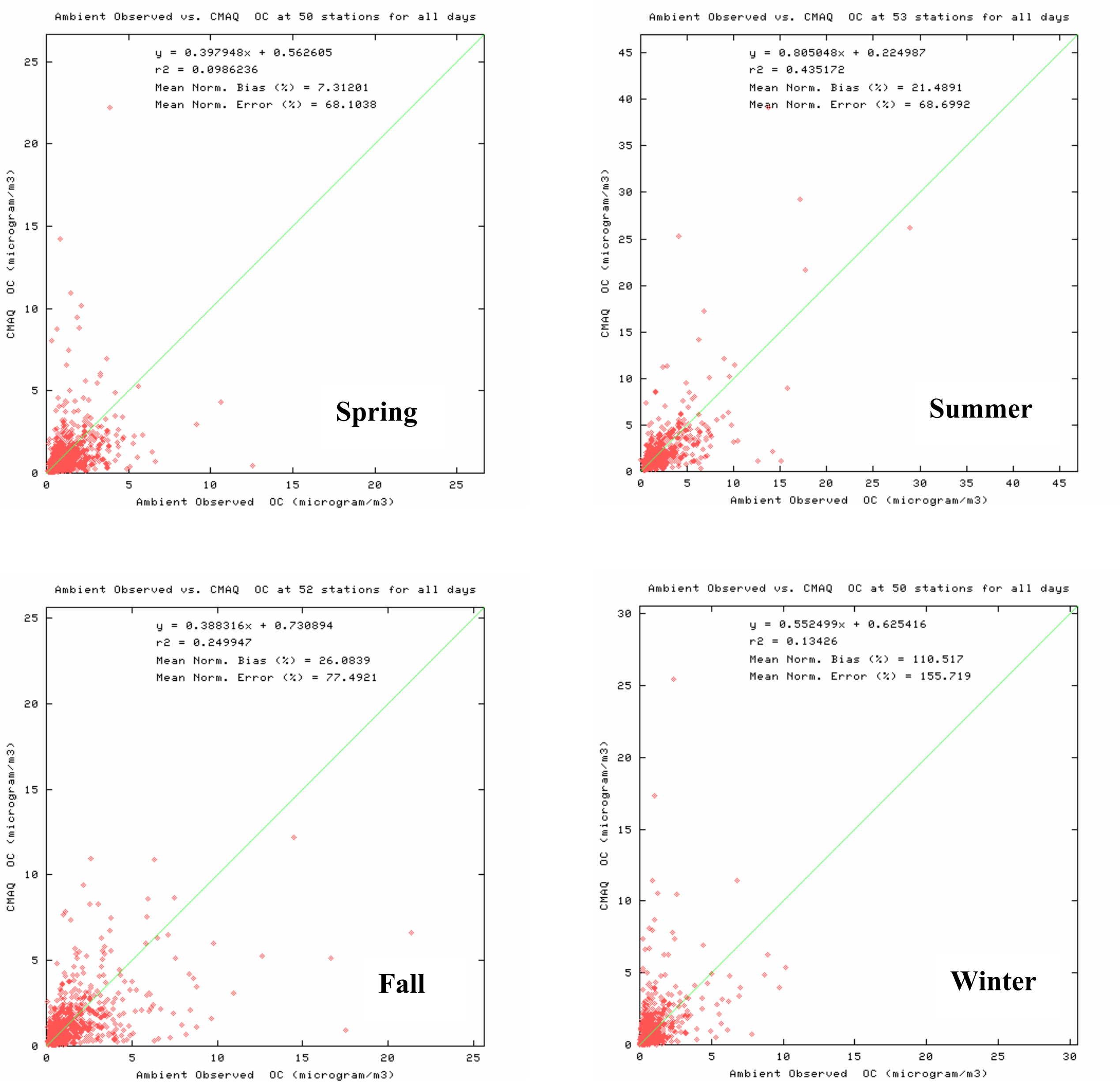


Figure 1.2.3.3. Seasonal comparison plots of model predictions versus all available observation data in all monitoring sites within modeling domain for OC.

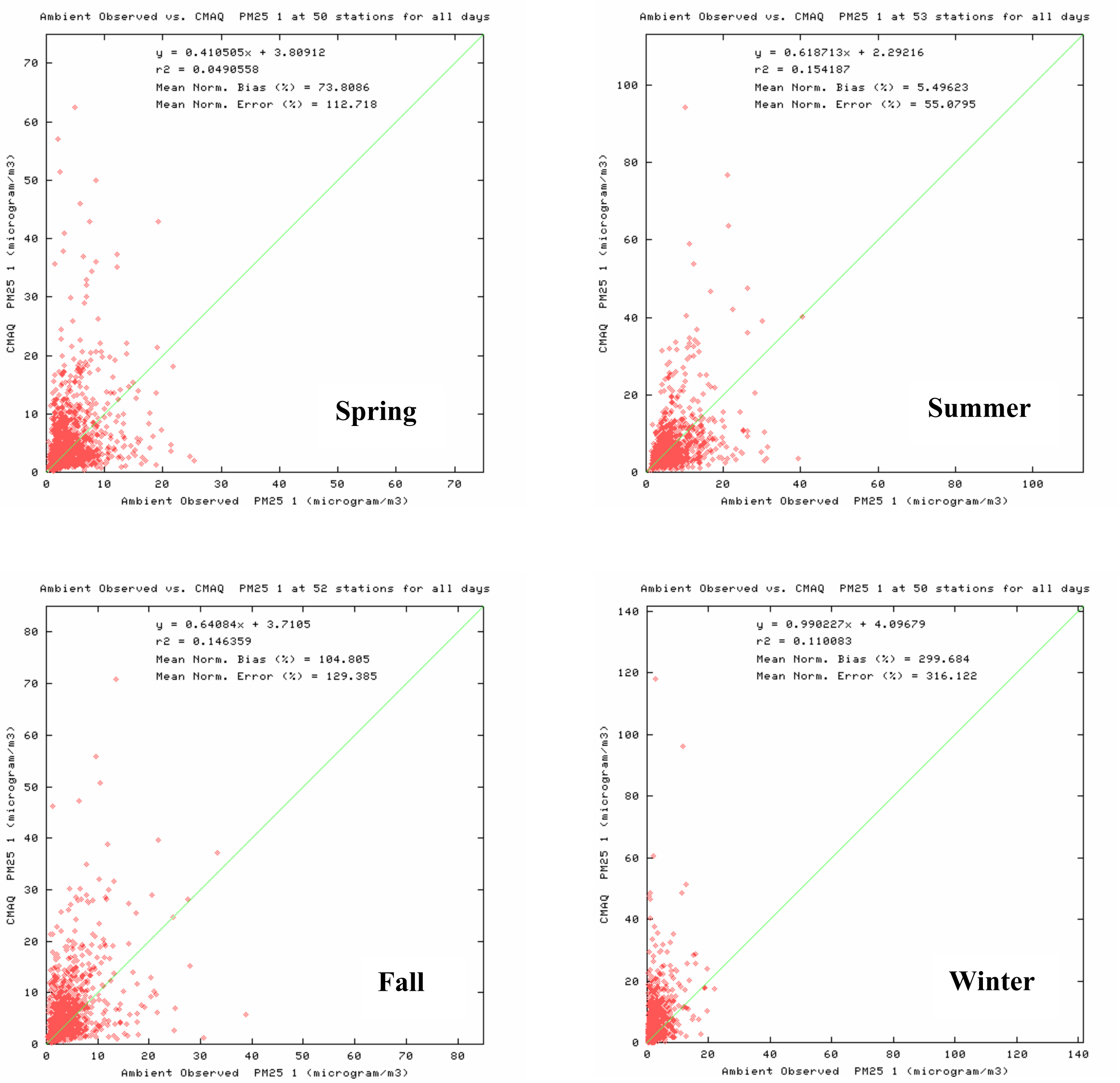


Figure 1.2.3.4. Seasonal comparison plots of model predictions versus all available observation data in all monitoring sites within modeling domain for $PM_{2.5}$.

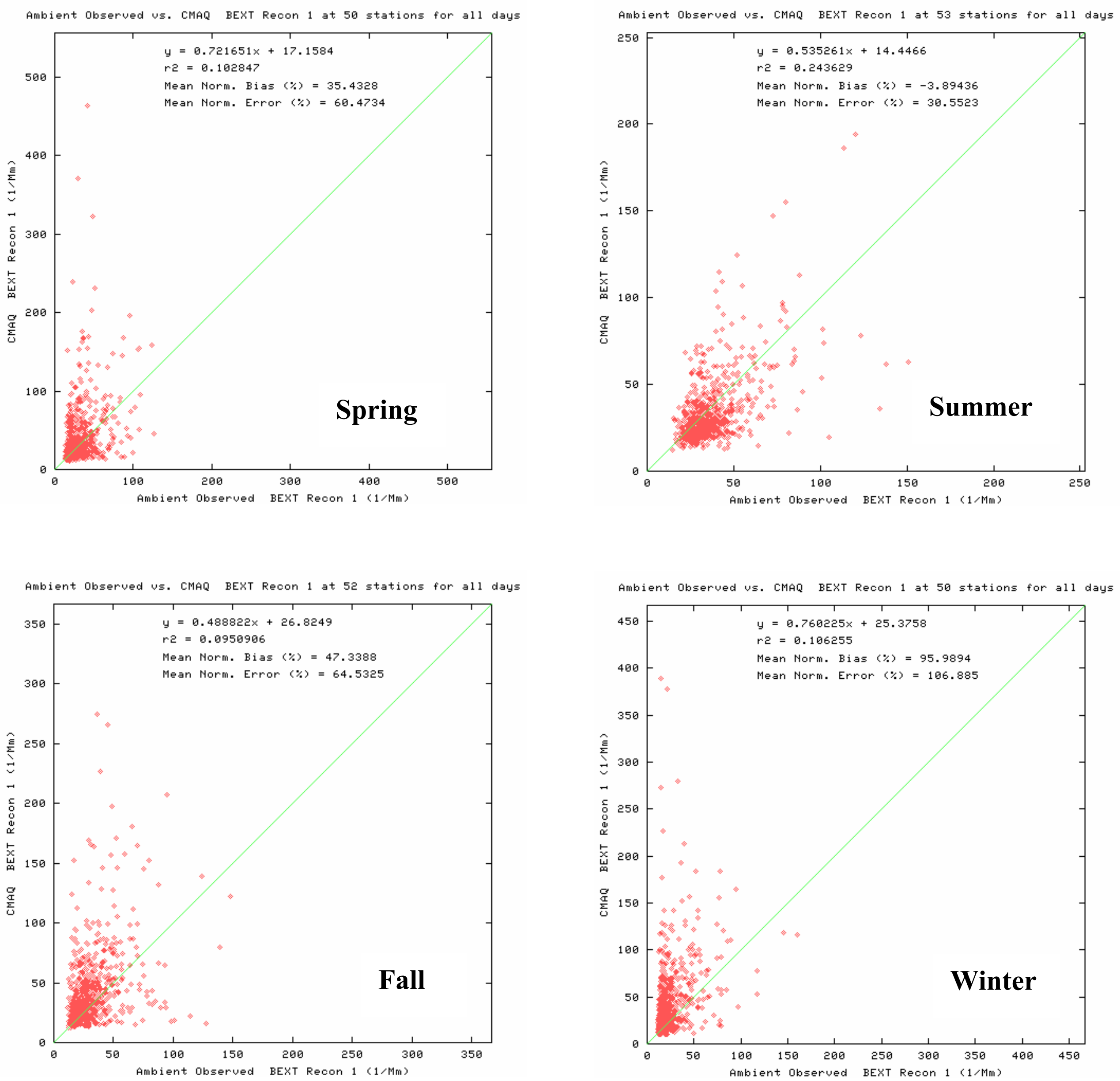


Figure 1.2.3.5. Seasonal comparison plots of model predictions versus all available observation data in all monitoring sites within modeling domain for B_{ext}.

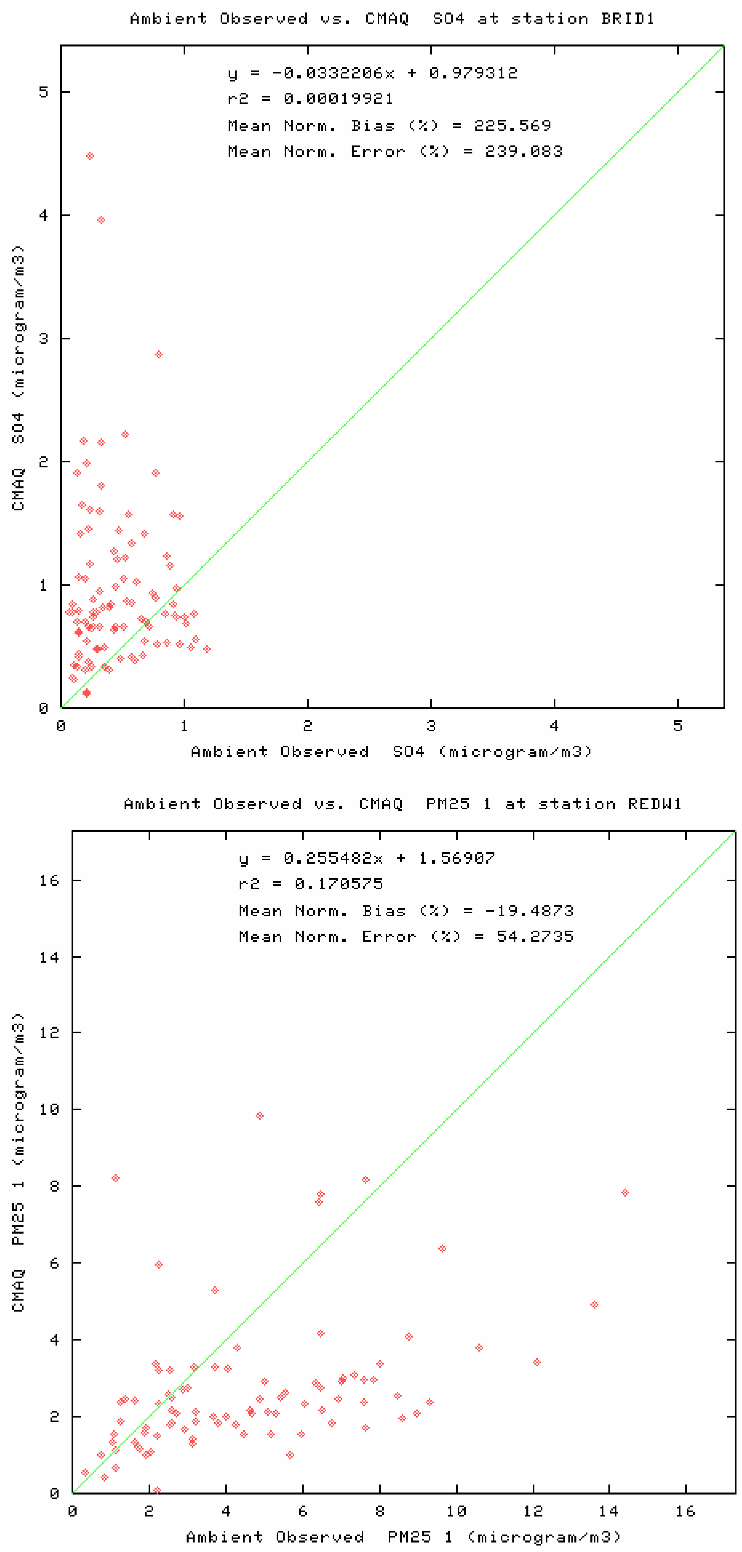


Figure 1.2.3.6. Example comparison plots of model predictions versus available observation data (all days) from one monitoring site (one site). Top: SO_4 at Bridger Wilderness, WY. Bottom: $PM_{2.5}$ at Redwood National Park, CA.

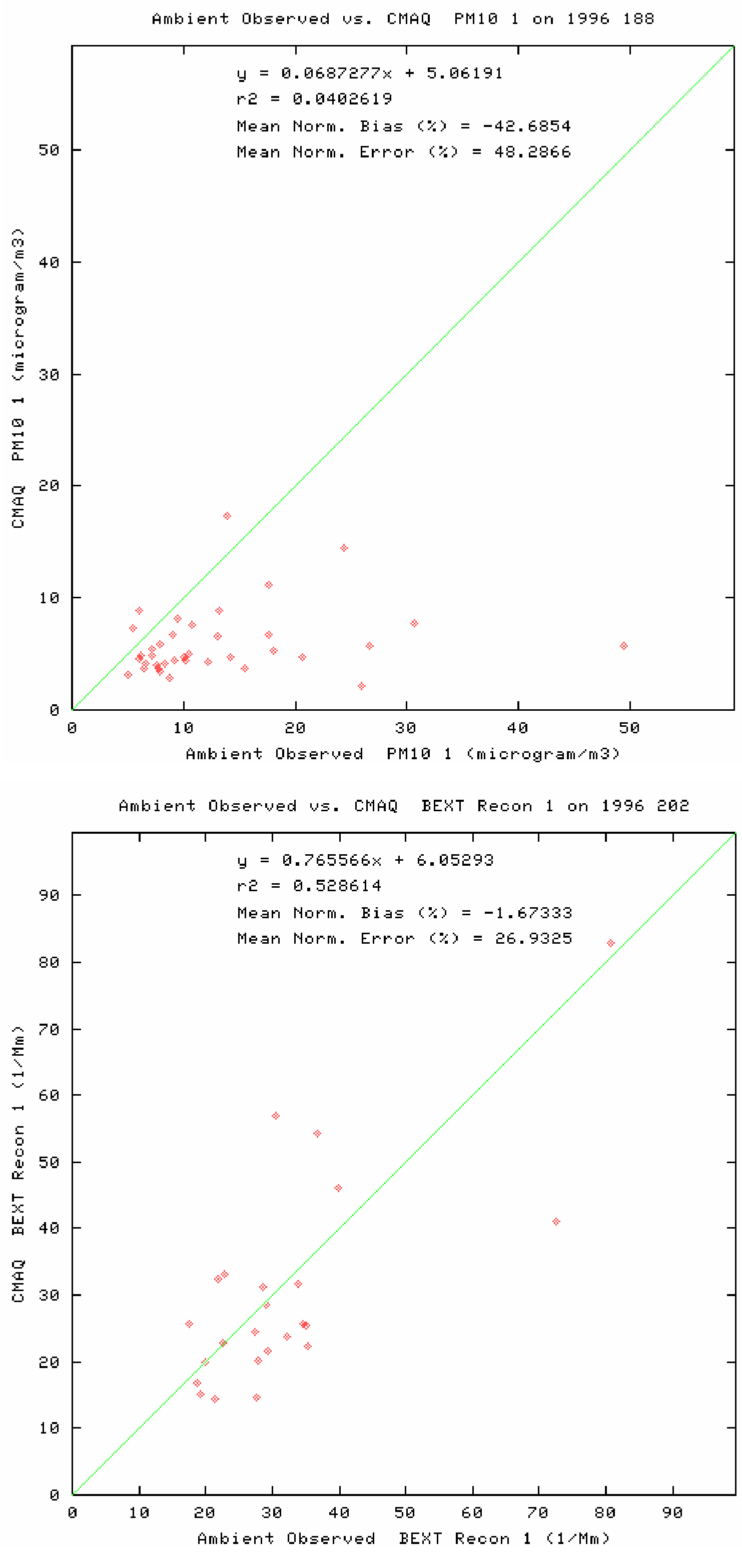


Figure 1.2.3.7. Example comparison plots of model predictions versus available observation data from all monitoring sites within modeling domain (one day, all sites). Top: $PM_{2.5}$ for all monitoring sites on Julian day 188 (July 6), 1996. Bottom: B_{ext} for all monitoring sites on Julian day 202 (July 20), 1996.

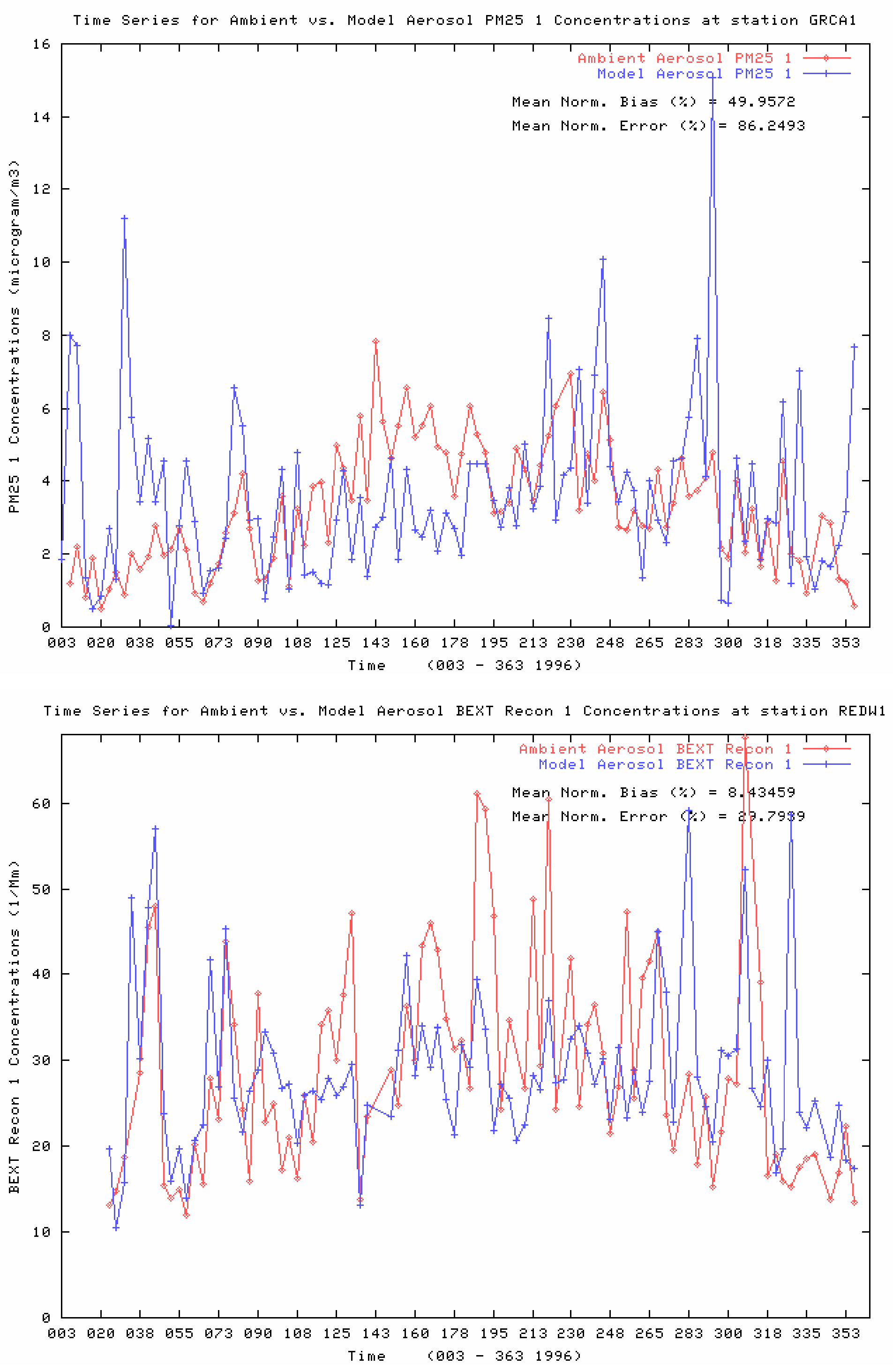


Figure 1.2.3.8. Example time series plots of model predictions vs. available observation data (on days for which measurements are reported) from one monitoring site (one site). Top: $PM_{2.5}$ concentration profiles in 1996 at Grand Canyon National Park, AZ (GRCA). Bottom: B_{ext} profiles in 1996 at Redwood National Park, CA (REDW).

Along the graphs, several statistical measures, including regression (r^2), mean normalized bias (MNB,%) and mean normalized error (MNE, %), are also provided. The statistical measures used in the evaluation have the following equations:

Mean Normalized Bias (MNB, %). The mean normalized bias is given by:

$$MNB(\%) = \frac{1}{N}\sum \frac{C_{predict} - C_{obs}}{C_{obs}}$$

where N equals the number of observations from all monitoring stations on days with available data. Mathematically, the bias is derived from the average signed deviation of the concentration residuals and is calculated using all pairs of predicted and observations.

Mean Normalized Error (MNE, %) The mean normalized error is calculated in a similar way to the bias, and is given by:

$$MNE(\%) = \frac{1}{N}\sum \frac{\left|C_{predict} - C_{obs}\right|}{C_{obs}}$$

The MNE quantifies the mean absolute deviation of the residuals.

All example plots were obtained using 1996 CMAQ annual simulations and compared with available IMPROVE measurements. Full sets of plots, including monthly and annual results, are posted on the RMC project website under 1996 model evaluation results:

http://pah.cert.ucr.edu/rmc/aerosol_webpage/index.shtml

Programs in this package are written in C++ and Perl script programming languages, and are set up to execute on all Linux machines. The whole evaluation package can also be downloaded from the RMC website:

http://pah.cert.ucr.edu/rmc/download.shtml

1.2.4. Model Performance Results

The WRAP annual and monthly evaluation statistics for the following PM species based on the IMPROVE monitoring data are shown in Table 1.2.4.1 and Figures 1.2.4.1 and 1.2.4.2. The species used in the model performance evaluation include the following: sulfate (SO_4); nitrate (NO_3); elemental carbon (EC); particulate organic carbon (OC); coarse mass (CM); soil (SOIL); $PM_{2.5}$; PM_{10}; and extinction coefficient (B_{ext}). While it is not easy to summarize annual model performance, some consistent trends do appear. The model substantially underpredicts soil and coarse mass. This most likely can be attributed to the lack of a fugitive dust emissions inventory, which was excluded because the uncertainty in fugitive dust emissions was so large. For other species the model performance is best for the summer months, and it has large positive bias in the winter months. Because the model has positive bias for most species, including EC, this suggests the possibility that the boundary layer height is too shallow for winter months. However, this hypothesis has not been investigated and this is a high priority for ongoing work.

Table 1.2.4.1. Summary statistics for speciated aerosol data and visibility for all monitoring stations within WRAP on days with available data.

Species	Annual Error Statistics	
	Mean Normalized Bias (%)	Mean Normalized Error (%)
SO_4	140.8	165.3
NO_3	1519.6	1579.2
OC	88.4	125.0
EC	146.5	191.1
SOIL	524.0	553.7
CM	-69.6	87.8
$PM_{2.5}$	78.7	123.1
PM_{10}	-8.7	79.8
B_{ext}	236.9	268.7

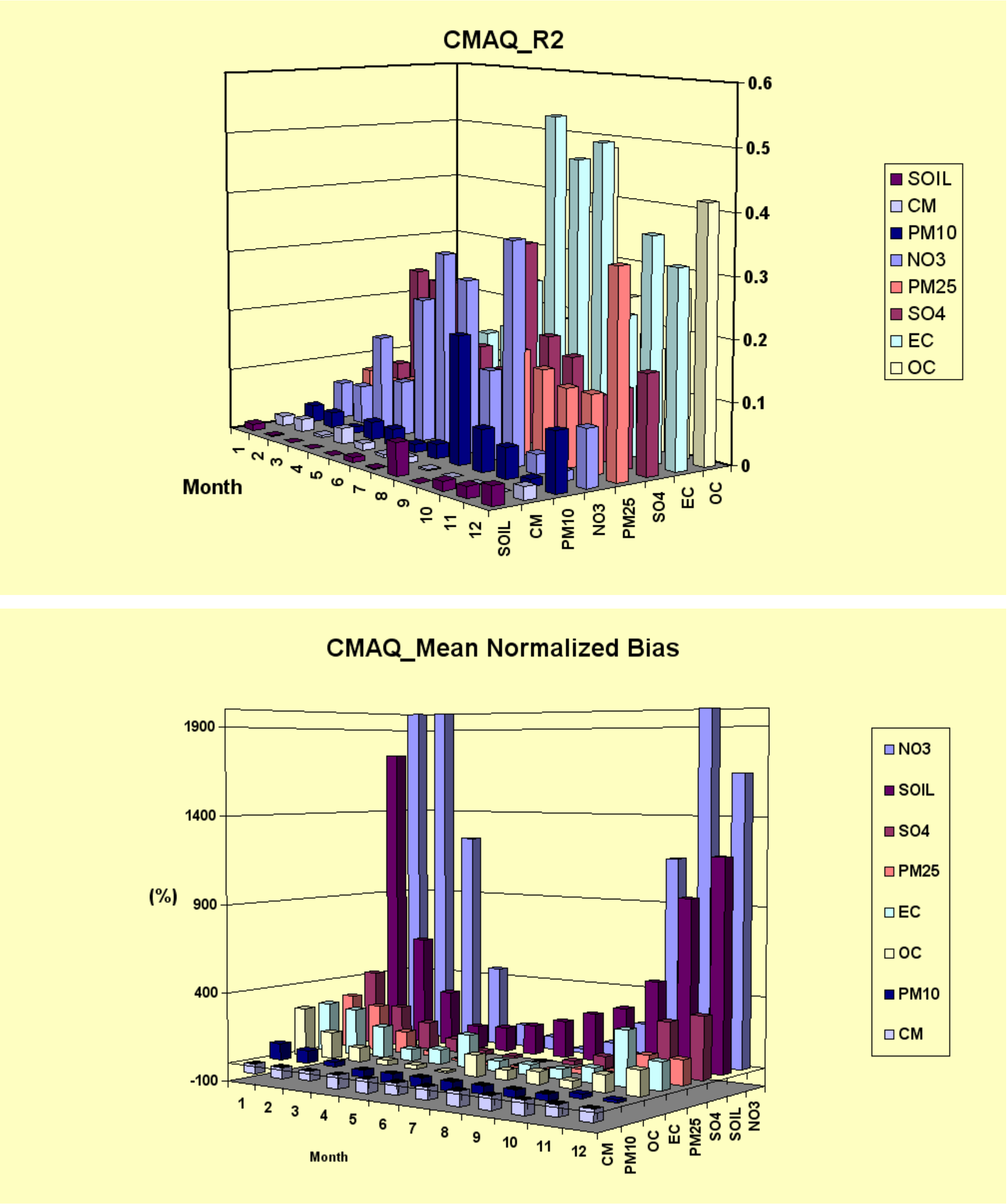
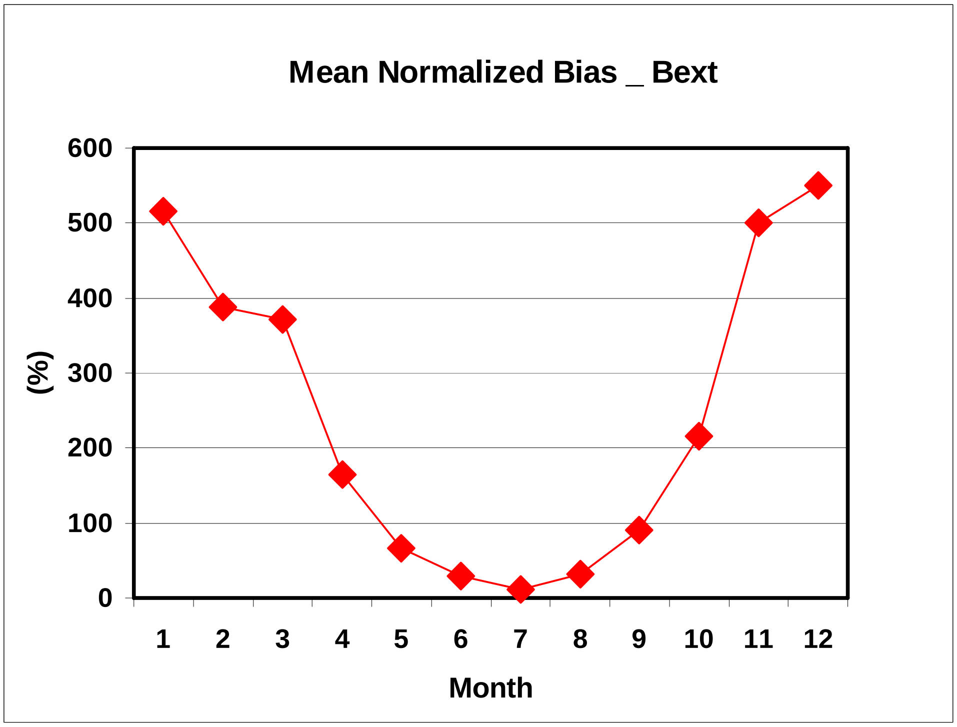


Figure 1.2.4.1. Monthly summary statistics for speciated aerosol data for all monitoring stations within WRAP region on days with available data.



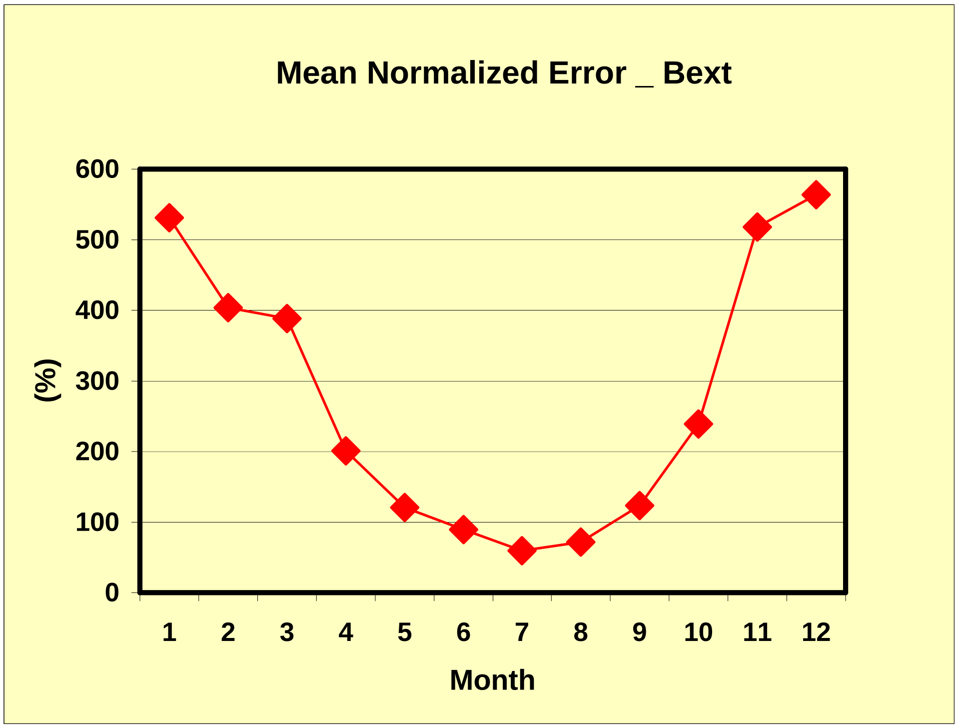


Figure 1.2.4.2. Monthly summary statistics for light extinction (B_{ext}) for all monitoring stations within the WRAP region on days with available data.

The model positive bias is by far the largest for NO_3. We hypothesize that this may be a result of overestimates of NH_3 emissions in the winter months. Although the original NH_3 emissions inventory included a small seasonal adjustment, current research at EPA/ORD suggests that a much larger reduction in NH_3 emissions may be appropriate for winter months. Based on these EPA/ORD results, we reduced the NH_3 emissions by 50% for the months of December, January and February. While this resulted in large reductions of nitrate, the model still overpredicted NO_3 in winter months, although the overprediction was closer in magnitude to that of the other species. There are several alternative hypotheses that could explain the model NO_3 over prediction:

1. Ambient NO_3 may be transferred to the coarse PM fraction in the form of $CaNO_3$ or $NaNO_3$. Coarse mass NO_3 would not be detected in the fine PM fractions at the IMPROVE sites, and, because the model does not represent $CaNO_3$ and $NaNO_3$, the model would partition all NO_3 to the fine fraction, thereby causing it to overestimate fine NO_3.

2. IMPROVE monitoring sites may underestimate actual ambient NO_3 due to sampling errors. This hypothesis is supported by the model comparison to CASTNet sites for which there was a smaller positive bias in the model NO_3 predictions.

3. The model may underestimate the deposition of NH_3 or HNO_3. In fact, there was an error in the model deposition velocity that accounted for part of the NO_3 over prediction

4. It is possible that the model incorrectly represents the conversion of NO_x to HNO_3 by nighttime N_2O_5 hydrolysis. There is very large uncertainty in this chemistry, and future updates to the model could either increase or decrease the model positive bias for NO_3 in future simulations.

Several efforts are underway to improve the model performance for NO_3 in modeling for §308 requirements. The cause of the NO_3 overpredictions could not be determined in the time frame of the §309 modeling. Therefore, for the model sensitivity simulations that were concerned with NO_x and NO_3, the model results were scaled to the ambient data. In the case of the mobile source sensitivity simulations, the analysis was restricted to the April-October period for which the model performed comparatively well.

1.2.5. Model Uncertainties and Quality Assurance

In comparison to traditional model performance evaluations for short-term O_3 episodes, the 1996 base case CMAQ simulation has large error and positive bias for most species, especially for winter months. However, two key issues must be considered when assessing the model performance for use in the §309 analysis. First, there do not exist well-established criteria for acceptable model performance for long-term model simulations. The model performance statistics used to judge episodic modeling may not be appropriate for use in long term modeling because in episodic modeling it is possible to fine-tune the model inputs. For example, observed meteorological data are typically used to nudge the meteorological model predictions toward the correct simulation of the temperature and wind fields in episodic modeling, and much more detail attention and adjustments to emissions inventories are typically applied in episodic modeling. Secondly, model performance criteria have not yet been established for evaluating PM and haze modeling. In the case of O_3 modeling, filters are typically applied to screen out low O_3 data, and the model performance assessment is focused on sites and times with relatively high O_3 concentrations. In the case of PM modeling, the best visibility days as well as poor visibility days must be analyzed, so filters have not been applied to eliminate low PM concentration data. Moreover, the formulations used in computing conventional model performance statistics of error and bias may be inappropriate for evaluating models under very clean conditions (Eder et al., 2002).

In the case of the 1996 CMAQ modeling uncertainty or errors in the meteorological modeling may have had an especially large effect on the model performance. Limited analysis and QA was performed for the 1996 MM5 simulation. Underestimates in inversion heights and PBL heights could cause large over predictions for all PM species. Moreover, errors in the modeled wind direction may cause CMAQ to advect pollutant plumes in the wrong direction and to predict high PM concentrations in the incorrect grid cell. In other words, it is possible that CMAQ may have over predicted PM in some cells and under predicted PM in other cells because of errors in wind direction. When calculating model error and bias a matched in time and space comparison of model predictions to ambient data was used, and this may have been an overly stringent criteria for judging model performance given the coarse grid resolution and uncertainty in met fields. Future model performance can also be evaluated in different ways, such as using unpaired-in-time-and-space metrics.

In spite of the caveats in the model performance evaluation, there are large errors or uncertainties in the key emissions inputs. The uncertainty in emissions combined with uncertainty in the meteorology and chemistry means that there is limited confidence in the useful of the 1996 CMAQ modeling for prescribing additional emissions control strategies. Therefore, the 1996 CMAQ results should be limited in their use. Appropriate uses include sensitivity studies, as in the PM, NO_x and mobile source sensitivity studies described in this document, where the results or these sensitivity studies represent a first attempt to estimate to gauge the relative importance of different emissions sources. In addition, because the sulfate chemistry and emissions are subject to less uncertainty than that of other species such as nitrate, OC and dust, the 1996 CMAQ modeling is useful for comparing the relative benefits of alterative SO_x emissions control strategies. However, these modeling results should not be solely relied upon to prescribe acceptable SO_x emissions. In addition to establishing more rigorous criteria for judging PM model performance, future additional control decisions for SO_x and other species should be based on weight of evidence approach that integrates data from other sources such as trajectory analysis, chemical mass balance modeling, and other source-receptor modeling approaches.

Efforts are currently underway to improve the model input data and model performance, and this should produce better model scenarios for use in analyzing emissions control strategies and options as part of the §308 process for developing future state and tribal implementation plans. Updates being carried out to improve the future §308 modeling work include the following:

- New emissions models and datasets for fugitive dust and ammonia.
- New meteorological data for 2002.

- Model simulations using finer resolution grids at 12 km and 4 km.
- Model simulations for the planning base year (calendar year 2002) that has a more extensive ambient monitoring database and improved emissions inventory data.
- More extensive model performance evaluations using AIRS, PAMS and PM supersite data in addition to the IMPROVE and CASTNet data.
- Development of criteria for model performance evaluations for PM and for seasonal and annual modeling that includes clean conditions.

Overall, the model performed best in the summer months, and for the alternative SO_x control strategy options that required evaluation. Also, the 7-month period (April-October) spanning the Summer months captures virtually all of the average 20% worst visibility days for Class I areas on the Colorado Plateau. Although there are limitations in the WRAP §309 modeling, it is fully adequate for its primary intended purpose of evaluating §309 control strategies and assessment of programs recommended by the GCVTC. The WRAP §309 technical assessments and modeling analyses also represent the best available science for regional haze at this time.

1.2.6. 1996 base cases and 2018 projection cases

After completing the model performance evaluation for the 1996 base case several additional annual model simulations to support requirements of §309 were performed. The goals of these modeling were to perform the following evaluations:

- Evaluate changes in visibility from 1996 to 2018 using a 2018 “base case” emissions inventory that includes growth and projected changes in emissions based on control measures already in place.
- Compare the SO_x Annex Milestones control strategy to a Best Available Retrofit Technology (BART) scenario and a “BART with uncertainty” scenario.
- Evaluate the sensitivity of visibility to changes in mobile source and road dust emissions from the GCVTC region, California, Las Vegas (Clark County), NV and Phoenix (Maricopa County), AZ.
- Evaluate the effects of a fire emissions “Optimal Smoke Management” strategy.
- Evaluate the sensitivity of visibility to changes in emissions from major point sources of NO_x and PM_{10}.
- Evaluate the progress by 2018 when all §309 control measures are implemented.

Sixteen (16) different emissions scenarios were modeled to perform these evaluations. For most of these scenarios annual model simulations were performed. In the case of the mobile source sensitivity, 7-month simulations were performed, that included the period from April to October. Winter months were excluded because of the high model bias for nitrate during the winter. Because of errors and updates in emissions inventories during the course of the project, some of these model simulations were repeated 2 or 3 times. Table 1.2.6.1 lists the inputs and purposes of the modeling runs.

Table 1.2.6.1. Control strategies and SMOKE files applied in each modeling run.

Scenario Name	Purpose	Emissions components included
1996 Base Case	Model performance evaluation	Point; Area; MOBILE6 and EMFAC2000 for CA; Old non-road mobile; 1996 BESI2 biogenics; actual 1996 wild fire; no windblown fugitive dust; no prescribed or agriculture burning
1996 Base with Typical Wildfire	Comparison to 2018 runs for calculating progress	Same as 1996 base case EXCEPT: New non-road mobile, Typical year wild fire; 2018 base cases for prescribed and agriculture burning
2018 Base Case	Base case for 2018	Point & Area Emissions grown to 2018; MOBILE6 and EMFAC2000, New non-road mobile, 1996 BESI2 biogenics, Typical year wild fire; 2018 base cases for prescribed and agriculture burning
Command and Control	SOx control strategy	Best Available Retrofit Technology; (all else same as 2018 base case)
Command and Control with Uncertainty	SOx control strategy	SOx Inventory with BART uncertainty; (all else same as 2018 base case)
Milestone/Annex	SO_2 Annex Milestones emissions cap scenario	Annex Milestones SOx inventory; (all else same as 2018 base case)
Mobile and Road Dust Sensitivity	Evaluate mobile source and road dust contributions at 16 Colorado Plateau Class I areas	Separate “Zero out” runs for GCVTC states’ mobile sources and road dust; (all else same as 2018 base case)
California Mobile Sensitivity	Evaluate mobile source contribution	Zero out California mobile sources; (all else same as 2018 base case)
Phoenix Mobile Sensitivity	Evaluate mobile source contribution	Zero out Phoenix area mobile sources; (all else same as 2018 base case)
Las Vegas Mobile Sensitivity	Evaluate mobile source contribution	Zero out Clark Co. mobile sources; (all else same as 2018 base case)
50% Point Source NOx reduction	Evaluate contribution of major NOx point sources	Across the board 50% reduction in major point source NOx (facility >100t/day (all else same as 2018 Annex Milestones case)
50% Point Source PM reduction	Evaluate contribution of major PM point sources	Across the board 50% reduction in major point source PM (facility >100t/day (all else same as 2018 Annex Milestones case)
25% Combined Point Source NOx & PM Increase	Evaluate sensitivity to NOx and PM increases	Across the board simultaneous 25% increase in major point source NOx and PM (facility >100t/day (all else same as 2018 Annex Milestones case)
Base Smoke Management (Scenario 1)	Visibility Improvement from 1996 to 2018 from §309 Control Strategies	Annex SOx inventory, Pollution Prevention Scenario (P2); Base Smoke Management; (all else same as 2018 base case)
All Control Case (Scenario 2)	Visibility Improvement from Base to Optimal Smoke Management Programs in 2018	Annex SOx inventory, Pollution Prevention Scenario (P2); Optimal Smoke Management; (all else same as 2018 base case)

In total, approximately 50 years of model simulation were performed, which generated well over 20 Terabytes of output data. Summaries of this data have been placed on the website and in various technical memorandums that describe the effects of these emissions scenarios at the 9 GCVTC Class 1 sites and the 16 Colorado Plateau sites. These results are discussed in detail in subsequent chapters.

1.2.7. Projection of Future-Year Visibility Using Relative Reduction Factors

The CMAQ modeling results for the 1996 Base Case and 2018 emission scenarios were processed following EPA's guidance for projecting visibility changes for demonstrating visibility goals of the Regional Haze Rule (EPA, 1997; 2001).

Future-year visibility is estimated starting with the IMPROVE reconstructed particulate matter (PM) mass measurements for six PM species:

- Sulfate [$(NH_4)_2SO_4$];
- Particulate Nitrate [NH_4NO_3];
- Organic Matter [OM];
- Elemental Carbon [EC];
- Other Fine Particulate [Soil]; and
- Coarse Matter [CM].

Associated with each PM species is an extinction coefficient that converts concentrations (in $\mu g/m^3$) to light extinction (in inverse megameters, Mm^{-1}). Sulfate and nitrate are hygroscopic so relative humidity adjustment factors [f(RH)] are used to modify the extinction coefficients that increase the particle's extinction efficiency with increasing RH to account for the particles taking on water and having higher light scattering properties.

$$B_{Sulfate} = 3 \times f(RH) \times [(NH_4)_2SO_4]$$
$$B_{Nitrate} = 3 \times f(RH) \times [NH_4NO_3]$$
$$B_{EC} = 10 \times [EC]$$
$$B_{OM} = 4 \times [OM]$$
$$B_{Soil} = 1 \times [Soil]$$
$$B_{CM} = 0.6 \times [CM]$$

Monthly average f(RH) factors are used as recommended in EPA's guidance (EPA, 1997; 2001). These values have been recently updated (SAIC, 2003) and are available at:

ftp://ftp.saic.com/raleigh/RegionalHaze_2002FRHcurve/fRH_analysis/

The total light extinction (B_{ext}) is assumed to be the sum of the light extinction due to the six PM species listed above plus Rayleigh (blue sky) background (B_{Ray}) that is assumed to be 10 Mm^{-1}.

$$B_{ext} = B_{Ray} + B_{Sulfate} + B_{Nitrate} + B_{EC} + B_{OM} + B_{Soil} + B_{CM}$$

The total light extinction (B_{ext}) in Mm^{-1} is related to visual range (VR) in km using the following relationship:

$$VR = 3912 / B_{ext}$$

The Regional Haze Rule requires that visibility be expressed in terms of deciview (dV) that uses natural logarithms of the extinction as follows:

$$dV = 10 \ln(B_{ext}/10)$$

It is generally believed that a perceptible change in visibility is approximately 1-2 dV.

The CMAQ modeling results are used in a relative fashion to project future-year visibility using relative reduction factors (RRFs). RRFs are expressed of the ratio of the modeling results for the future-year (2018) scenarios to the results of the base year (1996) and are Class I area and PM species specific. RRFs are applied to the base year observed PM species to project future-year PM levels from which visibility can be assessed using the extinction equations listed above. The specific steps used to project future-year visibility are as follows:

1. Map observed IMPROVE particulate matter (PM) measurements from the IMPROVE monitoring network to each Class I area using the Class I area clustering approach and proximity.
2. For each Class I area, identify the observed PM components for the days during 1996 that represent the Worst 20% and Best 20% visibility days using the extinction equations listed above and generate average observed PM species concentrations for the Worst 20% and Best 20% days and the six PM components of light extinction
3. Run the CMAQ model for the 1996 base-year base case and 2018 future-year emission scenarios, extract the PM species concentrations at the Class I areas for the observed Worst 20% and Best 20% days and generate model estimated average PM concentrations for the observed Worst 20% and Best 20% visibility days from 1996.
4. Develop Class I area and PM species specific Relative Reduction Factors (RRFs) of the average PM concentrations for the Worst 20% and Best 20% observed visibility days that are the ratio of the future-year to base-year modeling results. For example, the RRF for sulfate (SO_4) concentrations for the Worst 20% (W20%) days at the Grand Canyon (GC) for the 2018 Base Case (BC) would be obtained as follows:

   $$RRF_{SO4}(BC, GC, W20\%) = 2018Model_{SO4}(BC, GC, W20\%) / 1996Model_{SO4}(BC, GC, W20\%)$$

5. The future-year PM species estimates at each Class I area and the Worst 20% and Best 20% days are obtained by applying the model estimated RRFs to the observed values. For example, for projecting sulfate concentrations for the 2018 Base Case and the Grand Canyon:

   $$2018_{SO4}(BC, GC, W20\%) = Observed_{SO4}(BC, GC, W20\%) \times RRF_{SO4}(BC, GC, W20\%)$$

6. Two different sets of observed average PM concentrations for the Worst 20% and Best 20% days are used whether projecting improvements in visibility (Chapter 2) or comparing the relative visibility changes due to alternative stationary source control strategies (Chapter 4):

   Projection of Improvement: When projecting improvements in visibility at the 16 Colorado Plateau Class I areas in 2018, the EPA guidance for future-year visibility projections to be used in the future §308 plans were followed as closely as possible. The baseline observed visibility for the Worst 20% and Best 20% days is based on the latest five-year period for which IMPROVE measurements are available, which is 1997-2001. This was done for the following reasons: (1) to follow the EPA guidance as closely as possible; and (2) to take advantage of the availability of more IMPROVE monitors at Class I areas that started to become available in 2000.

   Relative Comparison of Alternative Stationary Source Control Strategies: For §309 the specific evaluation of the relative changes in alternative stationary source control strategies (e.g., comparison of the SO_2 Annex Milestone and BART with Uncertainty control scenarios) the observed average 1996 Worst 20% and Best 20% visibility days was used as the observed baseline. This was done for the following reasons: (1) these analyses are §309-specific; (2) the modeled RRFs and observed visibility baseline would be consistent and based on the same set of visibility days from 1996; and (3) these analyses compare the relative visibility benefits of these control strategies, so the observed baseline is not as important.

7. The future-year visibility estimate is obtained from the future-year PM species estimates using the extinction equation listed above from which visual range and deciview can be estimated also using the equations listed previously.

The EPA procedures (EPA, 2001) for projecting future-year visibility using model estimated RRFs were followed for 4 of the six PM components of light extinction. For the other fine particulate (Soil) and Coarse Matter (CM) components of PM the RRFs were set equal to unity:

$$RRF_{Soil} = RRF_{CM} = 1.0$$

This was done because the WRAP emissions inventory did not include any windblown fugitive dust emissions that is a component of the Soil and CM PM species. Thus, the relative change in the modeling results for these two species (i.e., the RRFs) would be incorrect. This assumes that the Soil and CM components for the Worst 20% and Best 20% visibility days in 2018 remain unchanged from the observed baseline levels.

Chapter 2 - Projection of Improvement

2.1. 2018 visibility improvement scenarios using §309 control strategies

Improvement in visibility for the 16 Colorado Plateau Class I areas was evaluated for two scenarios that anticipate implementation of regional emissions management programs identified in §309. Scenario 1 is designed to assess the effect of the GCVTC-recommended control strategies promulgated in §309, comparing the 1996 modeled base case to the visibility improvement resulting from the implementation of the following strategies: the SO_2 Annex Milestones, the regional pollution prevention program, maintenance of existing base smoke management (BSM) programs, and accounting for the 2018 base case emissions (known and adopted federal, tribal, state, and local control programs in the contiguous WRAP region). Visibility changes resulting from regional implementation of state pollution prevention programs were modeled by the Regional Modeling Center, as part of the other §309 control strategies. Visibility changes resulting from implementation of pollution prevention programs by individual states or tribes were not modeled. Emissions changes from state or tribal pollution prevention programs, and the resulting visibility changes are small, based on the regional pollution prevention emissions analysis, but are accounted for in the regional modeling.

Scenario 2 is designed to assess the effect of the implementation of Enhanced Smoke Management Programs (ESMP), as reflected in the Fire Emissions Joint Forum's 2018 Optimal Smoke Management (OSM) inventory. ESMPs were recommended by GCVTC and are required in §309. This scenario uses the emissions inventories from Scenario 1, except the OSM inventory was substituted for fire emissions. Thus, the results for Scenario 2 are a comparison of visibility changes resulting from emission reductions between the 2018 BSM and 2018 OSM fire inventories.

2.2. Projected visibility improvement in 2018

Presented in the next two subsections are the results of modeling analyses showing the projected visibility improvements at the 16 Class I areas on the Colorado Plateau. For comparison of model-predicted changes in visibility, the absolute modeling results are shown for the average 20% best and worst visibility days are described in Section 2.2.1. Following that in Section 2.2.2, the modeling results for the average 20% best and worst visibility days are shown, calculated using relative reduction factors, compared to the 1997-2001 baseline monitoring data, following the procedures and draft EPA guidance discussed in Chapter 1. The tables in each of the following sections present the projected visibility improvement for the 16 Class I areas on the Colorado Plateau in 2018.

2.2.1. Absolute Modeling Results

The absolute modeling results are shown in Tables 2.2.2.1 and 2.2.1.2, for the 1996 and 2018 base cases, and 2018 Scenarios 1 and 2. Absolute modeling results are not the method recommended in draft EPA guidance for demonstrating reasonable progress (EPA, 2001), but allow direct comparison of model results between years. Given that absolute modeling results have not had relative reduction factors applied, variation in the performance of the model in evaluating different emissions scenarios affecting each Class I area is apparent. Overall performance of the model was discussed in Chapter 1. Thus, the lack of a correlation between the downward-trending emissions reduction scenarios, i.e., 2018 base case to 2018 Scenario 1, and uniformly improving visibility at the 16 Class I areas is not unexpected. Other reasons for changes in visibility at specific Class I areas are discussed in Section 2.2.2.

On the 20% average worst visibility days, there is improving visibility projected between the 1996 and the 2018 base cases, and between the 2018 Scenarios 1 and 2, for all 16 Class I areas. This means that the model is likely accounting well for the noticeable emissions reductions expected from on-road mobile sources and specific stationary sources between 1996 and 2018, and for the anticipated fire emissions reductions expected from implementation of regional ESMPs. Between the 2018 base case and Scenario 1, projected visibility on the worst days stays about the same or degrades slightly, well within model uncertainty, which may be related to a number of factors; model performance at specific Class I areas, and/or emissions location and magnitude changes. Reasons for visibility changes between the 2018 Base Case and Scenario 1 are best evaluated using modeling results normalized using relative reduction factors, discussed in the next section.

On the 20% average best visibility days, projected visibility stays the same or improves between the 1996 and the 2018 base cases, and between the 2018 Scenarios 1 and 2. As above, this means that the model is likely accounting well for the noticeable emissions reductions expected from on-road mobile sources and specific stationary sources between 1996 and 2018, and for the anticipated fire emissions reductions expected from implementation of regional ESMPs. Between the 2018 base case and Scenario 1, projected visibility on the best days degrades slightly, well within model uncertainty, again which may be related to a number of factors; model performance at specific Class I areas, and/or emissions location and magnitude changes. Again, reasons for visibility changes between the 2018 Base Case and Scenario 1 are best evaluated using modeling results normalized using relative reduction factors, discussed in the next section.

Table 2.2.1.1. *Absolute* Modeling Results for Projected Visibility Improvement at the 16 Colorado Plateau Class I areas on the Average 20% Worst Visibility Days, for the 1996 Base Case, the 2018 Base Case, Scenario 1, and Scenario 2.

		***Absolute* Modeling Results (deciviews)**			
Colorado Plateau Class I area	**State**	**1996 Base Case** (20% Worst Days' Visibility)	**2018 Base Case** (20% Worst Days' Visibility for all controls "on the books" as of 2002)	**2018 Scenario 1** (20% Worst Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Base Smoke Management)	**2018 Scenario 2** (20% Worst Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Optimal Smoke Management)
Grand Canyon NP	**AZ**	10.86	9.99	10.58	10.23
Mount Baldy Wilderness	**AZ**	13.06	11.65	11.96	11.81
Petrified Forest NP	**AZ**	12.03	11.19	11.20	11.24
Sycamore Canyon Wilderness	**AZ**	10.04	9.24	9.66	9.44
Black Canyon of Gunnison NP	**CO**	12.08	11.18	11.32	11.39
Flat Tops Wilderness	**CO**	12.58	11.33	11.64	11.49
Maroon Bells-Snowmass WA	**CO**	9.98	9.15	9.44	9.39
Mesa Verde NP	**CO**	11.29	10.04	10.30	10.14
West Elk Wilderness	**CO**	12.40	11.08	11.27	11.17
Weminuche Wilderness	**CO**	14.26	13.55	13.75	13.79
San Pedro Parks Wilderness	**NM**	11.17	9.88	10.02	9.96
Arches NP	**UT**	10.11	9.33	9.77	9.62
Bryce Canyon NP	**UT**	12.74	12.00	12.31	12.29
Canyonlands NP	**UT**	11.37	10.00	10.30	10.17
Capitol Reef NP	**UT**	8.62	7.89	8.11	8.04
Zion NP	**UT**	12.31	10.93	11.03	11.01

Table 2.2.1.2. *Absolute* Modeling Results for Projected Visibility Improvement at the 16 Colorado Plateau Class I areas on the Average 20% Best Visibility Days, for the 1996 Base Case, the 2018 Base Case, Scenario 1, and Scenario 2.

		***Absolute* Modeling Results (deciviews)**			
Colorado Plateau Class I area	**State**	**1996 Base Case (20% Best Days' Visibility)**	**2018 Base Case (20% Best Days' Visibility for all controls "on the books" as of 2002)**	**2018 Scenario 1 (20% Best Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Base Smoke Management)**	**2018 Scenario 2 (20% Best Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Optimal Smoke Management)**
Grand Canyon NP	**AZ**	9.86	8.90	9.27	9.10
Mount Baldy Wilderness	**AZ**	13.17	11.79	12.17	12.04
Petrified Forest NP	**AZ**	9.81	8.92	9.24	9.22
Sycamore Canyon Wilderness	**AZ**	9.25	8.35	8.63	8.52
Black Canyon of Gunnison NP	**CO**	9.99	9.18	9.37	9.37
Flat Tops Wilderness	**CO**	12.63	11.20	11.58	11.47
Maroon Bells-Snowmass WA	**CO**	10.81	10.20	10.35	10.28
Mesa Verde NP	**CO**	12.48	11.16	11.54	11.41
West Elk Wilderness	**CO**	13.24	12.26	12.75	12.54
Weminuche Wilderness	**CO**	15.02	14.18	14.45	14.30
San Pedro Parks Wilderness	**NM**	13.03	11.79	12.09	11.91
Arches NP	**UT**	11.50	10.17	10.98	10.77
Bryce Canyon NP	**UT**	11.57	10.54	10.71	10.59
Canyonlands NP	**UT**	12.50	11.20	11.62	11.44
Capitol Reef NP	**UT**	12.11	11.00	11.44	11.26
Zion NP	**UT**	12.89	11.28	10.31	10.41

2.2.2. Visibility Modeling Results Using Relative Reduction Factors

Using the procedures from draft EPA guidance (EPA, 2001) discussed in Chapter 1, Tables 2.2.2.1 and 2.2.2.2 display the improvements in visibility from the 1997-2001 baseline period to 2018 under Scenario 1 and 2 conditions for, respectively, the Worst 20% and Best 20% visibility days. On the average 20% Worst visibility days, projected improvement from the 1997-2001 baseline data to 2018 Scenario 1 at the 16 Class I areas on the Colorado Plateau range from a maximum reduction of 3.89 dV at Sycamore Canyon National Park in Arizona to a maximum increase of 1.42 dV at San Pedro Parks Wilderness in New Mexico. On the Worst 20% days, Scenario 1 shows improving visibility at half and degradation in visibility for the other half of the 16 Colorado Plateau Class I areas.

On the average 20% Best visibility days, projected change from the 1997-2001 baseline data to 2018 Scenario 1 ranged from a maximum reduction of 2.11 dV at Zion National Park in Utah to a maximum increase of 1.51 dV at San Pedro Parks Wilderness Area in New Mexico. On the Best 20% days, Scenario 1 improves visibility conditions at three-quarters of the Class I areas on the Colorado Plateau. A comparison of the visibility estimates for 2018 Scenarios 1 and 2 at the 16 Class I areas on the Colorado Plateau for the Worst 20% and Best 20% days reveals that 2018 Scenario 2 always estimated reduced (improved) visibility as compared to 2018 Scenario 1. That is, the regional implementation of Enhanced Smoke Management Programs produces visibility improvements over the existing Base Smoke Management Programs across all 16 Class I areas for both the Worst 20% and Best 20% days.

The reason why visibility is projected to improve in some areas and degrade in others is due to the assumptions regarding the growth of emissions and the implementation of all controls "on-the-books" in 2002, as well as artifacts of the June 2000 version of the EPA NONROAD model. Figure 2.2.2.1 displays the differences in SO_2 emissions between the 1996 and 2018 Base Case emissions scenarios. Due to the implementation of SO_2 controls on the Navajo and Mojave power plants between 1996 and 2018, there are projected to be large reductions in SO_2 emissions in the counties in Arizona and Nevada that contain these two point sources. However, in many counties where there are not reductions in point source SO_2 emissions, SO_2 emissions are projected to increase. As discussed in more detail in Chapter 4 and assumed in the modeling results reported here, this is due in part to increased activity in the nonroad mobile source sector, the continued use of high sulfur diesel fuel in nonroad sources, and bugs in the June 2000 version of the EPA NONROAD emissions model, that overstates nonroad equipment activity as well as associated SO_2 emissions.

Visibility is projected to improve on the Worst 20% and Best 20% days for Class I areas in Arizona and southern Utah in close proximity to the large SO_2 reductions expected from controls on the Navajo plant, and downwind from the large SO_2 reductions at the Mojave plant in southern Nevada, as well as from emissions reductions from California. Similarly, the Class I areas where visibility is projected to degrade are near counties where SO_2 emissions are forecast to increase due to the assumed increases in SO_2 emissions from the nonroad mobile source sector. For example, the San Pedro Parks Wilderness Area in New Mexico lies in and near counties that are projected to have increases in SO_2 emissions under the 2018 Base Case conditions, and it is not surprising that the modeling results project that visibility would degrade at this Class I area. Future visibility modeling of the emissions projected by the updated NONROAD2002 model, accounting for proposed low sulfur diesel and emission control regulations for nonroad sources, and anticipating other local (e.g., 8-hour ozone and fine particulate) would likely produce improving visibility at all 16 Class I areas.

Table 2.2.2.1. Projected Visibility Improvement at the 16 Colorado Plateau Class I areas on the Average 20% Worst Visibility Days, comparing the 1997-2001 Monitoring Data to the 2018 Base Case, Scenario 1, and Scenario 2 Modeling Results, using Relative Reduction Factors.

			Modeling Results (deciviews)		
Colorado Plateau Class I area	**State**	**1997-2001 Monitoring Data** (20% Worst Days' Visibility - deciviews)	**2018 Base Case** (20% Worst Days' Visibility for all controls "on the books" as of 2002)	**2018 Scenario 1** (20% Worst Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Base Smoke Management)	**2018 Scenario 2** (20% Worst Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Optimal Smoke Management)
Grand Canyon NP	**AZ**	12.30	11.62	11.56	11.51
Mount Baldy Wilderness	**AZ**	14.30	12.22	12.02	11.96
Petrified Forest NP	**AZ**	13.00	11.99	11.82	11.74
Sycamore Canyon Wilderness	**AZ**	15.40	11.63	11.51	11.48
Black Canyon of Gunnison NP	**CO**	11.30	10.90	10.76	10.60
Flat Tops Wilderness	**CO**	10.50	11.04	10.91	10.73
Maroon Bells-Snowmass WA	**CO**	10.60	11.15	11.00	10.84
Mesa Verde NP	**CO**	13.10	12.24	12.03	11.84
West Elk Wilderness	**CO**	10.60	11.19	10.99	10.84
Weminuche Wilderness	**CO**	11.30	11.08	10.89	10.72
San Pedro Parks Wilderness	**NM**	10.70	12.33	12.12	11.71
Arches NP	**UT**	12.10	12.41	12.29	12.15
Bryce Canyon NP	**UT**	11.80	12.26	12.24	11.95
Canyonlands NP	**UT**	12.10	12.41	12.31	12.18
Capitol Reef NP	**UT**	12.10	12.51	12.49	12.36
Zion NP	**UT**	13.60	12.13	12.09	12.03

Table 2.2.2.2. Projected Visibility Improvement at the 16 Colorado Plateau Class I areas on the Average 20% Best Visibility Days, comparing the 1997-2001 Monitoring Data to the 2018 Base Case, Scenario 1, and Scenario 2 Modeling Results, using Relative Reduction Factors.

			Modeling Results (deciviews)		
Colorado Plateau Class I area	**State**	**1997-2001 Monitoring Data (20% Best Days' Visibility - deciviews)**	**2018 Base Case (20% Best Days' Visibility for all controls "on the books" as of 2002)**	**2018 Scenario 1 (20% Best Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Base Smoke Management)**	**2018 Scenario 2 (20% Best Days' Visibility for all §309 Control Strategies (SO_2 Annex Milestones and Pollution Prevention) with Optimal Smoke Management)**
Grand Canyon NP	**AZ**	4.80	4.76	4.72	4.64
Mount Baldy Wilderness	**AZ**	5.50	5.49	5.46	5.36
Petrified Forest NP	**AZ**	6.50	5.18	5.14	5.10
Sycamore Canyon Wilderness	**AZ**	6.30	4.85	4.82	4.75
Black Canyon of Gunnison NP	**CO**	4.60	3.89	3.83	3.75
Flat Tops Wilderness	**CO**	3.10	3.96	3.90	3.81
Maroon Bells-Snowmass WA	**CO**	3.10	3.90	3.85	3.80
Mesa Verde NP	**CO**	5.50	4.40	4.38	4.33
West Elk Wilderness	**CO**	3.10	3.89	3.83	3.74
Weminuche Wilderness	**CO**	4.60	3.97	3.92	3.82
San Pedro Parks Wilderness	**NM**	4.00	5.59	5.51	5.36
Arches NP	**UT**	5.50	4.85	4.72	4.61
Bryce Canyon NP	**UT**	4.30	3.91	3.92	3.89
Canyonlands NP	**UT**	5.60	4.87	4.76	4.67
Capitol Reef NP	**UT**	5.60	4.85	4.85	4.75
Zion NP	**UT**	5.90	3.81	3.79	3.75

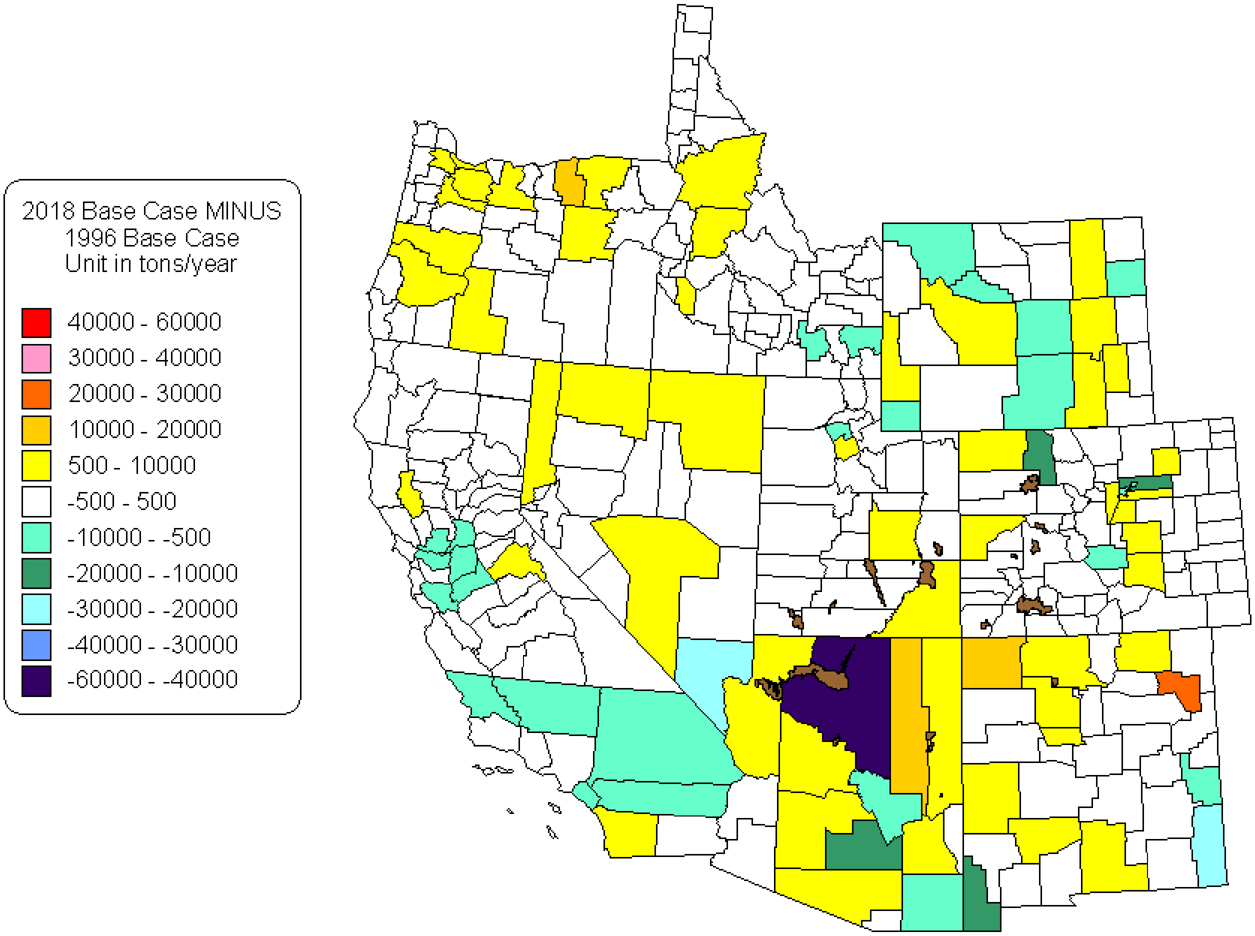


Figure 2.2.2.1. Differences in count average SO_2 emissions between the 1996 Base Case and the 2018 Base Case emissions scenarios.

Chapter 3 – Assessment of Clean Air Corridors

3.1. Clean Air Corridor (CAC) Requirements

The requirements of the regional haze rule regarding clean air corridors are found in §309(d)(3): *The plan must describe and provide for implementation of comprehensive emission tracking strategies for clean-air corridors to ensure that the visibility does not degrade on the least impaired days at any of the 16 Class I areas.*

More specifically, the rule requires that the §309 SIP:

1. Identify clean air corridors, with EPA evaluating the identification based on the work of the Meteorology Subcommittee of the Grand Canyon Visibility Transport Commission;
2. Within the clean air corridors, identify patterns of growth that could cause significant emissions increases that could impair visibility at one or more of the 16 Class I areas;
3. Identify significant emissions growth outside the clean air corridors that could impair the quality of the air in the corridor;
4. If impairment is identified, analyze the effects of increased emissions and provide for implementation of additional emissions reductions where necessary; and
5. Determine whether any other clean air corridors exist for any of the 16 Class I areas and identify any measures necessary to protect them against future degradation.

3.2. CAC Definition

The Clean Air Act Amendments of 1990 specifically require that visibility transport commissions address "the establishment of clean air corridors, in which additional restrictions on increases in emissions may be appropriate to protect visibility in affected class I areas."[1] The Grand Canyon Visibility Transport Commission (GCTVC) in its recommendations[2] found that clean air corridors exist and that, generally, clean air comes to the Colorado Plateau from the northwest. Using one of the proposed corridor alignments examined by the Meteorology Subcommittee, a corridor that would protect the 30% cleanest days on the Colorado Plateau, BBC Research and Consulting conducted an economic and demographic evaluation of the corridor to determine whether emissions increases expected by 2040 would approach 25%.

According to its projections, emissions are not expected to increase 25% by 2040.[3] The boundaries of the corridor defined in the report are shown in Figure 25. The WRAP adopts this boundary because of the extensive demographic, economic, and air quality impact analysis performed on this corridor and the subsequent review and approval, including the consensus reached by the Grand Canyon Visibility Transport Commission. This is a slight modification of the boundary used in the BBC Report. The grid cells used by the GCVTC did not follow state or

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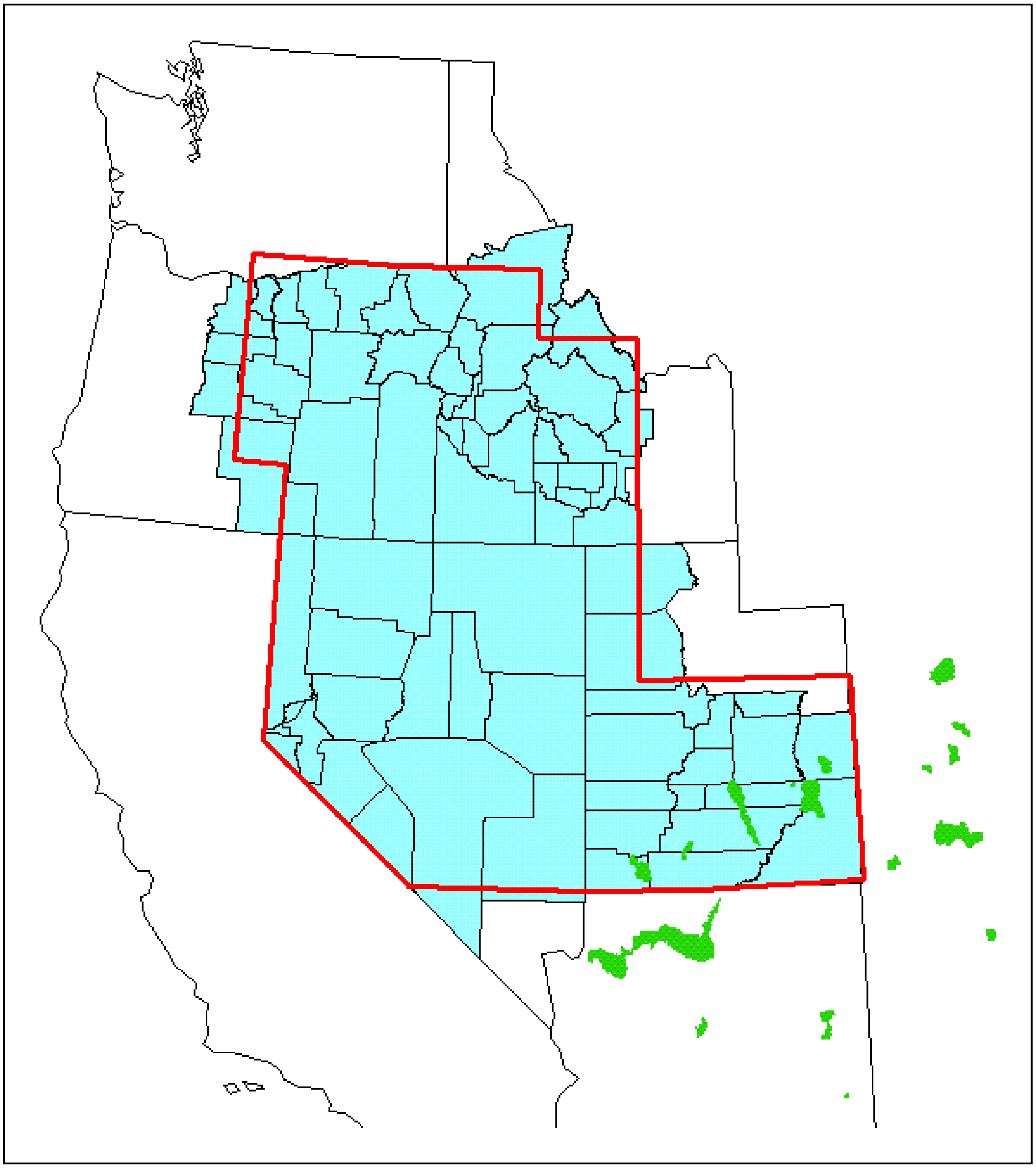
[1] 42 U.S.C. 2169B(d)(2)(A).

[2] Grand Canyon Visibility Transport Commission. "Recommendations for Improving Western Vistas". Western Governors' Association. Denver, CO. June 1996.

[3] BBC Report, page III-5

county boundaries, and for ease of administration, the WRAP has removed small areas of southern Washington and southwestern Montana from the corridor. These areas are far from the Colorado Plateau and it is unlikely that emissions increases in these small areas would affect the Class I areas on the Plateau. Also, the WRAP boundary includes all of Box Elder, Tooele and Grand Counties in Utah, Wasco and Sherman Counties in Oregon, and Cassia and Lemhi Counties in Idaho; these counties were not included within the BBC boundary.

Figure 25: Clean Air Corridor – WRAP (blue) – GCVTC/BBC (red) and Colorado Plateau Class I areas (green)



3.3. Emission Changes

Emission changes within the clean air corridor between the 1996 base year and the projection year of 2018, including the SO_2 Annex Milestones case are shown in Table 32. PM_{10} and $PM_{2.5}$ emissions are expected to increase about 7% and 18%, respectively. NO_x and VOC, however, are expected to decrease about 15% and 26%, respectively. SO_2 emissions are expected to increase about 5% within the corridor, even with the declining milestones of the backstop emissions cap program. Overall, SO_2 emissions are expected to decline by 17% in the 13-state GCVTC region by 2018, and the fact that the projections show a 5% increase in SO_2 within the clean air corridor is a result of non-road sources burning high-sulfur diesel fuel. This source of SO_2 is expected to drastically reduce (e.g., from a fuel sulfur content of more than 3,000 ppm to 15 ppm) before 2018 according to announcements by EPA to develop new engine certification standards for non-road vehicles and equipment. Thus, 5% should be viewed as an upper bound on the possible increase.

Table 32: Changes in CAC Emissions by 2018 (including milestones) from 1996

		Point	**Area**	**On Road**	**Non Road**	**Paved**	**Unpaved**	**Total**
SO_2	1996	51,413	9,260	2,065	10,838	0	0	73,576
	2018	45,330	10,614	413	21,596	0	0	77,954
	2018-1996	-6,082	1,354	-1,652	10,758	0	0	4,378
NO_x	1996	85,782	12,935	93,581	64,462	0	0	256,762
	2018	109,863	17,576	28,692	62,557	0	0	218,689
	2018-1996	24,080	4,641	-64,889	-1,905	0	0	-38,072
PM_{10}	1996	27,055	142,776	3,872	5,952	5,740	47,733	233,128
	2018	32,748	154,966	2,640	6,763	12,402	38,828	248,347
	2018-1996	5,692	12,190	-1,232	811	6,662	-8,904	15,219
$PM_{2.5}$	1996	11,987	41,595	3,495	5,487	1,435	7,160	71,160
	2018	14,583	52,069	2,058	6,228	3,101	5,824	83,863
	2018-1996	2,595	10,474	-1,438	740	1,665	-1,336	12,702
VOC	1996	5,993	95,921	69,899	38,535	0	0	210,349
	2018	7,921	95,515	22,651	29,233	0	0	155,321
	2018-1996	1,927	-406	-47,248	-9,301	0	0	-55,029

3.4. CAC emissions tracking using the WRAP Emissions Data Management System

The preamble of the RHR defines a CAC as “a region that generally brings clean air to a receptor region”, and also says, “the requirement to track emissions will enable states to quickly determine if changes in patterns of emissions will reduce the number of clean air days (defined as the average of the 20% clearest days) in any of the 16 Class I areas.” The actual requirements state that the §309 SIP or TIP must describe and provide for implementation of comprehensive emission tracking strategies for CAC to ensure that the visibility does not degrade on the least-impaired days at any of the 16 Class I areas.

Using the most recent emission inventory data available through the Emissions Data Management System (EDMS), WRAP will produce a report for each five-year implementation plan revision (2007-8, 2013, and 2018) on the current and projected emissions in the CAC and in areas surrounding the corridor and compare these emissions to a 1996 baseline, as part of a larger attribution of haze project managed by the Technical Oversight Committee (described in the next section).

The EDMS will have the capability to produce the following special reports in tabular and simple plots (i.e. bar graph and pie chart) formats and allow queries of the same information including presentation in GIS format, in addition to the standard reports:

- A summary report of the annual summed total emissions for all six source categories and all of the pollutants by county/state and tribal lands, as well as for the entire CAC.
- A summary report of the annual summed total emissions for all six source categories and all of the pollutants for the same types of political boundaries surrounding the CAC.
- A summary report of the comparison of the annual summed total emissions for all six source categories and all of the pollutants for the same types of political boundaries, as well as the entire CAC and the corresponding base year total emissions.

The EDMS to be developed is described in a draft technical report to the Emissions Forum: Needs Assessment for Evaluation and Design of an Emissions Data Reporting, Management, and Tracking System, (EA Engineering, Science, and Technology, June 26, 2003).

3.5. Process to analyze emissions growth in, and surrounding, the CAC

As part of the next round of analysis and preparation for regional haze SIPs due in 2007-08, the Technical Oversight Committee will be conducting two separate haze attribution exercises (discussed in the WRAP 2003-08 Strategic Plan), integrating analytical results from aerosol and meteorological monitoring, air quality modeling, and preparation of emissions inventories. These haze attribution exercises will identify the source regions and categories causing visibility impairment at Class I areas. As part of those haze attribution exercises, the TOC will analyze the changes in emissions for the counties and tribal lands in the CAC, as well as those surrounding the CAC. Better emissions inventory data expected to be available each time, as the TOC iterates through these 2 exercises. Specific results from each of the haze attribution exercises will address emissions growth both inside and surrounding the CAC, as well as the impact on visibility at affected Class I areas.

3.6. Other Clean Air Corridors

Other than the various options for selection of a clean air corridor for Grand Canyon National Park, shown above, no other corridors have been identified. If the growth of visibility-impairing emissions, in the corridor identified, remain protective of Grand Canyon National Park, then it should be protective of the other Colorado Plateau Class I areas. Localized emissions near the Class I areas within the Clean Air Corridor, however, may have more effect on those Class I areas. Similarly, disproportionate emissions growth in the southern portion of the corridor may have more effect on Grand Canyon National Park.

Chapter 4 – Assessment of Stationary Sources

4.1. Visibility Improvements of the SO_2 Milestone Annex versus the BART with Uncertainty Control Scenarios

One of the elements of §309 of the Regional Haze Rule (RHR) requires the demonstration that the SO_2 Annex Milestone stationary source control strategy recommended by the GCVTC is better than Best Available Retrofit Technology (BART) controls for SO_2 on stationary sources, for improving visibility at the 16 Class I Areas on the Colorado Plateau. This demonstration has been made in the SO_2 Annex submitted by WRAP, and adopted in rule by EPA. The modeling analyses discussed next serve to verify the original Annex analysis, and also provides estimates of visibility changes due to the SO_2 Annex and BART scenarios at other Class I areas as well. The CMAQ modeling system was applied to estimate fine particulate concentrations and visibility in the western U.S., using the 1996 MM5 meteorological data for three future-year emission scenarios:

- 2018 Base Case;
- 2018 SO_2 Annex Milestones; and
- 2018 BART with Uncertainty.

Chapter 1 of the TSD discusses the assumptions and emissions summaries of the 2018 Base Case, 2018 SO_2 Annex Milestones, and 2018 BART with Uncertainty emission scenarios.

The RHR uses two metrics to judge changes in visibility at Class I areas:

- The 5-year mean visibility (expressed as extinction or deciview) of the observed 20% worst visibility days; and
- The 5-year mean visibility of the observed 20% best visibility days.

For the future §308 regional haze implementation plans, the RHR requires demonstration of reasonable progress toward achieving natural visibility conditions (i.e., no man-made impairment) by 2064 for the mean of the Worst 20% observed days and show no degradation in visibility for the mean of the Best 20% observed days. To assess whether the 2018 SO_2 Annex control strategy is “better than” the 2018 BART with Uncertainty control scenario at the 16 Class I areas in the Colorado Plateau, the average 20% Worst and 20% Best visibility days' metrics are used. The RHR observed visibility baseline is the five-year 2000-2004 period. The §309 SIPs are due in 2003, so the 2000-2004 data are not yet available. Thus, a 1996 baseline period is used to assess the visibility impacts of the 2018 Base Case, 2018 SO_2 Annex, and 2018 BART with Uncertainty emission scenarios as the data for the RHR 2000-2004 baseline period are not yet available.

Future-year visibility estimates were generated for the 16 Class I areas on the Colorado Plateau using 1996 IMPROVE observations and the 1996 and 2018 CMAQ model estimates and the procedures discussed in Chapter 1 following EPA guidance (EPA, 1997; 2001). These procedures use the model in a relative sense to scale the observed visibility components using relative reduction factors (RRFs) to project future-year visibility estimates. IMPROVE measurements were not available at all of the 16 Class I areas during the 1996 baseline period. So for those Class I areas without IMPROVE observations the IMPROVE data from the closest most representative monitoring site were mapped to the Class I area as shown in Table 32. Note that although IMPROVE measurement data had to be mapped to some of the 16 Class I areas, the modeling results at the actual location of each Class I area were used to project future-year visibility estimates.

Table 4.1.1. Mapping of 1996 IMPROVE PM measurement data to the 16 Class I areas on the Colorado Plateau

Class I Area	**Mapped IMPROVE Monitor**
Arches NP	Canyonlands NP
Black Canyon of Gunnison NP	Weminuche Wilderness
Bryce Canyon NP	Bryce Canyon NP
Canyonlands NP	Canyonlands NP
Capitol Reef NP	Canyonlands NP
Flat Tops Wilderness	Mount Zirkel Wilderness
Grand Canyon NP	Grand Canyon NP
Maroon Bells-Snowmass Wilderness	Weminuche Wilderness
Mesa Verde NP	Mesa Verde NP
Mount Baldy Wilderness	Petrified Forest NP
Petrified Forest NP	Petrified Forest NP
San Pedro Parks Wilderness	Bandelier National Monument
Sycamore Canyon Wilderness	Grand Canyon NP
West Elk Wilderness	Weminuche Wilderness
Weminuche Wilderness	Weminuche Wilderness
Zion NP	Bryce Canyon NP

Table 4.1.2 displays the 2018 visibility estimates for the Worst 20% days at the 16 Class I areas on the Colorado Plateau and the 2018 Base Case, 2018 SO_2 Annex Milestone, and 2018 BART with Uncertainty emission scenarios. The visibility estimates are presented for the three 2018 emissions scenarios in terms of deciview (dV). Also shown in Table 33 are the differences in visibility for the Worst 20% days between the 2018 control scenarios and the 2018 Base Case. Based on the results in Table 33 we can draw the following conclusions regarding visibility changes due to the SO_2 Annex Milestone versus the BART with Uncertainty control scenarios:

- The two 2018 stationary source SO_2 control scenarios result in small improvements in visibility over the 2018 Base Case that are less than can be perceived (< 1 dV);
- The SO_2 Annex Milestone results in more visibility benefits than the BART with Uncertainty at 15 of the 16 (~94%) Class I areas on the Colorado Plateau.

The one Class I area of the 16 on the Colorado Plateau where more visibility improvements are estimated in the 2018 BART with Uncertainty scenario than the 2018 SO_2 Annex Milestone strategy is Petrified Forest National Park where the BART with Uncertainty estimates slightly more visibility benefits over the 2018 Base Case (-0.26 dV) than estimated for the SO_2 Annex Milestone (-0.24 dV) control strategy.

Table 4.1.2. Estimated visibility levels in deciviews (dV) at the 16 Class I areas on the Colorado Plateau for the **Worst** 20% days and the 2018 Base Case, 2018 SO_2 Annex Milestones, and 2018 BART with Uncertainty emission scenarios and the differences (improvements) in visibility due to the 2018 control scenarios from the 2018 Base Case.

Class I Areas	2018 Base Case (dV)	2018 SO_2 Annex (dV)	2018 BART w/Uncert. (dV)	Difference Annex – Base (dV)	Difference BART– Base (dV)
Arches NP	12.42	12.32	12.37	-0.10	-0.05
Black Canyon of Gunnison NP	10.95	10.79	10.85	-0.16	-0.10
Bryce Canyon NP	12.26	12.23	12.24	-0.03	-0.02
Canyonlands NP	12.27	12.17	12.21	-0.09	-0.05
Capitol Reef NP	12.50	12.46	12.49	-0.03	-0.01
Flat Tops Wilderness	10.89	10.74	10.79	-0.15	-0.10
Grand Canyon NP	11.77	11.69	11.71	-0.08	-0.06
Maroon Bells-Snowmass Wilderness	11.23	11.04	11.10	-0.19	-0.13
Mesa Verde NP	12.04	11.85	11.92	-0.18	-0.12
Mount Baldy Wilderness	12.26	12.09	12.14	-0.17	-0.13
Petrified Forest NP	11.99	11.76	11.73	-0.24	-0.26
San Pedro Parks Wilderness	12.32	12.11	12.16	-0.21	-0.16
Sycamore Canyon Wilderness	12.11	12.01	12.04	-0.10	-0.07
West Elk Wilderness	11.12	10.90	10.96	-0.22	-0.16
Weminuche Wilderness	11.01	10.80	10.87	-0.20	-0.14
Zion NP	12.03	12.00	12.02	-0.03	-0.01

Table 4.1.3 summarizes the changes in visibility at the 16 Class I areas for the Best 20% visibility days from 2018 Base Case levels for the 2018 SO_2 Annex Milestone and the 2018 BART with Uncertainty control scenarios. Both the 2018 SO_2 Annex and BART with Uncertainty estimate very small (hundredths of dV) improvements in visibility at the 16 Class I areas for the Best 20% days. For all 16 Class I areas on the Colorado Plateau and the Best 20% visibility days, the 2018 SO_2 Annex Milestone control strategy estimates more visibility improvement (12 Class I areas) or the same visibility improvement (4 Class I areas) from the 2018 Base Case than the 2018 BART with Uncertainty control scenario.

In conclusion, when looking at all 16 Class I areas on the Colorado Plateau and the Worst 20% and Best 20% visibility days, the 2018 SO_2 Annex Milestone control strategy estimate more visibility improvements than the 2018 BART with Uncertainty control scenario.

Table 4.1.3. Estimated visibility levels in deciviews (dV) at the 16 Class I areas on the Colorado Plateau for the **Best** 20% days and the 2018 Base Case, 2018 SO_2 Annex Milestones and 2018 BART with Uncertainty emission scenarios and the changes in visibility due to the 2018 control scenarios from the 2018 Base Case.

Class I Area	**2018 Base Case (dV)**	**2018 SO_2 Annex (dV)**	**2018 BART w/Uncert. (dV)**	**Difference Annex – Base (ΔdV)**	**Difference BART– Base (ΔdV)**
Arches NP	4.85	4.77	4.80	-0.08	-0.05
Black Canyon of Gunnison NP	3.87	3.83	3.85	-0.05	-0.02
Bryce Canyon NP	3.24	3.22	3.23	-0.01	-0.01
Canyonlands NP	4.78	4.71	4.74	-0.06	-0.04
Capitol Reef NP	4.84	4.81	4.82	-0.03	-0.02
Flat Tops Wilderness	3.89	3.83	3.85	-0.06	-0.03
Grand Canyon NP	4.76	4.69	4.71	-0.07	-0.05
Maroon Bells-Snowmass Wilderness	3.89	3.83	3.85	-0.06	-0.04
Mesa Verde NP	4.20	4.16	4.18	-0.03	-0.01
Mount Baldy Wilderness	5.46	5.42	5.42	-0.04	-0.04
Petrified Forest NP	5.19	5.14	5.15	-0.04	-0.04
San Pedro Parks Wilderness	5.55	5.49	5.52	-0.06	-0.04
Sycamore Canyon Wilderness	4.86	4.81	4.82	-0.05	-0.03
West Elk Wilderness	3.88	3.84	3.86	-0.05	-0.03
Weminuche Wilderness	3.93	3.89	3.91	-0.05	-0.03
Zion NP	3.80	3.78	3.79	-0.02	-0.01

4.1.1. Stationary Source SO_2 Control Scenario Modeling Results at the 16 Class I Areas on the Colorado Plateau

Although the modeling results suggest that overall the 2018 SO_2 Annex Milestone strategy is better than BART with Uncertainty for improving visibility at the 16 Class I areas on the Colorado Plateau, the reasons why the improvements are so small and why the SO_2 Annex estimates less improvement in visibility than BART with uncertainty for the 20% Worst days at Petrified Forest National Park need to be understood.

Figure 4.1.1.1 displays the difference in SO_2 emissions between the 1996 Base Case and the 2018 Base Case emissions scenario by county for the 9 western states that may opt-in to §309. Table 4.1.1.1 displays the SO_2 emissions for the 13 “WRAP” states (includes Nevada but not Alaska) and the 1996 and 2018 Base Cases and 2018 SO_2 Annex and BART with Uncertainty emissions scenarios. Figure 4.1.1.2 displays the differences in SO_2 emissions between the 2018 Base Case and 2018 SO_2 Annex Milestone control scenario, whereas Figure 4.1.1.3 displays the differences in SO_2 emissions between the 2018 SO_2 Annex and 2018 BART with Uncertainty emission control strategies. Observations on these figures and tables are as follows:

- Between the 1996 and 2018 Base Cases there is an approximately 210 thousand ton per year (TTPY) (-18%) reduction in SO_2 emissions from point sources that is partly offset by a 60 TTPY and 25 TTPY increase in SO_2 emissions from the non-road mobile and area source sectors, respectively, resulting in a net reduction in SO_2 emissions across the WRAP states of only 148 TTPY (-9%).
- The largest reductions in SO_2 emissions between the 1996 Base Case and the 2018 Base Case occur in Coconino County, Arizona (~60,000 TPY) and Clark County, Nevada (~25,000 TPY) that are mainly due to implementation of SO_2 controls on the Navajo and Mojave generating stations, respectively.
- In contrast to the controls on Navajo and Mojave electrical generating units (EGUs) between the 1996 and 2018 Base Cases that occur adjacent to or upwind of the 16 Class I areas on the Colorado Plateau, the additional SO_2 controls on EGUs due to the SO_2 Annex Milestone control scenario occur at locations more downwind from the 16 Class I areas, which explains the small impacts they have on visibility (Table 36).
- The differences in SO_2 emissions between the 2018 SO_2 Annex and 2018 BART with uncertainties (Figure 4.1.1.3) show counties with increases and decreases with the SO_2 Annex scenario generally having lower SO_2 emissions with a net reduction of approximately 40,000 TPY.
- The county in which the SO_2 Annex emissions scenario has the highest amount of SO_2 emissions compared to the BART with Uncertainty scenario (~7,000 TPY higher) is Navajo County, Arizona, which is due to the Cholla EGU. The effects of the market trading program estimates that Cholla would be a buyer of emission credits so would have greater emissions under the SO_2 Annex emission scenario than under a more traditional command and control BART with Uncertainty control strategy. As the Cholla EGU is nearby and upwind of the Petrified Forest National Park, these results explain why the BART with Uncertainty scenario produces slightly more visibility improvements than the SO_2 Annex Milestone control strategy.

Table 4.1.1.1. Summary of SO_2 emissions (thousand tons per year, TTPY) in the 13 WRAP states for the 1996 and 2018 Base Cases and 2018 SO_2 Annex Milestones and 2018 BART with Uncertainty emission control scenarios.

			% Diff			**% Difference**	
	1996 Base (TTPY)	**2018 Base (TTPY)**	**2018-1996 (%)**	**2018 Annex (TTPY)**	**2018 BART (TTPY)**	**Annex-Base (%)**	**BART-Base (%)**
Point	1197	985	-18%	768	809	-22%	-18%
Mobile	28	7	-77%	7	7	0%	0%
Non-Road	213	272	+28%	272	272	0%	0%
Area	142	167	+18%	167	167	0%	0%
Wildfire	25	25	0%	25	25	0%	0%
Ag Fire	1	1	0%	1	1	0%	0%
Rx Fire	31	31	0%	31	31	0%	0%
Total	1638	1490	-9%	1272	1312	-15%	-12%

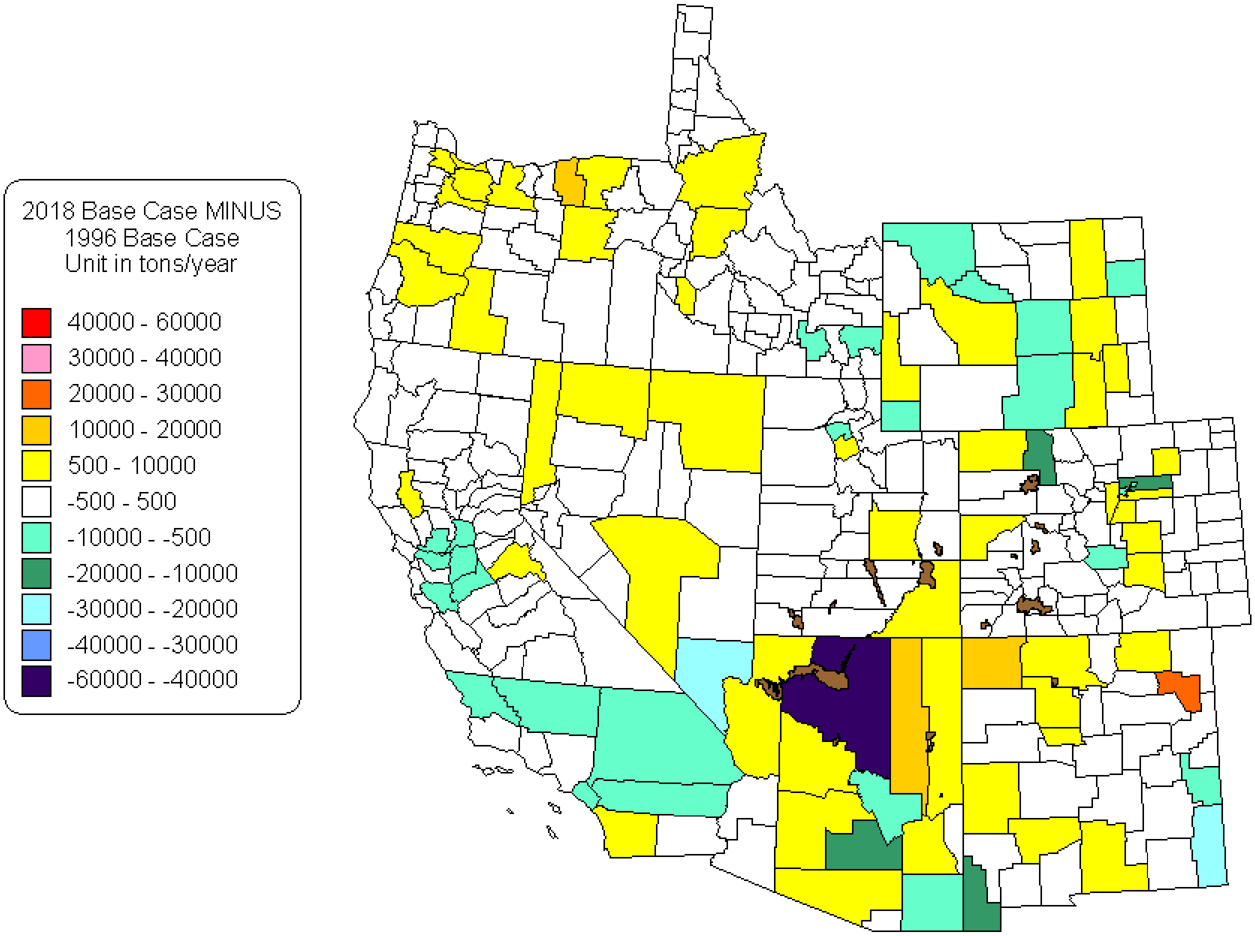


Figure 4.1.1.1. Changes in SO_2 emissions between the 1996 Base Case and 2018 Base Case emissions scenarios by county for the 9 potential §309 states.

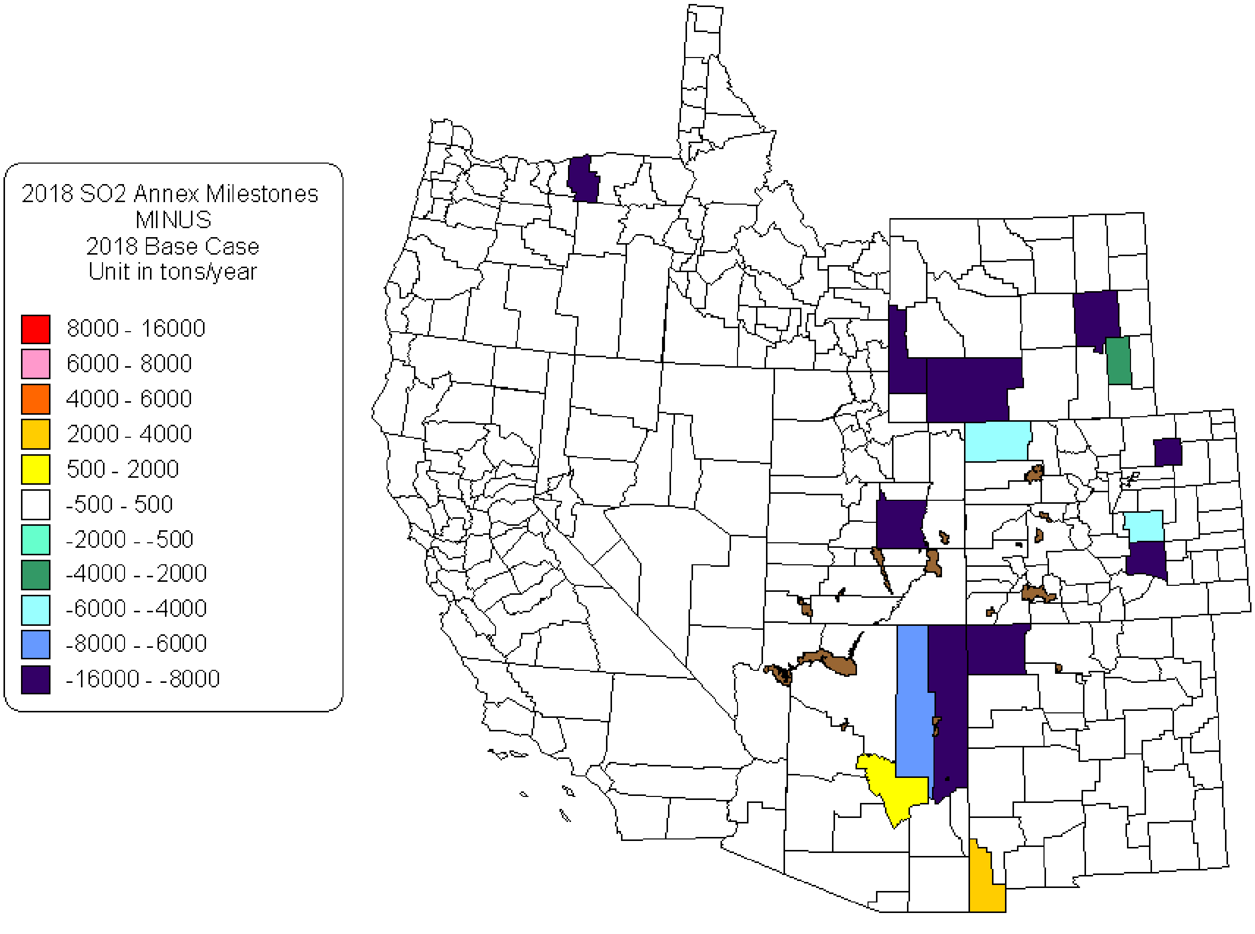


Figure 4.1.1.2. Changes in SO_2 emissions between the 2018 Base Case and 2018 SO_2 Annex Milestones control scenario by county for the 9 potential §309 states.

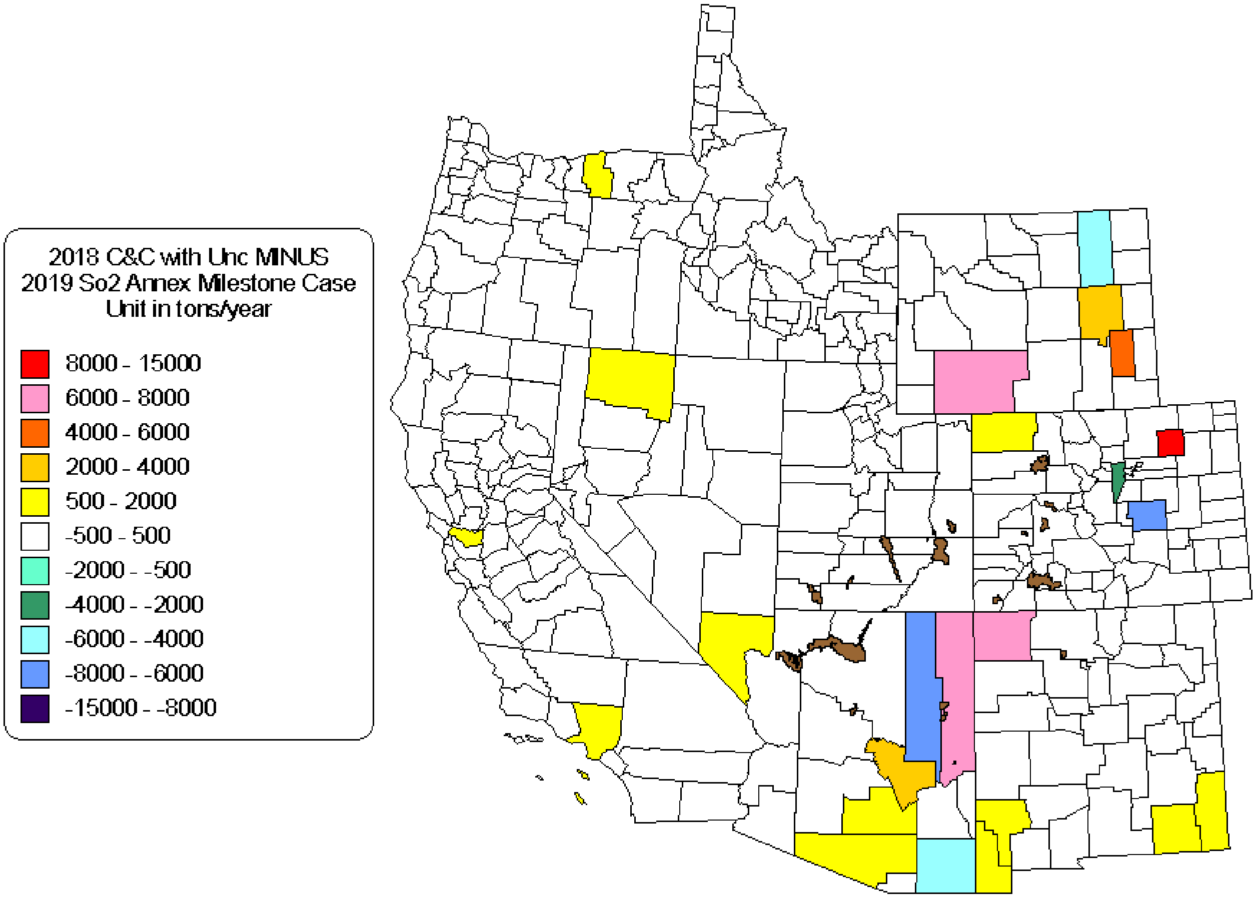


Figure 4.1.1.3. Changes in SO_2 emissions between the 2018 SO_2 Annex Milestones and 2018 BART with Uncertainty control scenarios by county for the 9 potential §309 states.

4.1.2. Stationary Source SO_2 Control Scenario Modeling Results for Western Class I Areas

Tables 4.1.2.1 and 4.1.2.2 list the changes in visibility from the 2018 Base Case for the 2018 SO_2 Annex Milestone and 2018 BART with Uncertainty control scenarios and the Worst 20% and Best 20% visibility days, respectively, for all Class I areas in the WRAP modeling domain (roughly west of the Mississippi River) ordered by state. The results can be summarized as follows:

Arizona: For the Worst 20% days, the SO_2 Annex Milestone estimates more visibility improvements than BART with Uncertainty for 13 of the 14 Class I areas in Arizona. The one exception is Petrified Forest National Park that has slightly less visibility improvements in the SO_2 Annex scenario due to the higher SO_2 emissions at the Cholla EGU described above. For the Best 20% days, the SO_2 Annex scenario estimates the same or more visibility improvements that BART with Uncertainty for 12 of the 14 Class I areas with the only exceptions being the Chiricahua Wilderness and National Monument near the Mexican border where very small -0.01 dV (SO_2 Annex) and –0.03 dV (BART with Uncertainty) improvements in visibility are estimated.

California: Both the SO_2 Annex and BART with Uncertainty scenarios both have essentially no effect on visibility at the 29 Class I areas in California on the Worst 20% and Best 20% days. This is due to the fact that there are very few large stationary SO_2 sources in California that would be affected by the two strategies.

Colorado: At the 12 Class I areas in Colorado, the 2018 SO_2 Annex scenario is estimated to have the same or more visibility improvements than the 2018 BART with Uncertainty scenario at each Class I area.

Idaho: The 2018 SO_2 Annex Milestone control scenario estimates approximately the same visibility benefits as the 2018 BART with Uncertainty control scenario at each of the four Class I areas in Idaho.

Michigan: The Isle Royal National Park is the only Class I area in Michigan and the SO_2 Annex and BART with Uncertainty control strategies estimate almost identical visibility benefits for the Worst 20% and Best 20% days.

Minnesota: The two 2018 control scenarios also estimate essentially the same visibility benefits at the two Class I areas in Minnesota.

Missouri: Almost identical visibility benefits are estimated for the SO_2 Annex and BART with Uncertainty control scenarios at the Mingo and Hercules-Glade Class I areas in Missouri.

Montana: For the 10 Class I areas in Montana and both the 20% Worst and 20% Best visibility days, the 2018 SO_2 Annex scenario estimates the same or better visibility improvements than the 2018 BART with Uncertainty control scenario.

North Dakota: The visibility benefits of the two 2018 control scenarios are essentially the same at the two Class I areas in North Dakota with exactly the same visibility improvements at Lostwood Wilderness and slightly more benefits exhibited by the SO_2 Annex scenario at Theodore Roosevelt National Park.

New Mexico: The visibility benefits due to the 2018 SO_2 Annex control scenario are estimated to be better than the 2018 BART with Uncertainty control scenario at all 9 Class I areas in New Mexico for both the Worst 20% and Best 20% visibility days.

Nevada: The SO_2 Annex scenario estimates slightly better visibility on both the Worst 20% and Best 20% days at the Jarbidge Wilderness Area, the only Class I area in Nevada.

Oklahoma: The estimated visibility improvements for the SO_2 Annex scenario are better than BART with Uncertainty for both the Worst 20% and Best 20% days at the Wichita Mountains Wilderness Area, the only Class I area in Oklahoma.

Oregon: At the 11 Class I areas in Oregon, the SO_2 Annex scenario estimates more visibility improvements than the BART with Uncertainty scenario on the Worst 20% days. For the Best 20% days, both 2018 scenarios estimate there will be no change in visibility over the 2018 Base Case conditions at most of the Class I areas, but when there are changes visibility is improved and the SO_2 Annex scenario estimates more improvements than the BART with Uncertainty scenario.

South Dakota: More improvements in visibility are estimated by the 2018 SO_2 Annex scenario than the 2018 BART with Uncertainty for the Worst 20% days at the two Class I areas in South Dakota. For the Best 20% days, the two 2018 control scenarios estimate essentially the same level of visibility improvements.

Texas: Nearly equivalent visibility benefits are estimated for both the Worst 20% and Best 20% days and both Class I areas in Texas, with the SO_2 Annex scenario always exhibiting the same or better improvements than BART with Uncertainty.

Utah: All five Class I areas in Utah are part of the 16 Class I areas on the Colorado Plateau. The SO_2 Annex Milestone scenario estimates more visibility improvements than the BART with Uncertainty scenario at all five Class I areas for the Worst 20% days and at 4 of the 5 Class I areas for the Best 20% days, with identical improvements at the other Class I area for the Best 20% days.

Washington: Essentially the same visibility improvements are estimates for the 2018 SO_2 Annex and 2018 BART with Uncertainty emission control scenarios for the Worst 20% and Best 20% days at the 8 Class I areas in Washington.

Wyoming: For the 7 Class I areas in Wyoming, the 2018 SO_2 Annex Milestones emissions scenario always estimated more visibility improvements than the 2018 BART with Uncertainty control scenario for both the Worst 20% and Best 20% days.

Table 4.1.2.1. Estimated visibility levels in deciviews (dV) at all western Class I areas in the WRAP modeling domain for the **Worst** 20% days and the 2018 Base Case, 2018 SO_2 Annex Milestones and 2018 BART with Uncertainty emission scenarios and the changes in visibility resulting from the 2018 control scenarios, from the 2018 Base Case.

Class I Area (Worst 20%)	**State**	**2018 Base Case (dV)**	**2018 SO_2 Annex (dV)**	**2018 BART w/Uncert. (dV)**	**Difference Annex – Base (dV)**	**Difference BART– Base (dV)**
Caney Creek Wilderness	AR	27.12	26.32	26.32	-0.80	-0.79
Upper Buffalo Wilderness	AR	27.04	26.26	26.26	-0.78	-0.77
Chiricahua NM	AZ	12.93	12.84	12.85	-0.09	-0.08
Chiricahua Wilderness	AZ	12.91	12.82	12.83	-0.09	-0.08
Galiuro Wilderness	AZ	12.43	12.38	12.42	-0.06	-0.01
Grand Canyon NP	AZ	11.77	11.69	11.71	-0.08	-0.06
Mazatzal Wilderness	AZ	14.38	14.26	14.28	-0.13	-0.10
Mount Baldy Wilderness	AZ	12.26	12.09	12.14	-0.17	-0.13
Petrified Forest NP	AZ	11.99	11.76	11.73	-0.24	-0.26
Pine Mountain Wilderness	AZ	14.44	14.31	14.33	-0.13	-0.10
Saguaro Wilderness	AZ	12.33	12.26	12.29	-0.07	-0.03
Sierra Ancha Wilderness	AZ	14.40	14.26	14.29	-0.14	-0.11
Superstition Wilderness	AZ	14.03	13.93	13.95	-0.10	-0.07
Sycamore Canyon Wilderness	AZ	12.11	12.01	12.04	-0.10	-0.07
Agua Tibia Wilderness	CA	22.44	22.44	22.45	0.00	0.01
Caribou Wilderness	CA	12.46	12.45	12.45	-0.01	-0.01
Cucamonga Wilderness	CA	21.17	21.17	21.20	0.00	0.03
Desolation Wilderness	CA	22.03	22.03	22.04	0.00	0.00
Dome Land Wilderness	CA	21.08	21.06	21.07	-0.02	0.00
Emigrant Wilderness	CA	18.54	18.53	18.54	0.00	0.00
Hoover Wilderness	CA	18.56	18.56	18.56	0.00	0.00
John Muir Wilderness	CA	22.24	22.23	22.24	-0.01	0.00
Joshua Tree NP	CA	20.76	20.76	20.78	0.00	0.01
Kaiser Wilderness	CA	22.12	22.12	22.13	0.00	0.01
Kings Canyon NP	CA	21.99	21.98	21.99	-0.01	0.00
Lava Beds Wilderness	CA	13.09	13.08	13.08	-0.01	-0.01
Lassen Volcanic NP	CA	12.45	12.43	12.44	-0.01	-0.01
Marble Mountain Wilderness	CA	15.71	15.69	15.70	-0.02	-0.01
Minarets Ansel Adams WA	CA	18.53	18.53	18.54	-0.01	0.00
Mokelumne Wilderness	CA	21.96	21.96	21.96	0.00	0.00
Pinnacles NM	CA	16.19	16.17	16.20	-0.02	0.01
Point Reyes NS	CA	18.54	18.49	18.51	-0.04	-0.03
Redwood NP	CA	17.23	17.21	17.22	-0.02	-0.01
San Gabriel Wilderness	CA	21.42	21.43	21.45	0.00	0.02
San Gorgonio Wilderness	CA	21.90	21.90	21.91	0.00	0.01
San Jacinto Wilderness	CA	21.85	21.85	21.87	0.00	0.02
San Rafael Wilderness	CA	16.57	16.56	16.58	-0.01	0.01
Sequoia NP	CA	21.65	21.63	21.64	-0.02	-0.01

Class I Area (Worst 20%)	State	2018 Base Case (dV)	2018 SO_2 Annex (dV)	2018 BART w/Uncert. (dV)	Difference Annex – Base (dV)	Difference BART– Base (dV)
South Warner Wilderness	CA	12.43	12.41	12.41	-0.02	-0.01
Thousand Lakes Wilderness	CA	12.61	12.60	12.61	-0.01	-0.01
Ventana Wilderness	CA	16.98	16.95	16.96	-0.03	-0.02
Yolla Bolly Middle Eel WA	CA	13.31	13.32	13.32	0.01	0.01
Yosemite NP	CA	18.41	18.40	18.41	-0.01	0.00
Black Canyon of Gunnison NP	CO	10.95	10.79	10.85	-0.16	-0.10
Eagles Nest Wilderness	CO	12.79	12.57	12.57	-0.21	-0.21
Flat Tops Wilderness	CO	10.89	10.74	10.79	-0.15	-0.10
Great Sand Dunes NM	CO	11.97	11.72	11.75	-0.24	-0.21
La Garita Wilderness	CO	11.80	11.61	11.66	-0.19	-0.14
Maroon Bells-Snowmass WA	CO	11.23	11.04	11.10	-0.19	-0.13
Mesa Verde NP	CO	12.04	11.85	11.92	-0.18	-0.12
Mount Zirkel Wilderness	CO	11.74	11.55	11.60	-0.19	-0.14
Rawah Wilderness	CO	13.17	12.99	13.05	-0.18	-0.12
Rocky Mountain NP	CO	13.16	12.99	13.05	-0.17	-0.11
West Elk Wilderness	CO	11.12	10.90	10.96	-0.22	-0.16
Weminuche Wilderness	CO	11.01	10.80	10.87	-0.20	-0.14
Craters of The Moon Wilderness	ID	14.71	14.66	14.67	-0.04	-0.04
Hells Canyon Wilderness	ID	14.94	14.85	14.85	-0.09	-0.08
Sawtooth Wilderness	ID	14.45	14.41	14.41	-0.04	-0.04
Selway-Bitterroot Wilderness	ID	15.13	15.07	15.08	-0.05	-0.05
Isle Royale NP	MI	26.90	26.52	26.53	-0.38	-0.37
Boundary Waters Canoe Area	MN	19.95	19.78	19.79	-0.17	-0.16
Voyageurs NP	MN	19.30	19.10	19.10	-0.20	-0.20
Hercules-Glades Wilderness	MO	26.87	26.14	26.15	-0.73	-0.73
Mingo Wilderness	MO	26.92	26.33	26.33	-0.59	-0.59
Anaconda-Pintler Wilderness	MT	17.59	17.47	17.48	-0.12	-0.11
Bob Marshall Wilderness	MT	17.81	17.73	17.74	-0.09	-0.07
Cabinet Mountains Wilderness	MT	17.88	17.78	17.79	-0.11	-0.10
Gates of the Mountain WA	MT	17.04	16.92	16.94	-0.11	-0.10
Glacier NP	MT	18.55	18.40	18.41	-0.15	-0.15
Medicine Lake Wilderness	MT	18.30	18.11	18.11	-0.20	-0.19
Mission Mountain Wilderness	MT	17.66	17.58	17.59	-0.08	-0.07
Red Rock Lakes Wilderness	MT	14.90	14.83	14.83	-0.07	-0.06
Scapegoat Wilderness	MT	17.35	17.26	17.27	-0.09	-0.08
UL Bend Wilderness	MT	17.55	17.22	17.25	-0.32	-0.30
Lostwood Wilderness	ND	18.40	18.22	18.22	-0.18	-0.18
Theodore Roosevelt NP	ND	18.06	17.82	17.84	-0.23	-0.22
Bandelier NM	NM	12.34	12.14	12.18	-0.19	-0.16
Bosque del Apache Wilderness	NM	14.46	14.20	14.28	-0.26	-0.18
Carlsbad Caverns NP	NM	14.57	14.40	14.42	-0.18	-0.16
Gila Wilderness	NM	15.02	14.81	14.85	-0.20	-0.16
Pecos Wilderness	NM	12.40	12.21	12.24	-0.20	-0.16

Class I Area (Worst 20%)	State	2018 Base Case (dV)	2018 SO_2 Annex (dV)	2018 BART w/Uncert. (dV)	Difference Annex – Base (dV)	Difference BART– Base (dV)
Salt Creek Wilderness	NM	14.72	14.54	14.59	-0.18	-0.13
San Pedro Parks Wilderness	NM	12.32	12.11	12.16	-0.21	-0.16
White Mountain Wilderness	NM	14.55	14.40	14.44	-0.15	-0.11
Wheeler Peak Wilderness	NM	12.51	12.28	12.33	-0.24	-0.18
Jarbidge Wilderness	NV	14.89	14.86	14.87	-0.03	-0.02
Wichita Mountains Wilderness	OK	26.03	25.13	25.16	-0.90	-0.88
Crater Lake NP	OR	15.39	15.37	15.38	-0.02	-0.02
Diamond Peak Wilderness	OR	15.64	15.59	15.60	-0.05	-0.04
Eagle Cap Wilderness	OR	14.93	14.81	14.82	-0.12	-0.11
Gearhart Mountain Wilderness	OR	15.06	15.03	15.04	-0.03	-0.02
Kalmiopsis Wilderness	OR	15.77	15.74	15.75	-0.03	-0.02
Mount Hood Wilderness	OR	14.84	14.79	14.80	-0.05	-0.05
Mount Jefferson Wilderness	OR	15.38	15.32	15.33	-0.06	-0.05
Mountain Lakes Wilderness	OR	15.18	15.14	15.15	-0.03	-0.02
Mount Washington Wilderness	OR	15.37	15.32	15.33	-0.04	-0.04
Strawberry Mountain Wilderness	OR	14.60	14.52	14.53	-0.08	-0.07
Three Sisters Wilderness	OR	14.88	14.86	14.86	-0.03	-0.02
Badlands NM	SD	18.04	17.73	17.77	-0.31	-0.26
Wind Cave NP	SD	17.79	17.51	17.56	-0.27	-0.23
Big Bend NP	TX	18.94	18.90	18.90	-0.05	-0.04
Guadalupe Mountains NP	TX	14.66	14.50	14.51	-0.16	-0.14
Arches NP	UT	12.42	12.32	12.37	-0.10	-0.05
Bryce Canyon NP	UT	12.26	12.23	12.24	-0.03	-0.02
Canyonlands NP	UT	12.27	12.17	12.21	-0.09	-0.05
Capitol Reef NP	UT	12.50	12.46	12.49	-0.03	-0.01
Zion NP	UT	12.03	12.00	12.02	-0.03	-0.01
Alpine Lakes Wilderness	WA	15.07	14.99	14.99	-0.08	-0.08
Glacier Peak Wilderness	WA	15.12	15.04	15.05	-0.07	-0.07
Goat Rocks Wilderness	WA	16.95	16.88	16.88	-0.07	-0.07
Mount Adams Wilderness	WA	17.06	16.99	17.00	-0.07	-0.06
Mount Rainier NP	WA	17.38	17.30	17.30	-0.08	-0.08
North Cascades NP	WA	15.26	15.19	15.20	-0.07	-0.07
Olympic NP	WA	15.72	15.69	15.69	-0.03	-0.03
Pasayten Wilderness	WA	15.21	15.14	15.14	-0.07	-0.07
Bridger Wilderness	WY	12.05	11.79	11.81	-0.27	-0.24
Fitzpatrick Wilderness	WY	12.13	11.97	11.99	-0.16	-0.14
Grand Teton NP	WY	14.74	14.66	14.67	-0.08	-0.07
North Absaroka Wilderness	WY	14.87	14.78	14.79	-0.09	-0.08
Teton Wilderness	WY	14.82	14.74	14.75	-0.08	-0.07
Washakie Wilderness	WY	14.79	14.71	14.71	-0.08	-0.07
Yellowstone NP	WY	14.92	14.85	14.86	-0.08	-0.07

Table 4.1.2.2. Estimated visibility levels in deciviews (dV) at all western Class I areas in the WRAP modeling domain for the **Best** 20% days and the 2018 Base Case, 2018 SO_2 Annex Milestones and 2018 BART with Uncertainty emission scenarios and the changes in visibility resulting from the 2018 control scenarios, from the 2018 Base Case.

Class I Area (Best 20%)	**State**	**2018 Base Case (dV)**	**2018 SO_2 Annex (dV)**	**2018 BART w/Uncert. (dV)**	**Difference Annex – Base (dV)**	**Difference BART– Base (dV)**
Caney Creek Wilderness	AR	12.40	12.09	12.10	-0.31	-0.30
Upper Buffalo Wilderness	AR	12.26	11.96	11.98	-0.30	-0.28
Chiricahua NM	AZ	5.77	5.76	5.74	-0.01	-0.03
Chiricahua Wilderness	AZ	5.75	5.74	5.72	-0.01	-0.03
Galiuro Wilderness	AZ	5.66	5.65	5.67	-0.01	0.01
Grand Canyon NP	AZ	4.76	4.69	4.71	-0.07	-0.05
Mazatzal Wilderness	AZ	7.26	7.21	7.21	-0.05	-0.05
Mount Baldy Wilderness	AZ	5.46	5.42	5.42	-0.04	-0.04
Petrified Forest NP	AZ	5.19	5.14	5.15	-0.04	-0.04
Pine Mountain Wilderness	AZ	7.32	7.27	7.27	-0.05	-0.05
Saguaro Wilderness	AZ	5.62	5.61	5.62	-0.01	0.00
Sierra Ancha Wilderness	AZ	7.40	7.33	7.35	-0.07	-0.05
Superstition Wilderness	AZ	7.18	7.12	7.15	-0.06	-0.03
Sycamore Canyon Wilderness	AZ	4.86	4.81	4.82	-0.05	-0.03
Agua Tibia Wilderness	CA	5.84	5.83	5.84	0.00	0.00
Caribou Wilderness	CA	3.31	3.31	3.31	-0.01	-0.01
Cucamonga Wilderness	CA	5.56	5.56	5.56	0.00	0.01
Desolation Wilderness	CA	12.24	12.24	12.25	0.00	0.00
Dome Land Wilderness	CA	7.62	7.62	7.63	0.00	0.01
Emigrant Wilderness	CA	4.97	4.95	4.96	-0.02	-0.01
Hoover Wilderness	CA	4.91	4.89	4.90	-0.02	-0.01
John Muir Wilderness	CA	7.87	7.87	7.87	0.00	0.00
Joshua Tree NP	CA	5.69	5.68	5.69	0.00	0.00
Kaiser Wilderness	CA	7.23	7.23	7.23	0.00	0.00
Kings Canyon NP	CA	7.82	7.82	7.83	0.00	0.00
Lava Beds Wilderness	CA	3.43	3.42	3.43	0.00	0.00
Lassen Volcanic NP	CA	3.30	3.30	3.30	-0.01	0.00
Marble Mountain Wilderness	CA	4.15	4.05	4.05	-0.10	-0.10
Minarets Ansel Adams WA	CA	4.88	4.86	4.87	-0.02	-0.01
Mokelumne Wilderness	CA	12.10	12.09	12.10	0.00	0.00
Pinnacles NM	CA	6.75	6.75	6.77	0.01	0.02
Point Reyes NS	CA	7.59	7.59	7.59	0.00	0.00
Redwood NP	CA	4.38	4.38	4.38	0.00	0.00
San Gabriel Wilderness	CA	5.63	5.63	5.64	0.00	0.01
San Gorgonio Wilderness	CA	5.76	5.76	5.76	0.00	0.00
San Jacinto Wilderness	CA	5.24	5.24	5.24	0.00	0.00
San Rafael Wilderness	CA	6.92	6.92	6.94	0.00	0.03
Sequoia NP	CA	7.68	7.68	7.69	0.00	0.01

Class I Area (Best 20%)	State	2018 Base Case (dV)	2018 SO_2 Annex (dV)	2018 BART w/Uncert. (dV)	Difference Annex – Base (dV)	Difference BART– Base (dV)
South Warner Wilderness	CA	3.29	3.28	3.28	-0.01	-0.01
Thousand Lakes Wilderness	CA	3.30	3.30	3.30	0.00	0.00
Ventana Wilderness	CA	6.76	6.76	6.76	0.00	0.00
Yolla Bolly Middle Eel WA	CA	3.29	3.29	3.29	0.00	0.00
Yosemite NP	CA	4.97	4.95	4.96	-0.02	-0.01
Black Canyon of Gunnison NP	CO	3.87	3.83	3.85	-0.05	-0.02
Eagles Nest Wilderness	CO	3.85	3.80	3.82	-0.05	-0.03
Flat Tops Wilderness	CO	3.89	3.83	3.85	-0.06	-0.03
Great Sand Dunes NM	CO	4.38	4.31	4.32	-0.07	-0.06
La Garita Wilderness	CO	4.28	4.23	4.24	-0.05	-0.04
Maroon Bells-Snowmass WA	CO	3.89	3.83	3.85	-0.06	-0.04
Mesa Verde NP	CO	4.20	4.16	4.18	-0.03	-0.01
Mount Zirkel Wilderness	CO	4.76	4.69	4.72	-0.08	-0.04
Rawah Wilderness	CO	4.01	3.96	3.98	-0.04	-0.03
Rocky Mountain NP	CO	3.84	3.80	3.82	-0.04	-0.02
West Elk Wilderness	CO	3.88	3.84	3.86	-0.05	-0.03
Weminuche Wilderness	CO	3.93	3.89	3.91	-0.05	-0.03
Craters of The Moon Wilderness	ID	5.29	5.25	5.26	-0.04	-0.03
Hells Canyon Wilderness	ID	5.73	5.62	5.63	-0.11	-0.10
Sawtooth Wilderness	ID	3.58	3.56	3.57	-0.01	-0.01
Selway-Bitterroot Wilderness	ID	5.63	5.51	5.52	-0.12	-0.11
Isle Royale NP	MI	10.39	10.39	10.39	0.00	0.00
Boundary Waters Canoe Area	MN	7.26	7.24	7.24	-0.02	-0.02
Voyageurs NP	MN	6.70	6.69	6.69	-0.01	-0.01
Hercules-Glades Wilderness	MO	12.20	11.92	11.94	-0.28	-0.27
Mingo Wilderness	MO	12.17	11.93	11.94	-0.24	-0.23
Anaconda-Pintler Wilderness	MT	7.00	6.90	6.91	-0.10	-0.09
Bob Marshall Wilderness	MT	7.14	7.09	7.09	-0.05	-0.05
Cabinet Mountains Wilderness	MT	7.20	7.15	7.15	-0.05	-0.04
Gates of the Mountain WA	MT	6.74	6.68	6.69	-0.06	-0.05
Glacier NP	MT	7.65	7.56	7.57	-0.09	-0.08
Medicine Lake Wilderness	MT	7.36	7.29	7.30	-0.06	-0.06
Mission Mountain Wilderness	MT	7.02	6.96	6.96	-0.06	-0.05
Red Rock Lakes Wilderness	MT	5.25	5.19	5.20	-0.06	-0.05
Scapegoat Wilderness	MT	6.94	6.88	6.89	-0.05	-0.05
UL Bend Wilderness	MT	7.05	7.00	7.00	-0.05	-0.05
Lostwood Wilderness	ND	7.48	7.38	7.38	-0.10	-0.10
Theodore Roosevelt NP	ND	7.24	7.16	7.16	-0.08	-0.07
Bandelier NM	NM	5.49	5.44	5.45	-0.05	-0.04
Bosque del Apache Wilderness	NM	6.83	6.71	6.75	-0.12	-0.08
Carlsbad Caverns NP	NM	6.84	6.74	6.76	-0.10	-0.08
Gila Wilderness	NM	7.45	7.39	7.42	-0.06	-0.04
Pecos Wilderness	NM	4.82	4.78	4.79	-0.04	-0.03

Class I Area (Best 20%)	State	2018 Base Case (dV)	2018 SO_2 Annex (dV)	2018 BART w/Uncert. (dV)	Difference Annex – Base (dV)	Difference BART– Base (dV)
Salt Creek Wilderness	NM	6.78	6.67	6.69	-0.11	-0.08
San Pedro Parks Wilderness	NM	5.55	5.49	5.52	-0.06	-0.04
White Mountain Wilderness	NM	6.85	6.77	6.80	-0.09	-0.05
Wheeler Peak Wilderness	NM	5.61	5.54	5.57	-0.06	-0.04
Jarbidge Wilderness	NV	3.62	3.62	3.62	-0.01	0.00
Wichita Mountains Wilderness	OK	11.79	11.58	11.61	-0.21	-0.18
Crater Lake NP	OR	4.69	4.69	4.69	0.00	0.00
Diamond Peak Wilderness	OR	4.39	4.39	4.39	0.00	0.00
Eagle Cap Wilderness	OR	5.73	5.64	5.64	-0.09	-0.08
Gearhart Mountain Wilderness	OR	4.20	4.20	4.20	0.00	0.00
Kalmiopsis Wilderness	OR	4.50	4.50	4.50	-0.01	-0.01
Mount Hood Wilderness	OR	4.74	4.73	4.74	0.00	0.00
Mount Jefferson Wilderness	OR	4.57	4.57	4.57	0.00	0.00
Mountain Lakes Wilderness	OR	4.29	4.29	4.30	0.00	0.00
Mount Washington Wilderness	OR	4.32	4.32	4.32	0.00	0.00
Strawberry Mountain Wilderness	OR	3.97	3.97	3.97	-0.01	0.00
Three Sisters Wilderness	OR	4.33	4.32	4.33	0.00	0.00
Badlands NM	SD	7.35	7.25	7.26	-0.10	-0.09
Wind Cave NP	SD	7.29	7.18	7.19	-0.10	-0.10
Big Bend NP	TX	7.75	7.69	7.71	-0.05	-0.04
Guadalupe Mountains NP	TX	6.89	6.79	6.80	-0.10	-0.09
Arches NP	UT	4.85	4.77	4.80	-0.08	-0.05
Bryce Canyon NP	UT	3.24	3.22	3.23	-0.01	-0.01
Canyonlands NP	UT	4.78	4.71	4.74	-0.06	-0.04
Capitol Reef NP	UT	4.84	4.81	4.82	-0.03	-0.02
Zion NP	UT	3.80	3.78	3.79	-0.02	-0.01
Alpine Lakes Wilderness	WA	6.03	5.99	6.00	-0.03	-0.03
Glacier Peak Wilderness	WA	6.04	5.97	5.97	-0.07	-0.07
Goat Rocks Wilderness	WA	5.75	5.73	5.73	-0.03	-0.02
Mount Adams Wilderness	WA	5.90	5.87	5.88	-0.03	-0.02
Mount Rainier NP	WA	5.61	5.59	5.60	-0.02	-0.01
North Cascades NP	WA	5.90	5.85	5.85	-0.05	-0.05
Olympic NP	WA	6.34	6.35	6.34	0.01	0.00
Pasayten Wilderness	WA	5.82	5.78	5.78	-0.04	-0.04
Bridger Wilderness	WY	3.23	3.17	3.18	-0.05	-0.05
Fitzpatrick Wilderness	WY	3.31	3.28	3.30	-0.02	-0.01
Grand Teton NP	WY	4.79	4.76	4.77	-0.03	-0.02
North Absaroka Wilderness	WY	5.08	5.03	5.04	-0.05	-0.04
Teton Wilderness	WY	5.12	5.09	5.11	-0.03	-0.02
Washakie Wilderness	WY	4.74	4.69	4.70	-0.05	-0.04
Yellowstone NP	WY	5.16	5.09	5.10	-0.07	-0.06

4.2. Stationary Source NO_X and PM sensitivity modeling

The modeling performed for the draft Market Trading Forum report entitled Review of Stationary Source NO_x and PM Emissions in the WRAP Region: An Initial Assessment of Emissions, Controls, and Air Quality Impacts (WRAP, 2003) is best described as a "sensitivity analysis". The intent is to get a preliminary assessment of the general atmospheric response to changes in NO_x and PM emissions from stationary sources. A secondary objective is to "practice" this type of modeling to get a better understanding of the key technical issues and to identify the most effective ways at evaluating and displaying model results. The results presented here are the best available predictions at this time, but forthcoming improvements to the modeling system may affect the results in ways that alter the policy implications. For this reason, results are discussed in a fairly broad and qualitative manner – i.e., spatial patterns and relative changes. As the modeling system improves and specific strategies are contemplated, additional emission scenarios will be designed and modeled.

The WRAP's regional-scale air quality modeling system used to support other aspects of the §309 plans was also used to provide information for this report. A description of the modeling system, in addition to model performance statistics, input files, and detailed model results, is available at:

http://pah.cert.ucr.edu/rmc

4.2.1. Emission Scenarios

Three emission scenarios were simulated:

- A 50 percent decrease in NO_x emissions from plants with NO_x emissions > 100 tons per year (tpy),
- A 50 percent decrease in PM_{10} emissions from plants with PM_{10} emission > 100 tpy, and
- A simultaneous 25 percent increase in NO_x and PM_{10} emissions from all stationary sources.

The first two scenarios are meant to address the §309 requirement to "assess emissions control strategies for stationary source NO_x and PM, and the degree of visibility improvement that would result from such strategies". As discussed in Section VI of the is report, many commercially-available technologies (and various combinations of such technologies) are capable of achieving a 50% or greater NO_x emission reduction without having to switch fuels. Hence, the 50% reduction, although intended primarily to gauge the general atmospheric response to NO_x reductions, is not an unreasonable level of control to assume for this exercise in terms of technical feasibility. Again with technical (and administrative) feasibility in mind, emission reductions were limited to plants with emissions greater than 100 tpy, similar to the approach in the Annex. The third scenario is meant to address the rule's requirement to "evaluate and discuss the need to establish emission milestones for NO_x and PM to avoid any net increase in these pollutants from stationary sources within the transport region." Hence, a 25 percent increase from all stationary sources was assumed to simulate potential growth in the economy and/or disproportionate growth in high-emitting sectors such as energy development, fossil-fueled electricity generation, and mineral processing.

For reasons implied in the rule, the emission changes in the scenarios described above were limited to the nine-state GCVTR[1]. Also, the emission changes were applied to the 2018 inventory, which includes reductions expected from full implementation of the Annex. This provides a basis for comparing results to other strategies being modeled by the WRAP.

4.2.2. Model Performance and Future Improvements

Nitrate concentrations are poorly predicted by the current modeling system, especially in the winter. For this reason, results for nitrate (and all other species) for the NO_x and PM sensitivity runs are only presented for the three-month period of July-September.

Several aspects of the modeling system are being improved and/or evaluated, which should improve confidence in future model predictions, both in the summer and winter. These improvements and evaluations involve the chemical mechanisms, the ammonia inventory, an off-road inventory based on NONROAD2002, a more robust meteorological database (2002 versus 1996), enhanced grid resolution (12 km versus 36 km), plume-in-grid capabilities, the introduction of an inventory for wind-blown dust emissions, and better temporal allocation and chemical speciation of point and area source emissions. A source apportionment mechanism is also expected to be included with the model.

4.2.3. Modeling Results

As stated above, results are presented in a fairly broad and qualitative manner – i.e., spatial patterns and relative changes. Relative (percent) changes are of particular interest because their errors are believed to be smaller than those of the absolute concentrations. It is not clear how the seasonal limitation of this analysis (July-September) may affect the relative changes, but it is likely to reduce them to some extent. First, nitrate concentrations tend to be lower in the summer than in the winter, especially in areas where nitrate concentrations are highest and the potential for change the greatest. Second, results are averaged over a full three-month period. Typically, visibility effects are measured by averaging conditions over the worst 20 percent of the days observed per year at an ambient monitoring site, which is approximately 22 days. But in this analysis, because it is limited to the July-September timeframe, the results are averaged over 92 consecutive days and do not represent a measure of the worst conditions, again when the potential for change is the greatest. Thus, while there are many uncertainties surrounding the model's nitrate predictions, the limitation of this study to July-September will tend to limit the apparent impacts from the NO_x (and to some extent) PM_{10} emission changes.

On a ton-per-ton basis, reductions in stationary source PM_{10} emissions appear to yield greater regional haze benefits than reductions in NO_x emissions. For instance, when stationary source PM_{10} emissions are reduced by 98,000 tpy (a 50 percent reduction from GCVTR facilities

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[1] - In 1996, stationary sources in the Grand Canyon Visibility Transport Region (GCVTR) emitted about 75 percent and 83 percent of the NO_x and PM_{10} emissions, respectively, in the 13-state WRAP region.

> 100 tpy), the average summer-time visibility improvement across all Class I areas in the GCVTR (in Mm^{-1}) is about 0.4 percent. When stationary source NO_x emissions are reduced by 412,000 tpy (a 50 percent reduction from GCVTR facilities > 100 tpy), the visibility improvement is only somewhat greater, at 0.5 percent.[1] Hence, on a purely technical basis (without considering existing controls, costs, or other implementation issues), reductions in PM emissions might be more effective at improving regional haze than reductions in NO_x emissions.

Nevertheless, the 50 percent NO_x reduction scenario tends to produce slightly greater regional haze benefits than the 50 percent PM_{10} reduction scenario. This is because stationary sources comprise 33 percent of the total NO_x inventory but only 7 percent of the total PM_{10} inventory. So even though much of the NO_x is never converted to the particulate phase, the sheer volume of NO_x emission reductions relative to PM_{10} reductions and the fact that nitrate scatters light more efficiently than primary PM make the NO_x reduction scenario more meaningful in terms of regional haze benefits than the PM_{10} reduction scenario. The fact that stationary source NOx emissions are not as well controlled as stationary source PM_{10} emissions in the West actually lends some relevance to the outcome that NO_x emissions are altered more in the sensitivity analysis than PM_{10} emissions.

For the three-month summer period examined in this analysis, NO_x changes have very little effect on aerosol concentrations beyond changes in nitrate. Other species that could be indirectly affected – e.g., ozone concentrations and subsequent oxidation of SO_2 and organic gases into the particulate phase – do not appear influenced by the levels of NO_x reductions (16 percent of the total inventory) assumed in this analysis. This finding may change after implementing all the model improvements noted above, but since nitrate currently appears as the largest responder to NO_x changes, and given the information above regarding the NO_x and PM scenarios, the maps, tables, and discussion below place somewhat more emphasis on nitrate and the results of the 50 percent NO_x reduction scenario than on other species and scenarios.

Figures 4.2.3.1 and 4.2.3.2 show the model-predicted 2018 base case (Annex included) surface-layer concentrations of ammonium nitrate (NH_4NO_3) and $PM_{10,}$ respectively, averaged over the three- month period of July-September. The values in these maps should not be construed as the *expected* ammonium nitrate and PM_{10} concentrations in 2018, which are determined by scaling the ambient monitoring data by the relative changes predicted by the model. Rather, these maps are intended to provide a sense of the spatial variability and span of concentrations, which are useful for interpreting the following maps of relative (percent) changes – e.g., a high percentage change in a low-concentration area may be less meaningful than a moderate percentage change in a high concentration area.

Figures 4.2.3.3 and 4.2.3.4 show the absolute and percentage change, respectively, in NH_4NO_3 concentrations from a 50 percent reduction in stationary source NO_x emissions from facilities in the GCVTR greater than 100 tpy. The largest absolute changes occur in southern CA, where concentrations in Class I areas are predicted to decrease by 0.15 to 0.25 ug/m^3. A second area of reductions is predicted in the central-east Rocky Mountains, especially in north-central CO.

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[1] - In some Class I areas, the visibility improvement can be two to five percent on some days.

Although the reductions are not as large as in southern CA (0.04 to 0.11 ug/m^3), they are larger than average across the domain and exhibit the largest percentage reduction (10 to 20 percent).

It is interesting to compare these results with those simulating the effects of the SO_2 backstop emissions trading program, or Annex. In the case of the Annex, an SO_2 emission reduction of 15 percent (132,000 tons) in the GCVTR produced a sulfate reduction of 4 percent averaged across all Class I areas in the GCVTR on the 20% worst modeled days. In the case of the NO_x sensitivity run, a NO_x emission reduction of 15 percent (412,000 tons) in the GCVTR produced a nitrate reduction of 5 percent averaged across all Class I areas in the GCVTR on the July-September modeled days. The nitrate reduction does not produce as much visibility benefit at most Class I areas because its concentrations are much smaller, but the response of nitrate to NO_x reductions is similar in proportion to the response of sulfate to SO_2 reductions.

Figures 4.2.3.5 and 4.2.3.6 show the absolute and percentage change, respectively, in NH_4NO_3 concentrations from a 25 percent increase in stationary source NO_x and PM_{10} emissions from all stationary sources in the GCVTR. The spatial pattern of changes is very similar to that in the 50 percent NO_x reduction scenario, although the magnitude of changes are about half. Again, it is interesting to see some proportionality in the modeling results – i.e., an emission change that is half as large produces aerosol changes that are about half as large. The percent increase in NH_4NO_3 concentrations and visibility impairment (in Mm^{-1}) in this scenario is 2 percent and 0.5 percent, respectively, when averaged over all Class I areas in the GCVTR for July-September.

Figures 4.2.3.7 and 4.2.3.8 show the absolute and percentage change, respectively, in PM_{10} concentrations from a 50 percent reduction in stationary source PM_{10} emissions from facilities in the GCVTR greater than 100 tpy. Maximum reductions in PM_{10} are about 0.1 to 0.5 ug/m^3, or about 4 to 8 percent. Compared to the NO_x reduction scenario, reductions in ambient PM_{10} are more dispersed, with a greater number of local maximums. This may reflect the fact that there are a fewer number of large PM_{10} sources than large NO_x sources and that much of the PM_{10} emissions are coarse particles, with shorter transport distances.

Figures 4.2.3.9 and 4.2.3.10 show the absolute and percentage change, respectively, in PM_{10} concentrations from a 25 percent increase in stationary source NO_x and PM_{10} emissions from all stationary sources in the GCVTR. The spatial pattern of changes reflects where both relatively large NH_4NO_3 changes (southern CA and central-east Rockies) and PM_{10} changes (additional areas) are predicted. The largest PM_{10} increases are about 0.1 to 0.3 ug/m^3, or 2 to 3 percent. Less than half of this is NH_4NO_3.

Table 4.2.3.1 shows the predicted change in light extinction and NH_4NO_3 at each Class I area in the GCVTR averaged over the July-September period as a result of reducing NO_x emissions by 50 percent from stationary sources with emissions greater than 100 tpy in the GCVTR. As shown in the maps, the greatest impacts occur in southern CA, followed by areas in CO. The average improvement in light extinction in these areas is about 0.3 to 1.5 Mm^{-1} (1 to 2.5 percent). The average improvement in NH_4NO_3 is about 0.05 to 0.25 ug/m^3 (3 to 20 percent).

Figure 4.2.3.1. Base Case Ammonium Nitrate Concentrations (μg/m^3).

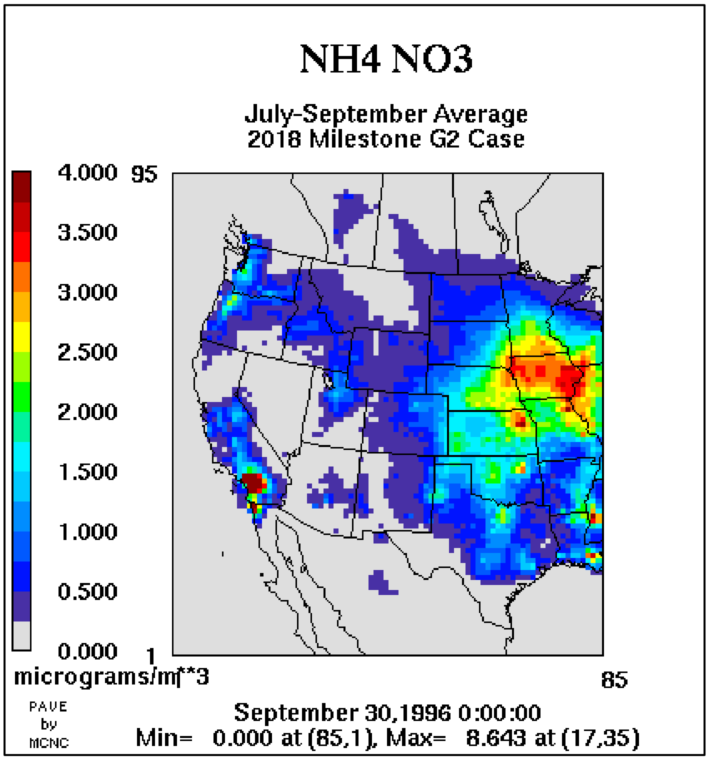


Figure 4.2.3.2. Base Case PM_{10} Concentrations (μg/m^3).

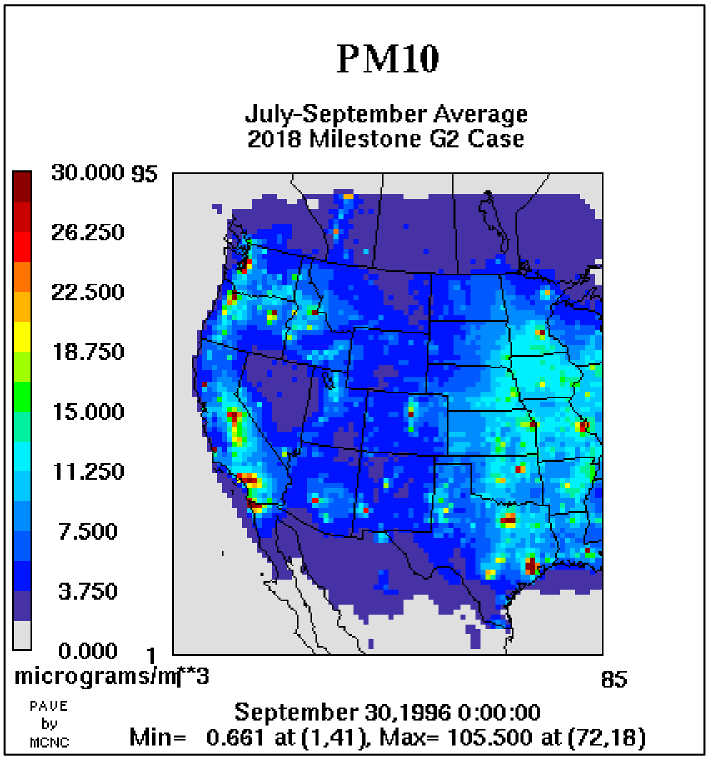


Figure 4.2.3.3. Change in Ammonium Nitrate Concentrations Resulting from a 50% Reduction in Stationary Source NO_x Emissions > 100 tpy.

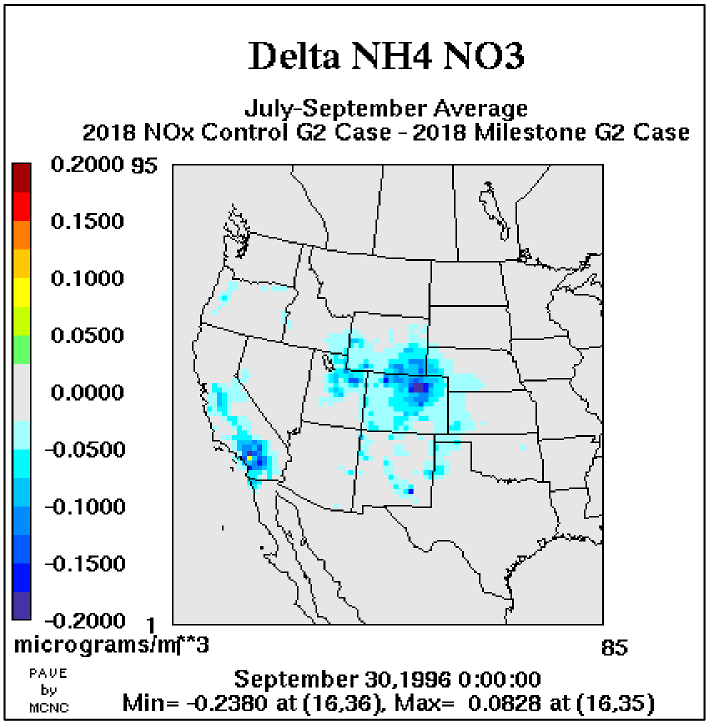


Figure 4.2.3.4. Relative Change in Ammonium Nitrate Concentrations Resulting from a 50% Reduction in Stationary Source NO_x Emissions > 100 tpy.

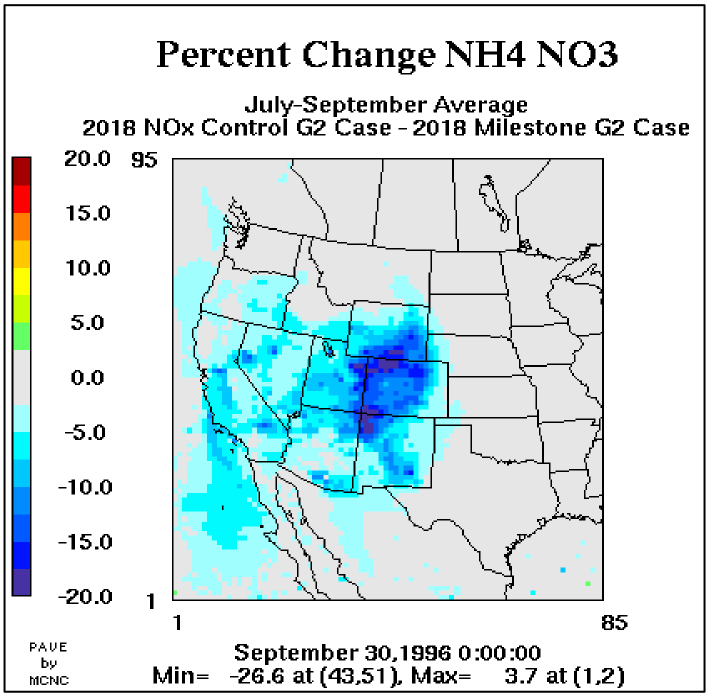


Figure 4.2.3.5. Change in Ammonium Nitrate Concentrations Resulting from a 25% Increase in Stationary Source NO_x and PM_{10} Emissions.

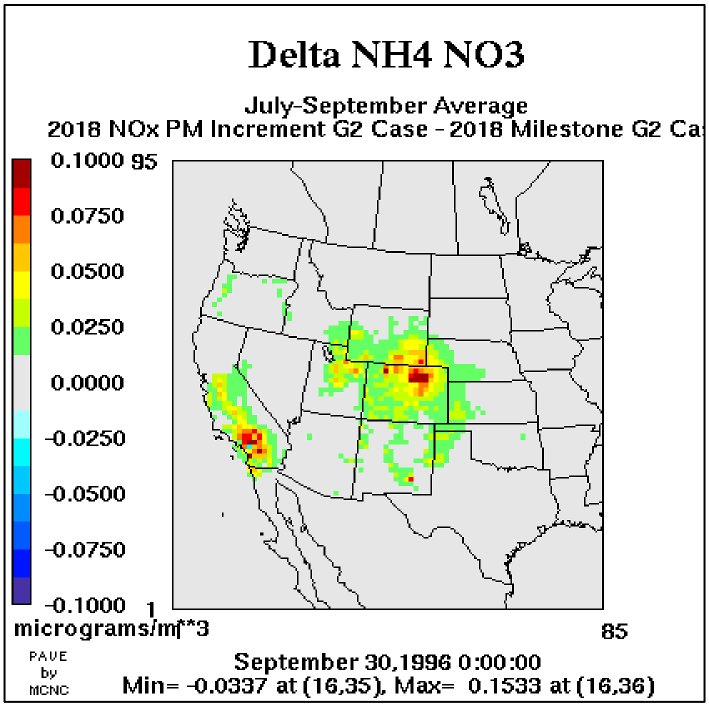


Figure 4.2.3.6. Relative Change in Ammonium Nitrate Concentrations Resulting from a 25% Increase in Stationary Source NOx and PM_{10} Emissions.

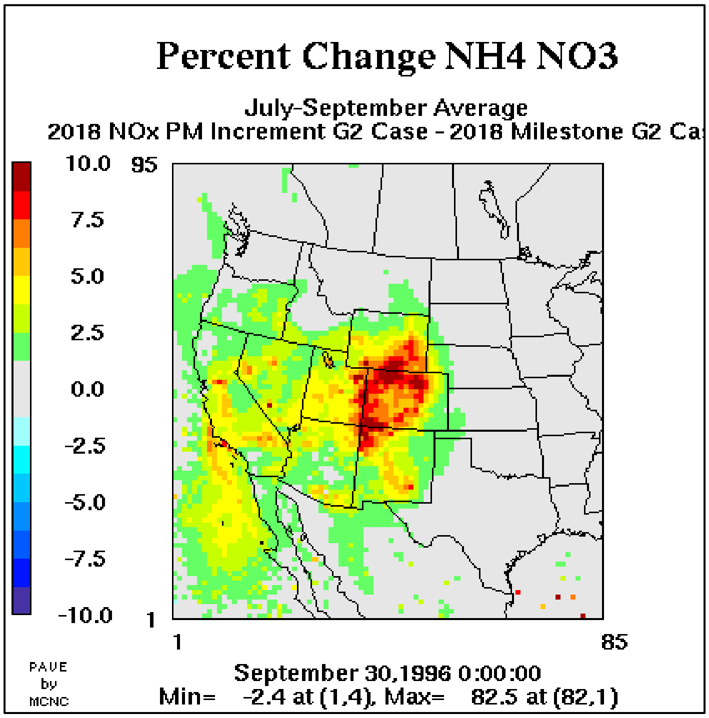


Figure 4.2.3.7. Change in PM_{10} Concentrations Resulting from a 50% Reduction in Stationary Source PM_{10} Emissions > 100 tpy.

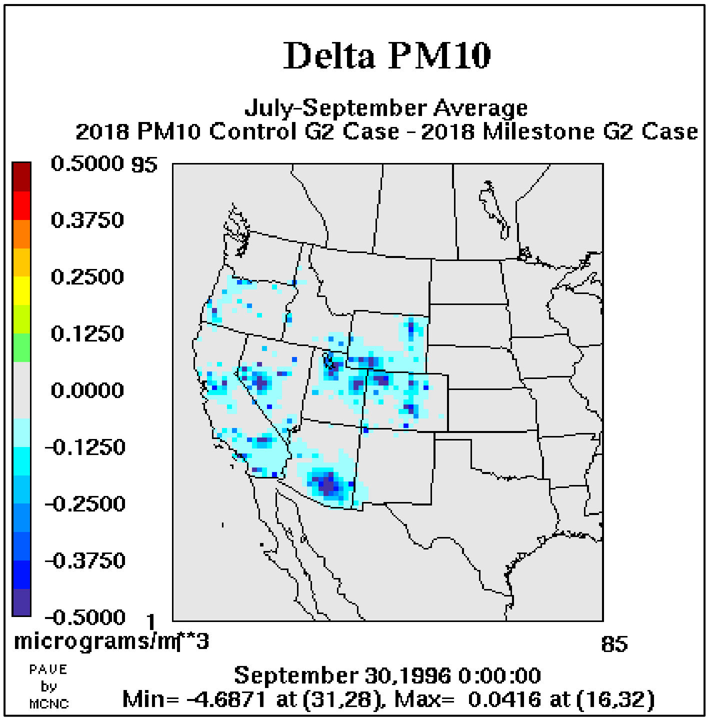


Figure 4.2.3.8. Relative Change in PM_{10} Concentrations Resulting from a 50% Reduction in Stationary Source PM_{10} Emissions > 100 tpy.

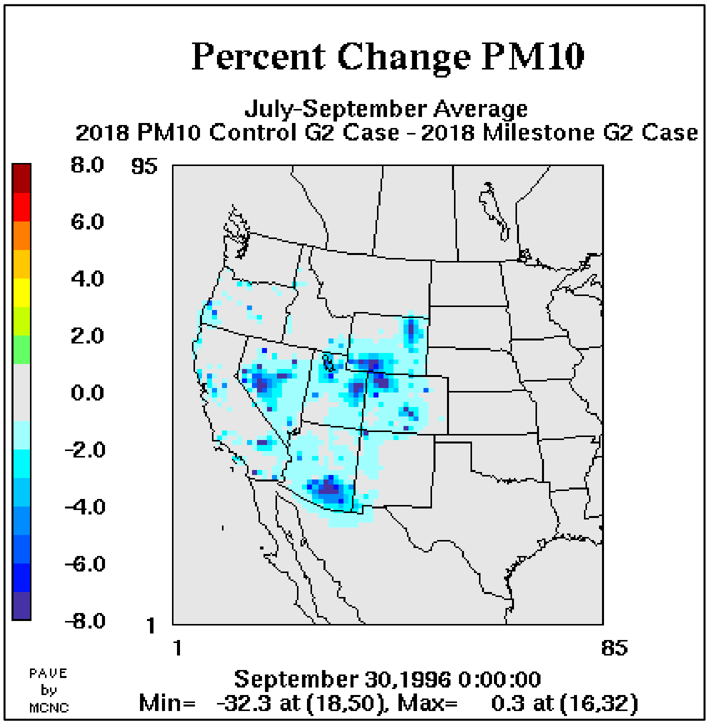


Figure 4.2.3.9. Change in PM_{10} Concentrations Resulting from a 25% Increase in Stationary Source NO_x and PM_{10} Emissions.

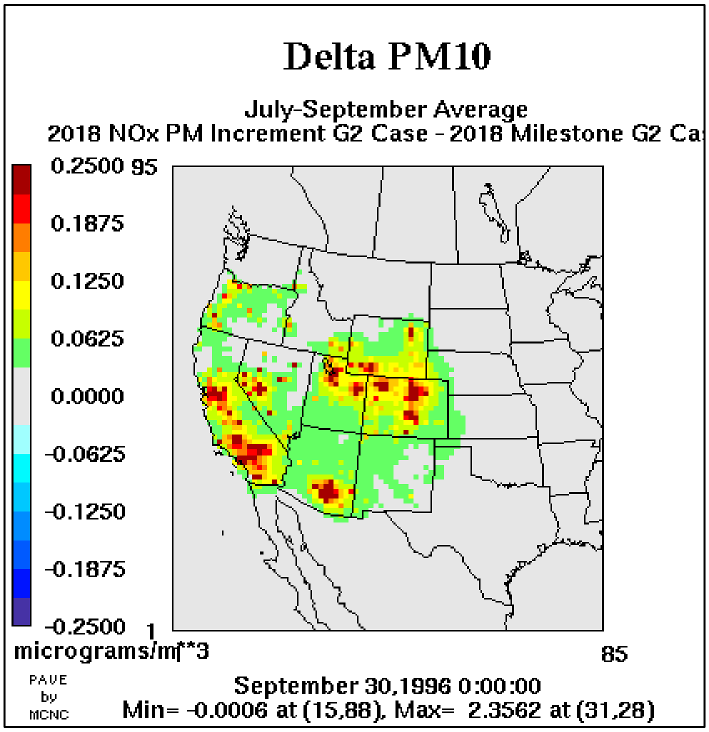
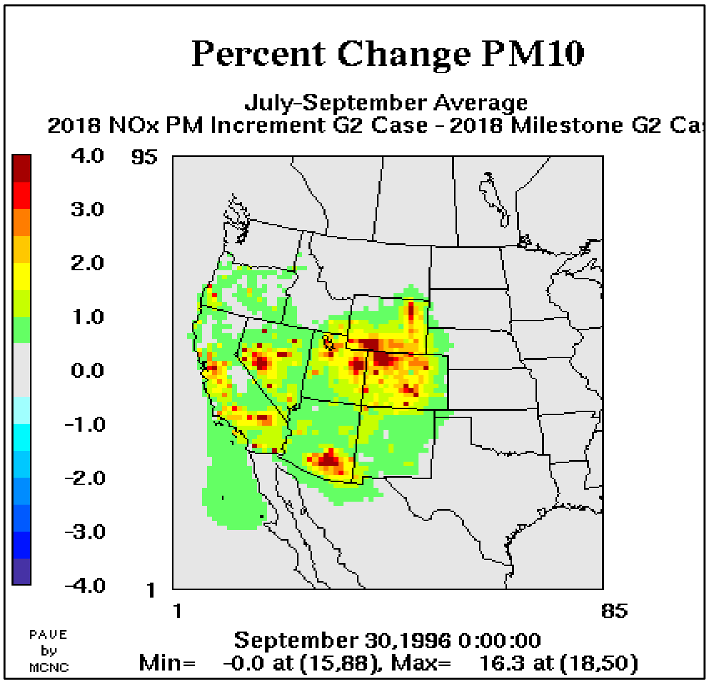


Figure 4.2.3.10. Relative Change in PM_{10} Concentrations Resulting from a 25% Increase in



Stationary Source NO_x and PM_{10} Emissions.

Table 4.2.3.1. Light Extinction and Ammonium Nitrate Changes Resulting from a 50% Reduction in Stationary Source NO_x Emissions > 100 tpy, Sorted by Average Light Extinction.

		Light Extinction		**NH_4NO_3**	
State	**GCVTR Class I Area**	**Mm^{-1} Change**	**% Change**	**$\mu g/m^3$ Change**	**% Change**
CA	Cucamonga Wilderness	-1.59	-1.37	-0.25	-3.25
CA	San Jacinto Wilderness	-1.13	-1.18	-0.19	-2.97
CA	San Gabriel Wilderness	-0.83	-0.82	-0.13	-3.06
CA	Agua Tibia Wilderness	-0.81	-1.05	-0.12	-2.77
CA	San Gorgonio Wilderness	-0.80	-0.93	-0.16	-2.65
CO	Rawah Wilderness	-0.69	-2.41	-0.11	-16.84
CO	Mount Zirkel Wilderness	-0.61	-2.28	-0.09	-20.86
CO	Rocky Mountain NP	-0.57	-1.68	-0.09	-14.14
CA	Joshua Tree NP	-0.47	-0.77	-0.13	-3.69
CO	Eagles Nest Wilderness	-0.45	-1.41	-0.07	-11.97
CO	Great Sand Dunes NM	-0.43	-1.57	-0.06	-13.87
NM	White Mountain Wild.	-0.36	-1.11	-0.05	-10.51
CO	Flat Tops Wilderness	-0.34	-1.28	-0.05	-13.82
CO	La Garita Wilderness	-0.34	-1.27	-0.05	-12.15
CO	West Elk Wilderness	-0.33	-1.19	-0.05	-12.09
CO	Black Canyon of Gunnison	-0.31	-0.97	-0.04	-14.83
CO	Weminuche Wilderness	-0.29	-1.14	-0.04	-13.02
CO	Maroon Bells-Snowmass	-0.29	-1.00	-0.04	-10.62
CA	Dome Land Wilderness	-0.27	-0.46	-0.04	-4.48
CA	Pinnacles NM	-0.26	-0.86	-0.04	-5.93
NM	Wheeler Peak Wilderness	-0.24	-0.91	-0.03	-8.94
AZ	Mount Baldy Wilderness	-0.22	-0.64	-0.03	-6.25
NM	Salt Creek Wilderness	-0.22	-0.71	-0.02	-7.75
AZ	Petrified Forest NP	-0.21	-0.73	-0.01	-6.88
WY	Bridger Wilderness	-0.20	-0.77	-0.03	-7.51
CA	Hoover Wilderness	-0.20	-0.19	-0.04	-2.60
CA	Emigrant Wilderness	-0.19	-0.25	-0.03	-3.08
NM	Gila Wilderness	-0.18	-0.34	-0.02	-3.81
CA	Minarets	-0.18	-0.23	-0.03	-2.71
OR	Mount Jefferson Wild.	-0.17	-0.28	-0.02	-2.59
NM	San Pedro Parks Wild.	-0.17	-0.64	-0.02	-10.43
NM	Bandelier NM	-0.17	-0.58	-0.02	-7.42
AZ	Superstition Wilderness	-0.16	-0.40	-0.02	-2.04
OR	Mount Washington Wild.	-0.16	-0.30	-0.02	-2.55
OR	Mount Hood Wilderness	-0.14	-0.22	-0.03	-1.83
CA	Kaiser Wilderness	-0.14	-0.19	-0.02	-2.63
CA	Kings Canyon NP	-0.14	-0.22	-0.02	-2.83
CA	John Muir Wilderness	-0.14	-0.23	-0.02	-2.69
CA	San Rafael Wilderness	-0.14	-0.32	-0.01	-5.40
AZ	Sierra Ancha Wilderness	-0.13	-0.35	-0.01	-1.76
CA	Sequoia NP	-0.13	-0.24	-0.02	-4.56
CA	Yosemite NP	-0.13	-0.17	-0.02	-2.63
UT	Arches NP	-0.13	-0.51	-0.01	-14.82

		Light Extinction		NH_4NO_3	
State	GCVTR Class I Area	Mm^{-1} Change	% Change	$\mu g/m^3$ Change	% Change
NM	Pecos Wilderness	-0.12	-0.44	-0.03	-7.29
WY	Fitzpatrick Wilderness	-0.12	-0.46	-0.02	-4.83
NM	Bosque del Apache Wild.	-0.12	-0.44	-0.01	-8.65
OR	Kalmiopsis Wilderness	-0.11	-0.34	-0.01	-3.05
OR	Eagle Cap Wilderness	-0.11	-0.31	-0.02	-4.29
OR	Three Sisters Wilderness	-0.11	-0.24	-0.02	-2.55
AZ	Grand Canyon NP	-0.11	-0.40	-0.01	-7.36
UT	Capitol Reef NP	-0.11	-0.45	-0.01	-8.21
WY	Grand Teton NP	-0.11	-0.36	-0.02	-3.47
WY	Teton Wilderness	-0.10	-0.36	-0.02	-3.56
OR	Crater Lake NP	-0.10	-0.21	-0.01	-2.09
ID	Hells Canyon Wilderness	-0.10	-0.13	-0.02	-3.87
OR	Strawberry Mountain Wild.	-0.10	-0.15	-0.01	-2.89
AZ	Sycamore Canyon Wild.	-0.10	-0.32	-0.01	-5.25
CA	Marble Mountain Wild.	-0.10	-0.23	-0.01	-2.57
AZ	Chiricahua NM	-0.10	-0.36	0.00	-6.65
AZ	Chiricahua Wilderness	-0.10	-0.36	0.00	-6.65
AZ	Galiuro Wilderness	-0.10	-0.30	-0.01	-4.30
UT	Canyonlands NP	-0.09	-0.42	-0.01	-10.61
OR	Diamond Peak Wild.	-0.09	-0.18	-0.01	-2.20
AZ	Saguaro Wilderness	-0.09	-0.28	-0.01	-6.84
UT	Bryce Canyon NP	-0.08	-0.32	-0.01	-6.14
AZ	Pine Mountain Wild.	-0.08	-0.24	-0.01	-2.82
AZ	Mazatzal Wilderness	-0.08	-0.23	-0.01	-2.82
NM	Carlsbad Caverns NP	-0.08	-0.26	-0.01	-4.03
OR	Mountain Lakes Wild.	-0.07	-0.18	-0.01	-2.43
UT	Zion NP	-0.07	-0.21	-0.01	-7.22
CO	Mesa Verde NP	-0.07	-0.21	-0.03	-17.68
CA	Lava Beds Wilderness	-0.06	-0.15	-0.01	-2.09
WY	Yellowstone NP	-0.06	-0.20	-0.01	-2.50
CA	South Warner Wilderness	-0.06	-0.19	-0.01	-3.77
ID	Selway-Bitterroot Wild.	-0.05	-0.12	-0.01	-2.19
WY	North Absaroka Wild.	-0.05	-0.19	-0.01	-2.43
WY	Washakie Wilderness	-0.05	-0.19	-0.01	-2.43
CA	Point Reyes NS	-0.05	-0.15	0.00	-2.80
ID	Craters of The Moon Wild.	-0.04	-0.14	-0.01	-3.89
OR	Gearhart Mountain Wild.	-0.04	-0.13	0.00	-2.24
CA	Caribou Wilderness	-0.04	-0.11	0.00	-3.38
CA	Thousand Lakes Wild.	-0.03	-0.09	0.00	-2.30
CA	Lassen Volcanic NP	-0.03	-0.07	0.00	-2.28
CA	Yolla Bolly Middle Eel Wild.	-0.03	-0.09	0.00	-1.13
NV	Jarbidge Wilderness	-0.03	-0.13	0.00	-4.49
CA	Ventana Wilderness	-0.02	-0.12	0.00	-5.24
CA	Redwood NP	-0.02	-0.06	0.00	-2.92
	Average	-0.21	-0.51	-0.03	-5.79

4.3. Tracking pre-trigger stationary source SO_2 emissions using the WRAP EDMS

The SO_2 Annex program, as proposed by WRAP and adopted by EPA, requires the tracking of SO_2 emissions from eligible stationary sources within states or tribal reservations participating in §309, to determine if the regional SO_2 emissions cap has been exceeded. This is known as "pre-trigger" tracking. Beginning with the 2003 calendar year and continuing through 2018, each state and tribe participating in the program will submit an annual SO_2 emissions report to the WRAP EDMS for the sources covered by the program. These annual reports will contain the following information:

- Identification and explanation for new/additional SO_2 sources which emissions are greater than100 tpy that were not contained in the previous year's emissions report.
- Explanation for sources shut down or removed from the previous year's emissions report.
- Explanation for emissions variations at any covered source that exceeds +/- 20% from the previous year.
- Identification and explanation of new emissions reporting methods at any source.

The Emissions Forum will compile these annual emissions reports for the program, using the EDMS, as submitted by the participating states and tribes, to provide a regional emission report for SO_2. By December 31 of the year following the applicable compliance year, WRAP will prepare a regional emission report that will include the following information:

- Summary of regional SO_2 emissions (tpy).
- Identification of any paper emission increases and decreases that have occurred due to changes in emission inventory techniques since the last revision of the regional haze implementation plan. The report will contain a running regional total, as well as supporting documentation identifying the specific changes that have occurred at individual sources.
- Average emissions for the last three (3) years (if applicable) for comparison to the regional milestone.
- Regional milestone for the compliance period.
- Draft determination that the milestone has either been met, or has been exceeded thereby triggering the backstop trading program.

The EDMS will have the capability to produce the following special reports in tabular and simple plots (i.e. bar graph and pie chart) formats and allow queries of the same information including presentation in GIS format, in addition to the standard reports.

- A summary report of the annual WRAP region emissions from the stationary sources emitting more than 100 tpy of SO_2 in the base year for each state, tribe, and the entire region.
- A summary report of the new stationary sources emitting more than 100 tpy of SO_2 that were not contained in the previous year's inventory for each state, tribe, and the entire region.

- A summary report of the stationary sources emitting more than 100 tpy of SO_2 that are retired compared to the previous year's inventory for each state, tribe, and the entire region.
- A summary report of the regional average SO_2 emissions from stationary sources emitting more than 100 tpy of SO_2 for the last three (3) years and comparison to the regional milestone for the compliance period.
- A summary report of the stationary sources emitting more than 100 tpy of SO_2 which emissions exceed +/- 20% compared to the previous year's inventory for each state, tribe, and the entire region.
- A summary report identifying all the stationary sources emitting more than 100 tpy of SO_2 that choose to opt in the program for each state, tribe, and the entire region.
- A summary report identifying all the stationary sources emitting more than 100 tpy of SO_2 that were not included in the base year for each state, tribe, and the entire region.

The EDMS to be developed is described in a draft technical report to the Emissions Forum: Needs Assessment for Evaluation and Design of an Emissions Data Reporting, Management, and Tracking System, (EA Engineering, Science, and Technology, June 26, 2003).

Chapter 5 – Assessment of Mobile Sources

5.1. Mobile source emissions inventory requirements

Revisions to the requirements for analyzing and tracking mobile source emissions under §309 of the Regional Haze Rule were proposed in the Federal Register by EPA, using simultaneous proposals of a rule revision and a direct final rule (39842 Federal Register, Volume 68, No. 128, Thursday, July 3, 2003). The rule change will be effective September 2, 2003, unless adverse comments are received. The changes are a result of a WRAP Board recommendation. Following are the requirements of the revised rule, from the Federal Register.

PART 51—REQUIREMENTS FOR PREPARATION, ADOPTION, AND SUBMITTAL OF IMPLEMENTATION PLANS
1. The authority citation for part 51 continues to read as follows: **Authority:** *42 U.S.C. 7410, 7414, 7421, 7470–7479, 7492, 7601, and 7602.*

Subpart P—Protection of Visibility
2. Section 51.309 is amended by revising paragraphs (b)(6) and (d)(5)(i), deleting paragraphs (d)(ii) and (d)(iii), and renumbering (d)(iv) to (d)(ii), to read as follows:

§ 51.309 Requirements related to the Grand Canyon Visibility Transport Commission.

(b)(6) Continuous decline in total mobile source emissions means that the projected level of emissions from mobile sources of each listed pollutant in 2008, 2013, and 2018, are less than the projected level of emissions from mobile sources of each listed pollutant for the previous period (i.e., 2008 less than 2003; 2013 less than 2008; and 2018 less than 2013).

(d)(5)(i) Statewide inventories of onroad and nonroad mobile source emissions of VOC, NO_X, SO_2, $PM_{2.5}$, *elemental carbon, and organic carbon for the years 2003, 2008, 2013, and 2018.*

(A) The inventories must demonstrate a continuous decline in total mobile source emissions (onroad plus nonroad; tailpipe and evaporative) of VOC, NO_X, $PM_{2.5}$, *elemental carbon, and organic carbon, evaluated separately. If the inventories show a continuous decline in total mobile source emissions of each of these pollutants over the period 2003–2018, no further action is required as part of this plan to address mobile source emissions of these pollutants. If the inventories do not show a continuous decline in mobile source emissions of one or more of these pollutants over the period 2003–2018, the plan submission must provide for an implementation plan revision by no later than December 31, 2008 containing any necessary long-term strategies to achieve a continuous decline in total mobile source emissions of the pollutant(s), to the extent practicable, considering economic and technological reasonableness and Federal preemption of vehicle standards and fuel standards under title II of the CAA.*

(B) The plan submission must also provide for an implementation plan revision by no later than December 31, 2008 containing any long-term strategies necessary to reduce emissions of SO_2 *from nonroad mobile sources, consistent with the goal of reasonable progress. In assessing the need for such long-term strategies, the State may consider emissions reductions achieved or*

anticipated from any new Federal standards for sulfur in nonroad diesel fuel.

(ii) [text of (iv) retained same as before]

The original rule text for analyzing and tracking mobile source emissions under §309 of the Regional Haze Rule was as follows:

(5) Mobile sources. The plan submission must provide for:

(i) Statewide inventories of current annual emissions and projected future annual emissions of VOC, NO_x, SO_2, elemental carbon, organic carbon, and fine particles from mobile sources for the years 2003 to 2018. The future year inventories must include projections for the year 2005, or an alternative year that is determined by the State to represent the year during which mobile source emissions will be at their lowest levels within the State.

(ii) A determination whether mobile source emissions in any areas of the State contribute significantly to visibility impairment in any of the 16 Class I Areas, based on the statewide inventory of current and projected mobile source emissions.

(iii) For States with areas in which mobile source emissions are found to contribute significantly to visibility impairment in any of the 16 Class I areas:

(A) The establishment and documentation of a mobile source emissions budget for any such area, including provisions requiring the State to restrict the annual VOC, NO_x, SO_2, elemental and organic carbon, and/or fine particle mobile source emissions to their projected lowest levels, to implement measures to achieve the budget or cap, and to demonstrate compliance with the budget.

(B) An emission tracking system providing for reporting of annual mobile source emissions from the State in the periodic implementation plan revisions required by paragraph (d)(10) of this section. The emission tracking system must be sufficient to determine the States' contribution toward the Commission's objective of reducing emissions from mobile sources by 2005 or an alternate year that is determined by the State to represent the year during which mobile source emissions will be at their lowest levels within the State, and to ensure that mobile source emissions do not increase thereafter.

(iv) Interim reports to EPA and the public in years 2003, 2008, 2013, and 2018 on the implementation status of the regional and local strategies recommended by the Commission Report to address mobile source emissions.

Technical analysis work on mobile source emissions and modeling for the visibility significance requirement was conducted by the WRAP Mobile Sources and Air Quality Modeling Forums. Emissions analyses are described in a WRAP technical memorandum: (http://64.27.97.126/forums/ef/inventories/mobile/FinalMobile_Emissions_Memo_Nov26.doc), and the visibility modeling results in another WRAP memorandum: (http://64.27.97.126/forums/ef/inventories/mobile/FinalMobile_Sig_Mem_Nov4.doc). After review by the WRAP Technical and Initiatives Oversight Committees, respectively, and the WRAP Board of Directors, a letter from the Board requesting that EPA modify the mobile source requirements through a rule change was sent (http://64.27.97.126/forums/msf/documents/whitman5-6-03.pdf). The rule change was proposed by EPA on July 3, 2003, and is cited at the beginning of this section (http://64.27.97.126/forums/msf/documents/Proposed_Rule.pdf).

5.2. Mobile source emissions inventory trends

The revisions to mobile source emissions portion of §309 of the Regional Haze Rule described above require the demonstration of a continuous decline in total mobile source emissions. As above, this means that the projected level of emissions from mobile sources of each listed pollutant (statewide inventories of on-road and non-road mobile source emissions of VOC, NO_X, SO_2, $PM_{2.5}$, elemental carbon, and organic carbon for the years 2003, 2008, 2013, and 2018) in 2008, 2013, and 2018, are to be shown to be less than the projected level of emissions from mobile sources of each listed pollutant for the previous period (i.e., 2008 less than 2003; 2013 less than 2008; and 2018 less than 2013). Also reported are 1996 on-road mobile source emissions data. Estimates of on-road mobile source SO_2 emissions, based on already adopted federal and state rules, are reported for each of the 5 years. The trend data start with 1996; these on-road emissions were used in the air quality “base case” modeling discussed in Chapter 2.

5.2.1. On-road emissions trends

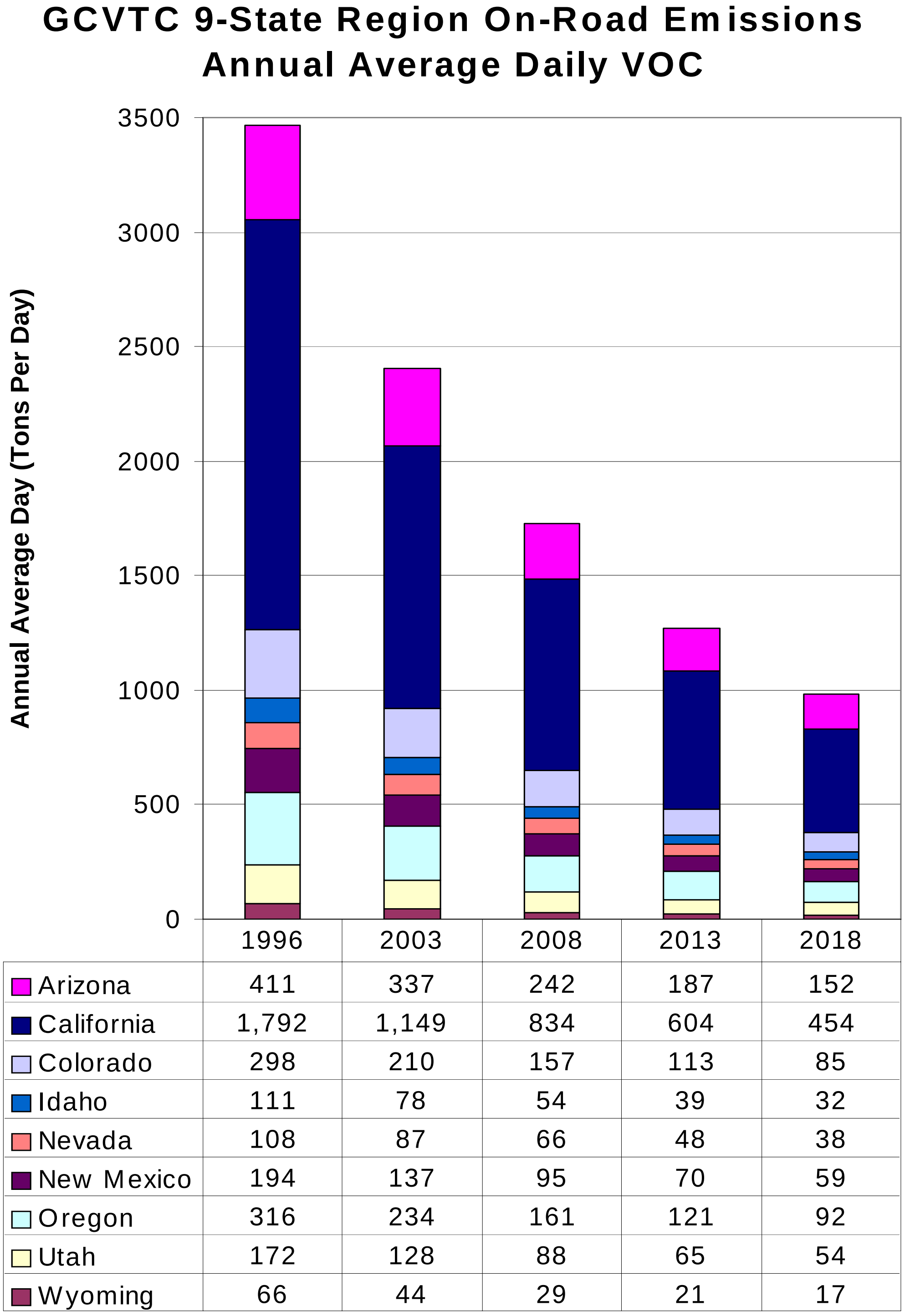
As discussed earlier, WRAP on-road emission inventories are available for five years: the 1996 base year, and projection years 2003, 2008, 2013, and 2018 [Pollack, 2003]. The projection year inventories include all promulgated on-road control programs, as listed in Chapter 1. Neither EPA nor CARB is currently developing any further on-road regulations for criteria or visibility-related pollutants. On-road mobile source emissions are a major contributor to the total anthropogenic NO_x (35% in 1996, 14% in 2018) and VOC (38% in 1996, 15% in 2018) emissions; they contribute only negligibly to $PM_{2.5}$ and SO_2 emissions.

Table 5.2.1.1 shows the net emissions change from on-road sources by pollutant, in 2018. Elemental and organic carbon emissions are fixed fractions of the $PM_{2.5}$ emissions, and vary by gas and diesel engine distributions. These values will be published as this document is updated. Figures 5.2.1.1 through 5.2.1.4 show the VOC, NO_X, SO_2, and $PM_{2.5}$ on-road mobile source emissions inventory data for the GCVTC 9-state region, for the 1996 through 2018 timeframe. On-road VOC, NO_X, and $PM_{2.5}$ emissions in the 9-state region are projected to decline consistently from 1996 to 2018 as a result of fleet turnover; i.e., older vehicles will be scrapped and replaced with newer vehicles that meet tighter emissions standards (for both light-duty and heavy-duty vehicles). On-road SO_2 emissions will decrease significantly between 2003 and 2008 with the introduction of low sulfur gasoline in 2004 and low sulfur diesel fuel in 2006; from 2008 onward SO_2 emissions will increase as the fuel sulfur levels stay constant but fuel consumption increases.

Table 5.2.1.1. Net emissions change from 2003 to 2018 for on-road sources, by pollutant.

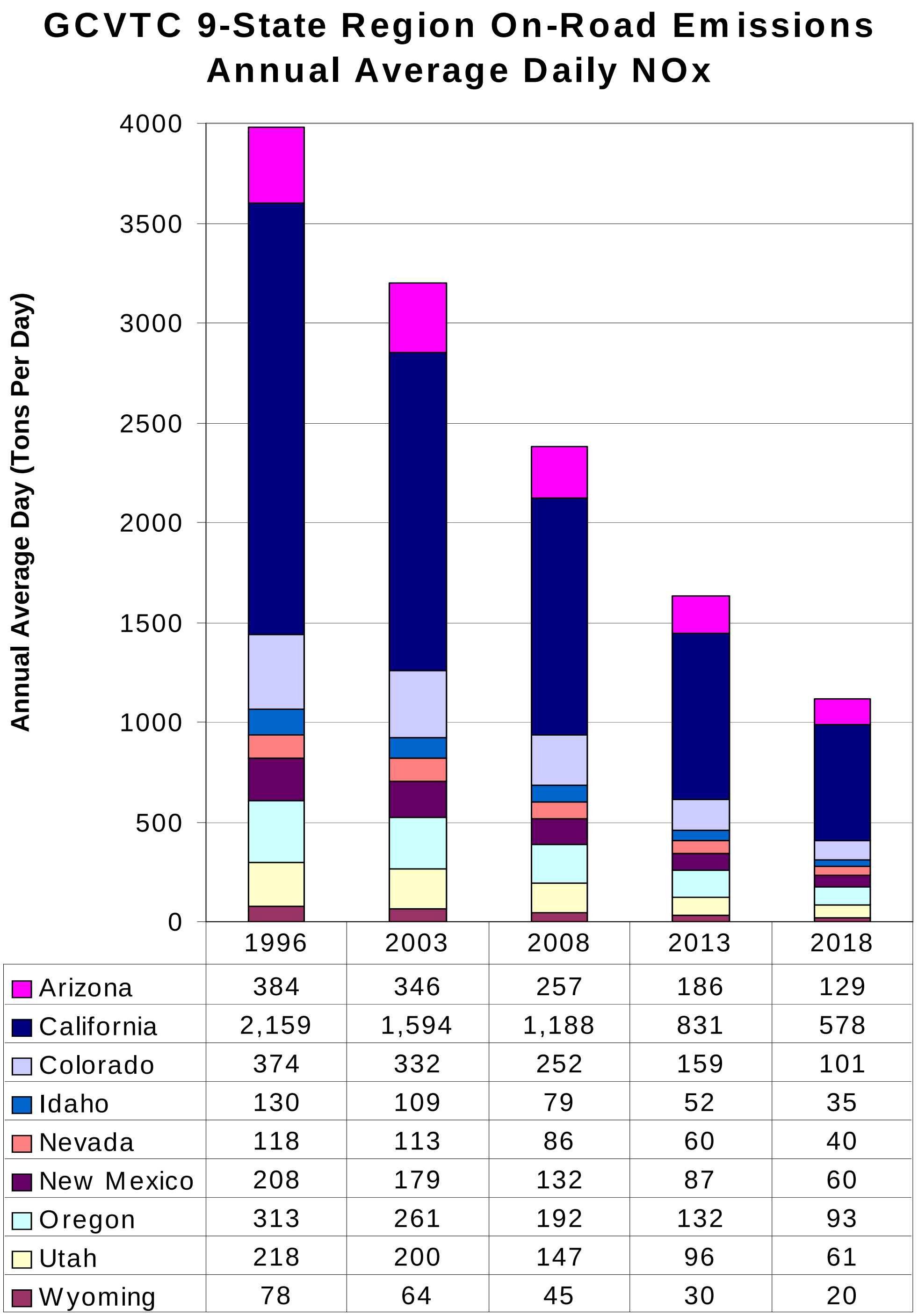
	~~2018 On-road Emissions (tons per day)~~				Reduction from 2003 (%)			
State	**VOC**	**NO_x**	**$PM_{2.5}$***	**SO_2**	**VOC**	**NO_x**	**$PM_{2.5}$**	**SO_2**
Arizona	152.3	129.5	4.6	2.1	55%	63%	47%	78%
California	453.7	577.8	27.5	6.0	61%	64%	16%	44%
Colorado	84.7	100.8	4.8	1.8	60%	70%	53%	84%
Idaho	32.1	34.5	1.7	0.6	59%	68%	47%	87%
Montana	23.4	26.8	1.4	0.4	59%	68%	46%	90%
Nevada	38.4	40.4	1.8	0.7	56%	64%	51%	64%
New Mexico	59.2	59.5	3.3	1.0	57%	67%	51%	87%
North Dakota	16.0	17.6	0.9	0.3	62%	69%	48%	87%
Oregon	91.7	93.3	3.6	1.4	61%	64%	43%	87%
South Dakota	19.5	22.2	1.1	0.3	59%	68%	46%	86%
Utah	54.2	61.1	3.7	1.0	58%	69%	49%	81%
Washington	175.3	145.8	5.7	1.9	62%	66%	44%	88%
Wyoming	17.5	19.8	1.0	0.3	60%	69%	47%	88%
13 States	1218.0	1329.3	61.1	17.9				
9 GC States	983.8	1116.9	51.9	14.9				

* - exhaust emissions only, includes elemental and organic carbon.



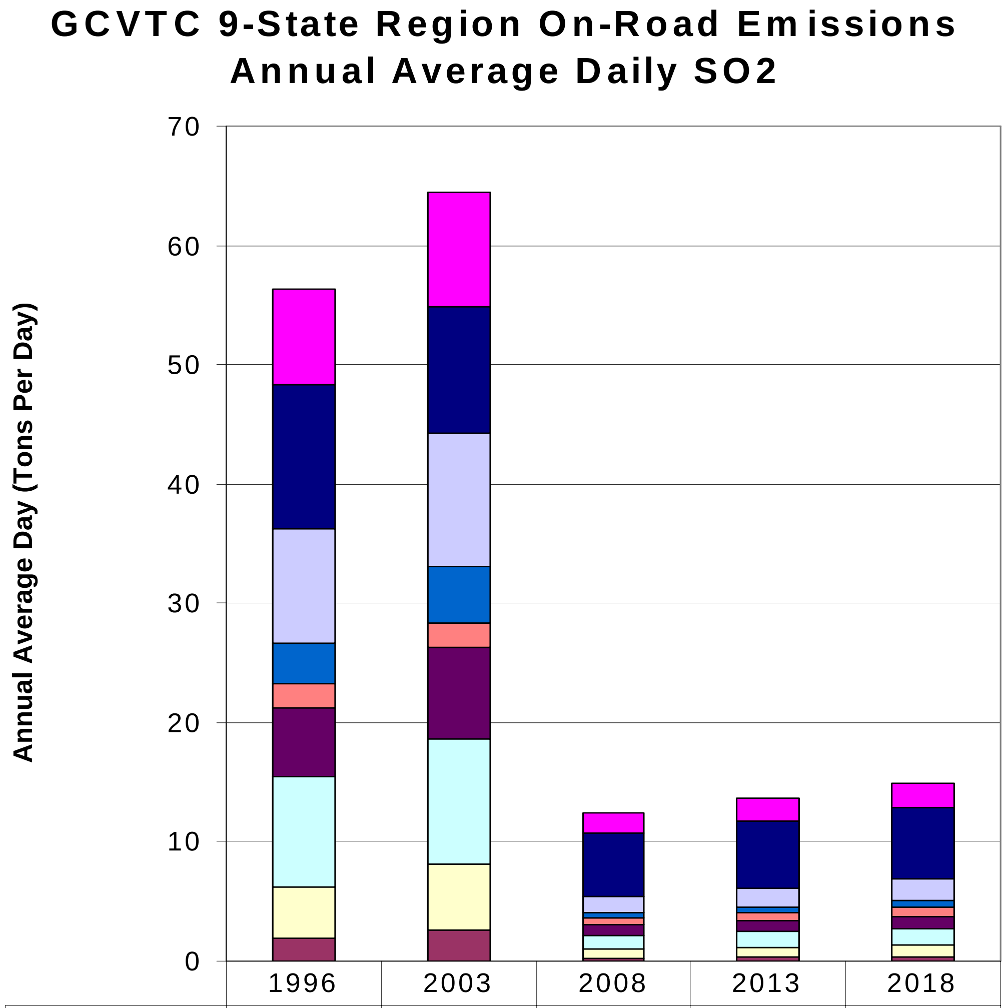
	1996	2003	2008	2013	2018
■ Arizona	411	337	242	187	152
■ California	1,792	1,149	834	604	454
■ Colorado	298	210	157	113	85
■ Idaho	111	78	54	39	32
■ Nevada	108	87	66	48	38
■ New Mexico	194	137	95	70	59
■ Oregon	316	234	161	121	92
■ Utah	172	128	88	65	54
■ Wyoming	66	44	29	21	17

Figure 5.2.1.1. Trends in on-road mobile VOC emissions by GCVTC state.



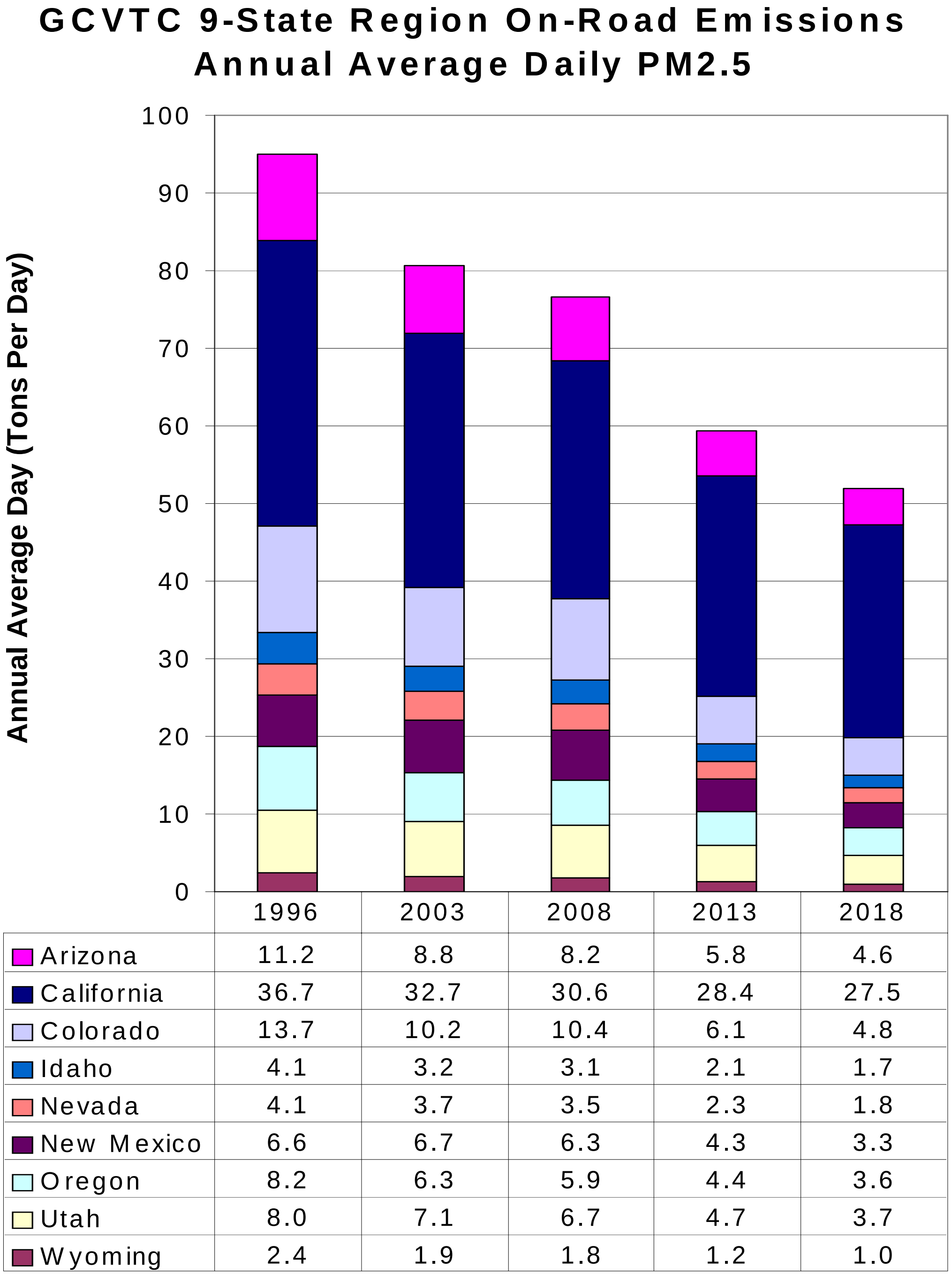
	1996	2003	2008	2013	2018
■ Arizona	384	346	257	186	129
■ California	2,159	1,594	1,188	831	578
■ Colorado	374	332	252	159	101
■ Idaho	130	109	79	52	35
■ Nevada	118	113	86	60	40
■ New Mexico	208	179	132	87	60
■ Oregon	313	261	192	132	93
■ Utah	218	200	147	96	61
■ Wyoming	78	64	45	30	20

Figure 5.2.1.2. Trends in on-road mobile NO_x emissions by GCVTC state.



	1996	2003	2008	2013	2018
Arizona	8.0	9.6	1.6	1.8	2.1
California	12.0	10.7	5.3	5.6	6.0
Colorado	9.6	11.1	1.4	1.6	1.8
Idaho	3.4	4.8	0.5	0.5	0.6
Nevada	2.0	2.0	0.6	0.6	0.7
New Mexico	5.7	7.6	0.8	0.9	1.0
Oregon	9.2	10.5	1.1	1.3	1.4
Utah	4.4	5.5	0.8	0.9	1.0
Wyoming	1.9	2.6	0.3	0.3	0.3

Figure 5.2.1.3. Trends in on-road mobile SO_2 emissions by GCVTC state.



	1996	2003	2008	2013	2018
■ Arizona	11.2	8.8	8.2	5.8	4.6
■ California	36.7	32.7	30.6	28.4	27.5
■ Colorado	13.7	10.2	10.4	6.1	4.8
■ Idaho	4.1	3.2	3.1	2.1	1.7
■ Nevada	4.1	3.7	3.5	2.3	1.8
■ New Mexico	6.6	6.7	6.3	4.3	3.3
■ Oregon	8.2	6.3	5.9	4.4	3.6
■ Utah	8.0	7.1	6.7	4.7	3.7
■ Wyoming	2.4	1.9	1.8	1.2	1.0

Figure 5.2.1.4. Trends in on-road mobile $PM_{2.5}$ emissions by GCVTC state.

5.2.2. Non-road emissions trends

As discussed earlier, WRAP non-road emission inventories are available for five years: the 1996 base year, and projection years 2003, 2008, 2013, and 2018. The projection year inventories include all promulgated on-road and non-road controls, as listed in Chapter 1. Further non-road controls, however, have been proposed. As discussed in Chapter 1, in April 2003, EPA proposed further emissions controls for large non-road diesel equipment, along with a requirement for low sulfur non-road diesel fuel to enable the emissions control technology. The projection year emission inventories do not include anticipated effects of these proposed controls. As discussed in Chapter 1, the NONROAD2002 model was run with ultra low sulfur (≤15 ppm) diesel fuel for non-road equipment in the development of the 2008, 2013, and 2018 non-road emissions estimates, and the emission estimates were adjusted to back out the effects of the low sulfur diesel. These emissions estimates were calculated by applying the known state averages of diesel fuel sulfur to the NONROAD2002 data. Table 5.2.2.1 shows the net emissions change from non-road sources by pollutant, in 2018. Elemental and organic carbon emissions are fixed fractions of the $PM_{2.5}$ emissions, and vary by gas and diesel engine distributions.

Table 5.2.2.1. Net emissions change from 2003 to 2018 for non-road sources, by pollutant.

	2018 Non-road Emissions (tons per day)					**Reduction from 2003 (%)**		
State	**VOC**	**NO_x**	**$PM_{2.5}$***	**SO_2****	**SO_2*****	**VOC**	**NO_x**	**$PM_{2.5}$**
Arizona	69.7	107.8	13.4	8.4	8.1	38%	28%	5%
California	266.0	602.1	52.2	77.5	82.6	37%	37%	19%
Colorado	55.5	138.4	11.6	22.7	10.9	40%	28%	20%
Idaho	27.8	56.1	4.9	7.5	4.4	41%	28%	23%
Montana	19.2	123.0	8.3	13.3	14.2	39%	26%	24%
Nevada	31.5	136.7	8.3	11.6	15.8	35%	22%	8%
New Mexico	16.6	20.9	3.6	5.8	0.4	38%	34%	17%
North Dakota	18.6	121.1	9.4	24.5	8.4	46%	33%	42%
Oregon	64.7	300.3	12.5	17.7	24.1	35%	28%	14%
South Dakota	14.9	62.8	6.9	21.6	0.1	46%	31%	38%
Utah	37.6	94.6	8.3	20.6	5.8	38%	28%	17%
Washington	79.4	207.4	15.8	22.8	31.3	39%	32%	17%
Wyoming	16.9	113.5	5.2	4.9	16.8	32%	24%	16%
13 States	718.4	2084.6	160.3	258.9	222.8			
9 GC States	586.3	1570.3	119.9	176.6	168.7			

* - exhaust emissions only, includes elemental and organic carbon.

** - SO_2 at present diesel fuel sulfur levels from land-based sources (no planes, trains, or ships).

*** - SO_2 from planes, trains, and ships.

5.2.3. Total mobile source emissions trends

Total mobile source emissions trends are reported next.

Table 5.2.3.1. Net emissions change from 2003 to 2018 for total mobile sources, by pollutant.

	2018 Total Mobile Source Emissions (tons per day)				Reduction from 2003 (%)			
State	**VOC**	**NO_x**	**$PM_{2.5}$***	**SO_2**	**VOC**	**NO_x**	**$PM_{2.5}$**	**SO_2**
Arizona	222.0	237.3	18.1	10.3	51%	52%	21%	51%
California	719.7	1179.9	79.7	97.3	54%	54%	18%	42%
Colorado	140.2	239.2	16.4	12.8	54%	54%	33%	66%
Idaho	59.9	90.6	6.6	5.0	52%	51%	31%	69%
Montana	42.6	149.8	9.7	14.7	52%	40%	28%	44%
Nevada	69.9	177.1	10.1	16.6	49%	38%	20%	27%
New Mexico	75.8	80.4	6.9	1.4	54%	62%	38%	89%
North Dakota	34.7	138.7	10.3	8.8	55%	42%	42%	71%
Oregon	156.5	393.6	16.1	25.5	53%	42%	23%	43%
South Dakota	34.3	85.0	8.0	0.5	54%	47%	39%	97%
Utah	91.7	155.7	12.0	6.9	51%	53%	30%	73%
Washington	254.7	353.2	21.6	33.4	57%	52%	27%	51%
Wyoming	34.4	133.3	6.2	17.1	50%	37%	23%	14%
13 States	1936.4	3413.9	221.4	250.5				
9 GC States	1570.1	2687.1	171.9	193.1				

* - exhaust emissions only, includes elemental and organic carbon.

Data showing continuous declines in total mobile source emissions are presented next. Elemental and organic carbon emissions are fixed fractions of the $PM_{2.5}$ emissions, and vary by gas and diesel engine distributions. Most of the data used to develop these fractional carbon estimates are from a 1999 Desert Research Institute study by Gillies and Gertler, prepared for EPA, and used by ENVIRON for the WRAP mobile source emissions inventories (Pollack, 2003). Elemental and organic carbon emissions shown here are averages of the gasoline, light-duty diesel, and heavy-duty diesel exhaust fractions of $PM_{2.5}$ emissions. On average, exhaust emissions of elemental and organic carbon total just over 87% of $PM_{2.5}$ exhaust emissions. Average organic carbon exhaust emissions are 33.7% of $PM_{2.5}$ exhaust emissions, and average elemental carbon exhaust emissions are 53.4% of $PM_{2.5}$ exhaust emissions.

Table 5.2.3.2. Continuous declines in total mobile source emissions.

2003-08 Emissions Changes (tons per day)					
State	**VOC**	**NO_x**	**$PM_{2.5}$***	**Organic Carbon**	**Elemental Carbon**
Arizona	-128.8	-115.3	-0.1	-0.3	-0.5
California	-367.1	-537.4	-0.7	-1.9	-3.0
Colorado	-79.7	-113.2	-0.1	-0.3	-0.6
Idaho	-34.2	-42.2	-0.1	-0.2	-0.3

Montana	-24.7	-51.8	-0.1	-0.4	-0.6
Nevada	-35.2	-55.8	-0.1	-0.2	-0.3
New Mexico	-49.3	-52.6	-0.1	-0.2	-0.4
North Dakota	-22.2	-46.9	-0.3	-0.9	-1.4
Oregon	-96.9	-130.4	-0.2	-0.4	-0.7
South Dakota	-21.8	-29.5	-0.2	-0.5	-0.8
Utah	-54.0	-74.1	-0.2	-0.4	-0.7
Washington	-191.0	-173.1	-0.3	-0.9	-1.4
Wyoming	-18.1	-47.0	-0.1	-0.2	-0.3

2008-13 Emissions Changes (tons per day)

State	**VOC**	**NO$_x$**	**PM$_{2.5}$***	**Organic Carbon**	**Elemental Carbon**
Arizona	-63.1	-84.5	-0.4	-1.0	-1.6
California	-291.0	-492.8	-0.9	-2.4	-3.8
Colorado	-51.8	-109.2	-0.7	-1.9	-3.0
Idaho	-20.6	-34.0	-0.2	-0.6	-0.9
Montana	-14.6	-30.6	-0.3	-0.7	-1.0
Nevada	-20.3	-34.0	-0.2	-0.5	-0.9
New Mexico	-27.2	-48.6	-0.3	-0.8	-1.3
North Dakota	-13.3	-32.8	-0.4	-1.2	-1.9
Oregon	-48.0	-96.6	-0.3	-0.8	-1.3
South Dakota	-13.1	-28.5	-0.3	-0.9	-1.4
Utah	-28.8	-63.8	-0.4	-1.0	-1.6
Washington	-95.1	-116.3	-0.5	-1.3	-2.1
Wyoming	-10.7	-21.3	-0.1	-0.3	-0.5

2013-18 Emissions Changes (tons per day)

State	**VOC**	**NO$_x$**	**PM$_{2.5}$***	**Organic Carbon**	**Elemental Carbon**
Arizona	-34.8	-59.4	-0.1	-0.4	-0.6
California	-194.1	-335.1	-0.6	-1.5	-2.4
Colorado	-31.4	-63.4	-0.2	-0.5	-0.8
Idaho	-10.7	-19.8	-0.1	-0.2	-0.4
Montana	-6.9	-17.7	-0.1	-0.3	-0.4
Nevada	-10.4	-20.5	-0.0	-0.1	-0.2
New Mexico	-11.2	-29.5	-0.1	-0.4	-0.6
North Dakota	-6.5	-20.2	-0.2	-0.5	-0.8
Oregon	-31.6	-60.0	-0.1	-0.3	-0.5
South Dakota	-6.1	-17.8	-0.1	-0.4	-0.6
Utah	-14.4	-37.8	-0.1	-0.3	-0.5
Washington	-46.8	-85.8	-0.2	-0.5	-0.7
Wyoming	-5.5	-11.4	-0.1	-0.1	-0.2

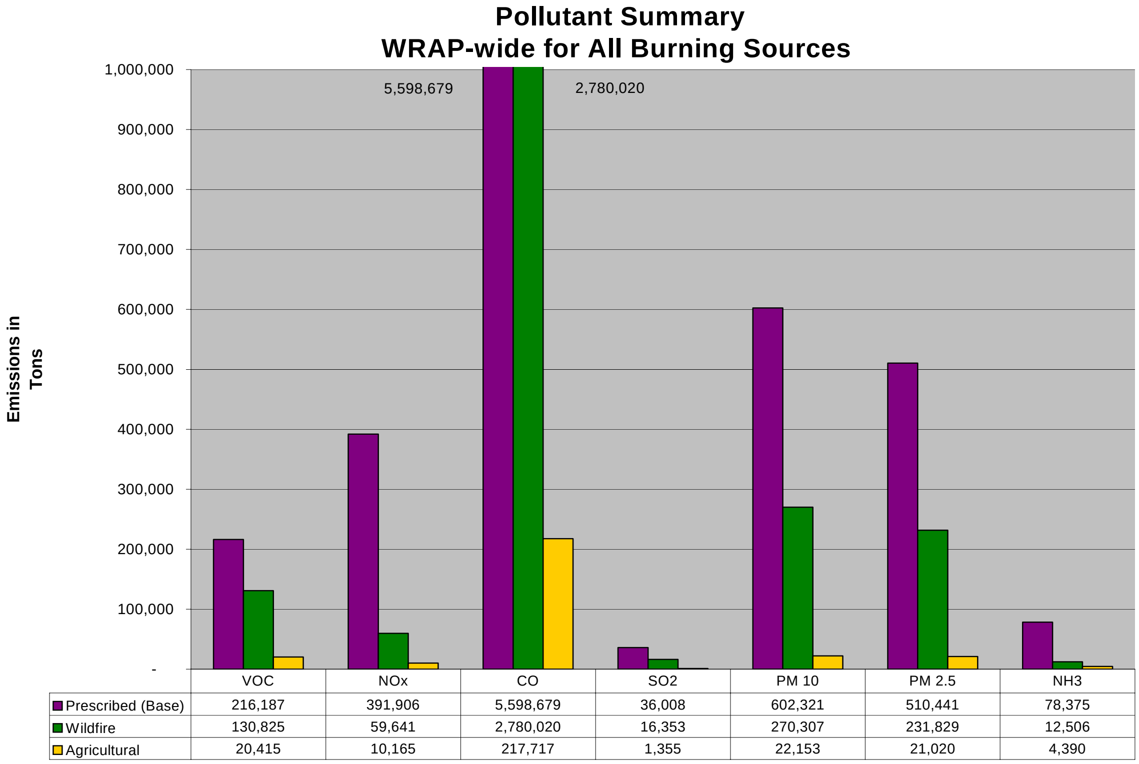
* - exhaust emissions only

Chapter 6 – Assessment of Fire Programs

6.1. Fire emissions inventories for 2018 Smoke Management Scenarios

The Fire Emissions Joint Forum (FEJF) of the Western Regional Air Partnership (WRAP) addressed three different emission reduction scenarios for the 2018 projected emission inventory for fire, "no control," "base," and "optimal." The base and optimal scenarios were utilized in the modeling and are briefly compared and summarized here. For the full documentation and discussion of the 2018 fire emission projections, please follow the reference in Appendix D to the contractor technical report entitled "Integrated Assessment Update and 2018 Emissions Inventory for Prescribed Fire, Wildfire, and Agricultural Burning," Air Sciences Inc., March 2003. A pollutant summary of the "base" emission inventories for prescribed fire, wildfire, and agricultural burning is shown next.

Figure 6.1.1. Pollutant summary of the base emission inventories for prescribed fire, wildfire, and agricultural burning.



	VOC	NOx	CO	SO2	PM 10	PM 2.5	NH3
🟪 Prescribed (Base)	216,187	391,906	5,598,679	36,008	602,321	510,441	78,375
🟩 Wildfire	130,825	59,641	2,780,020	16,353	270,307	231,829	12,506
🟨 Agricultural	20,415	10,165	217,717	1,355	22,153	21,020	4,390

6.1.1. Wildfire scenario comparison

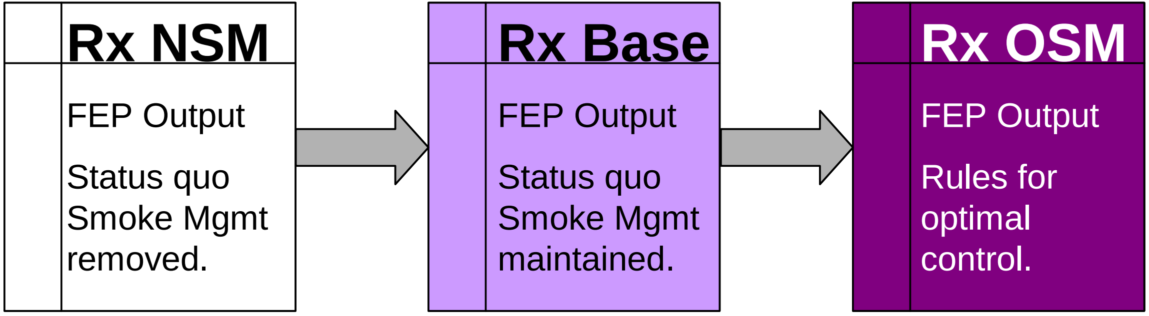
A single emission projection for wildfire was submitted by the FEJF for use in all three modeling scenarios. The WRAP Modeling and Emissions Forums called on the FEJF to produce a wildfire projection that represented a "typical year" of wildfire activity within the 13-state WRAP region, which were used in all control strategy modeling.

6.1.2. Prescribed burning scenario comparison

For prescribed burning, base and optimal scenarios originated in the Fire Emissions Project (FEP) commissioned by the Grand Canyon Visibility Transport Commission (GCVTC). The GCVTC solicited quantitative activity and burn-practices estimates from land managers in the West and synthesized this information to emission projection scenarios. The FEP 2015 projections were taken by the FEJF to represent 2018 WRAP projections.

The FEP database application calculated emissions given various forest types, activity levels, pre-burn fuel treatments, and smoke management techniques. The base scenario was calculated using the mix of emission reduction techniques defined by the land managers or by default values. The optimal scenario included the same fire treatments as the base scenario but applied a set of *optimal* smoke management practices (emission reduction techniques) to further reduce emissions. The set and effect of optimal smoke management practices were defined by expert opinion and essentially replaced the surveyed practices. A schematic showing the development of the prescribed fire smoke management scenarios is shown next.

Figure 6.1.2.1. Prescribed Fire Smoke Management Scenario Flowchart.

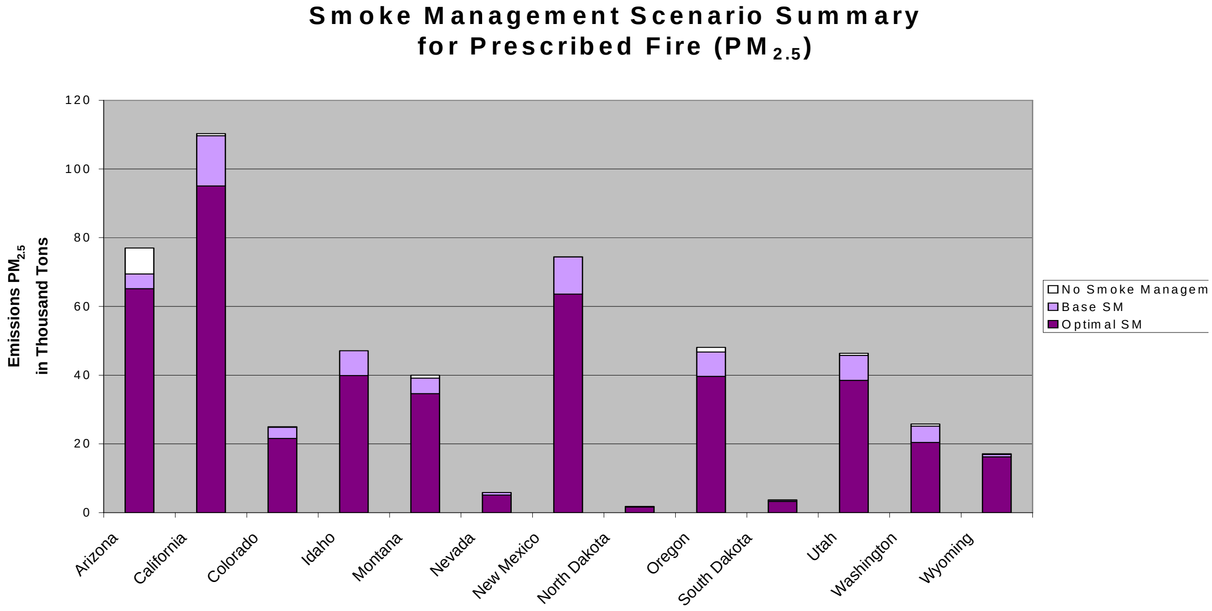


Data tables were created for the three different prescribed fire smoke management scenarios. The spatial and temporal refinement documented in Chapter 1 was performed on the base smoke management scenario. Refined emission inventories for the two other cases were created by scaling the emissions of the base scenario. In this way, the event-based emission inventories for all three scenarios are identical except for emission mass. By comparing the FEP data tables by-grid, by-owner, by-pollutant, and by-season a percent increase or decrease was identified and applied. The prescribed burning optimal smoke management scenario resulted in an overall 13 percent reduction of $PM_{2.5}$ emissions relative to base. A summary of $PM_{2.5}$ emissions from prescribed fire for the three smoke management scenarios are presented next.

Table 6.1.2.1. Summary of $PM_{2.5}$ emissions from prescribed burning by state and smoke management scenario.

	No Smoke Management		Base Smoke Management		Optimal Smoke Management	
State	**Absolute (tons x 10^3)**	**Relative (%)**	**Absolute (tons x 10^3)**	**Relative (%)**	**Absolute (tons x 10^3)**	**Relative (%)**
Arizona	77.0	15%	69.5	14%	65.2	15%
California	110.3	21%	109.7	21%	95.1	21%
Colorado	25.0	5%	24.8	5%	21.6	5%
Idaho	47.1	9%	47.1	9%	39.9	9%
Montana	40.0	8%	39.1	8%	34.6	8%
Nevada	5.9	1%	5.8	1%	5.1	1%
New Mexico	74.5	14%	74.4	15%	63.6	14%
North Dakota	1.8	0%	1.8	0%	1.6	0%
Oregon	48.1	9%	46.7	9%	39.7	9%
South Dakota	3.7	1%	3.6	1%	3.3	1%
Utah	46.4	9%	45.7	9%	38.5	9%
Washington	25.8	5%	25.2	5%	20.5	5%
Wyoming	17.1	3%	16.9	3%	16.2	4%
TOTAL	**522.6**	**100%**	**510.4**	**100%**	**444.8**	**100%**

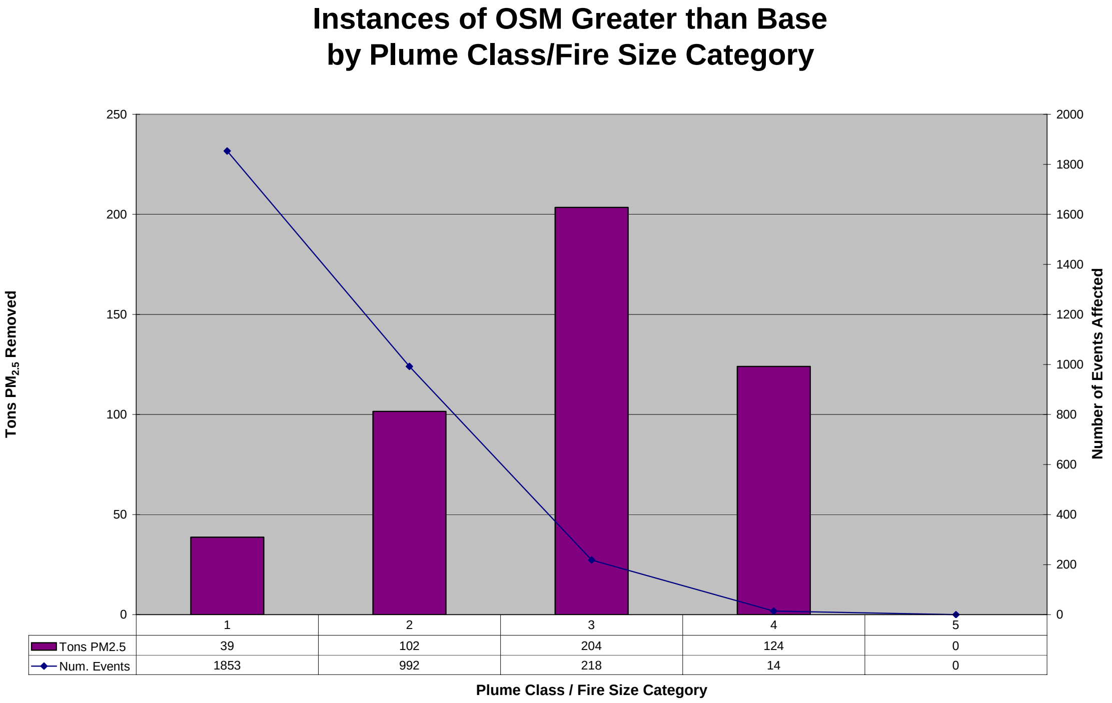
Figure 6.1.2.2. Summary of $PM_{2.5}$ emissions from prescribed burning by state and smoke management scenario.



In the course of conducting QA/QC on the dispersion modeling results and fire emissions inventories, it was discovered that in limited cases the optimal smoke management scenario in FEP yielded greater emissions than base. Through consultation with the developers of FEP, the Emissions Task Team (ETT) of the FEJF determined that any instances of OSM producing greater emissions than base are unintended. The FEJF will investigate the cause for the unintended outputs from FEP and may modify the code in FEP to remedy the problem. In the short term, the ETT elected to employ data processing techniques to prepare OSM data files that include prescribed fire events that in all cases are less than or equal to base. This data processing resulted in the removal of 468 tons of $PM_{2.5}$ (1% of the total $PM_{2.5}$ in the prescribed fire inventory) from 3,077 fire events (2% of the total number of events in the prescribed fire inventory) of the optimal smoke management emission inventory.

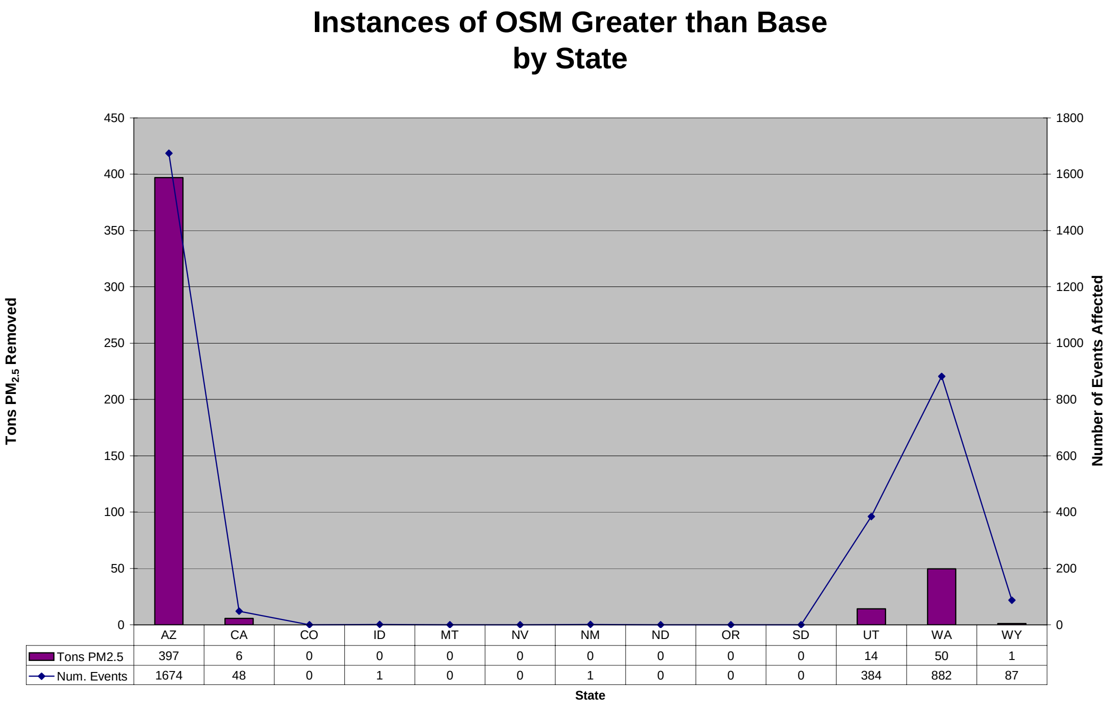
The three figures below illustrate the effects of the data processing on the prescribed fire inventory. Figure 53 shows the number of events modified and the quantity of $PM_{2.5}$ emissions removed by fire size categories. Figure 54 displays the number of events modified and quantity of $PM_{2.5}$ emissions removed by state. Figure 55 presents the number of events modified and quantity of $PM_{2.5}$ emissions removed by month.

Figure 6.1.2.3. Effect of OSM Data Processing – by Plume Class / Fire Size Category



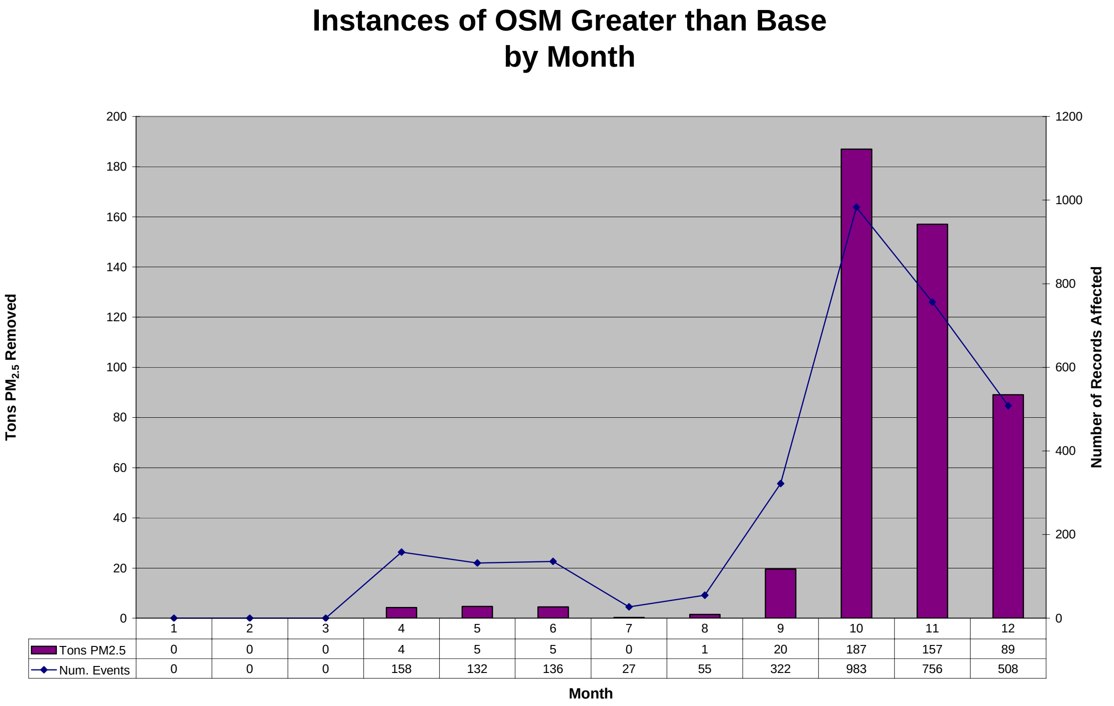
	1	2	3	4	5
Tons PM2.5	39	102	204	124	0
Num. Events	1853	992	218	14	0

Figure 6.1.2.4. Effect of OSM Data Processing – by State



	AZ	CA	CO	ID	MT	NV	NM	ND	OR	SD	UT	WA	WY
Tons PM2.5	397	6	0	0	0	0	0	0	0	0	14	50	1
Num. Events	1674	48	0	1	0	0	1	0	0	0	384	882	87

Figure 6.1.2.5. Number of events modified and quantity of $PM_{2.5}$ emissions removed by month.



	1	2	3	4	5	6	7	8	9	10	11	12
Tons PM2.5	0	0	0	4	5	5	0	1	20	187	157	89
Num. Events	0	0	0	158	132	136	27	55	322	983	756	508

6.1.3. Findings of Initial Investigation of FEP Results

The FEJF charged the fire emissions contractor with investigating the Base and OSM output from FEP in order to guide the process of revising the FEP input or code to eliminate the occurrences of OSM emissions being greater than Base emissions. FEP is an intricate emissions model with many layers of input data and algorithms and this investigative process was intended to make any necessary modifications to FEP more efficient.

FEP was queried for as many of the characteristics of the OSM data that could possibly lead to the surprising results of OSM greater than Base. These data were reviewed using automated scripts and cross tabulations to identify patterns or trends in the data. In addition, the summary of the methods used to develop FEP (included as Appendix A of the report on the 2018 fire emissions inventories, Integrated Assessment Update and 2018 Emissions Inventory for Prescribed Fire, Wildfire, and Agricultural Burning) was reviewed. Several potential reasons (all pertaining to the application of smoke management rules as input to FEP) for the surprising OSM versus Base outputs of FEP are provided below:

- A set of smoke management / emission control “rules” were prepared in the development of FEP. These rules were applied to the Base and OSM scenarios independently. That is, there was no inherent mechanism to ensure that OSM emissions would be less than Base. Because smoke management rules were applied independently – and often in complex combinations – different emission factors, control factors, and treatment application rates resulted causing varying emission reduction effects across the landscape.
- In some instances, smoke management application levels as input to FEP were strictly higher in Base than in OSM. That is, for the same smoke management applied in Base and in OSM, the emission reduction factors are lower (i.e., the resulting emission estimates are higher) in OSM.

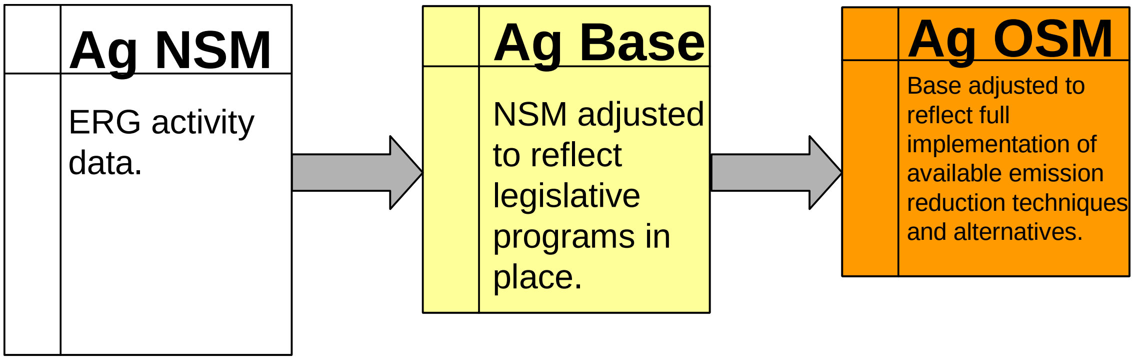
Certain smoke management treatments (specifically, “Mass Ignition / Shortened Fire Duration” and “Rapid Mop-Up”) triggered the smoldering flag to be turned on in FEP. An increased application of “Rapid Mop-Up” is disproportionately represented in the FEP records where OSM is greater than Base.

6.1.4. Agricultural burning scenario comparison

The FEJF prepared three agricultural burning emission inventories representing three emission control scenarios. The no control scenario is based upon the FEJF's 1996 agricultural burning activity database (as complied by Eastern Research Group (ERG)) without adjustment. The base projection was developed through post-processing the spatially and temporally refined no control inventory. Adjustments for the base case reflected existing regulatory programs that will serve to reduce emissions from "uncontrolled levels" in 2018. The optimal scenario is derived based upon adjustments made to the base inventory. Adjustments for the optimal smoke management scenario reflect the full implementation of reasonably known emission control techniques, alternatives to agricultural burning, and burn permitting programs. A flowchart showing the development of the agricultural burning smoke management scenarios is shown next. The Ag

OSM database is a subset of the Ag Base data, which is subset of the Ag NSM database. For the Ag Base, the ETT developed a set of calculations to convert the legislative programs in place to emission reduction targets. To derive the Ag Base database, agricultural burning events were removed from Ag NSM until the total of the emissions removed equaled the Ag Base emission reduction target. Similarly, the ETT developed a set of calculations to convert the full implementation of available emission reduction techniques WRAP-wide to emission reduction targets for Ag OSM and burning events were removed from Ag Base until the total of the emissions removed equaled the Ag OSM emission reduction target.

Figure 6.1.4.1. Agricultural Smoke Management Scenario Flowchart.



To form the base scenario, the FEJF identified three jurisdictions in the WRAP with existing emission reduction programs already codified into laws and/or regulations. These programs are assumed to have their full regulatory effect in 2018: California's Sacramento Valley has a program focused on reducing the amount of rice stubble burned. Washington State has established a goal to reduce emissions from wheat stubble burning and Oregon's Willamette Valley limits open-field burning of seed grass. For each case, emission reduction targets were developed on a per-crop and per-county basis and applied to selectively shrink the 2018 no control dataset.

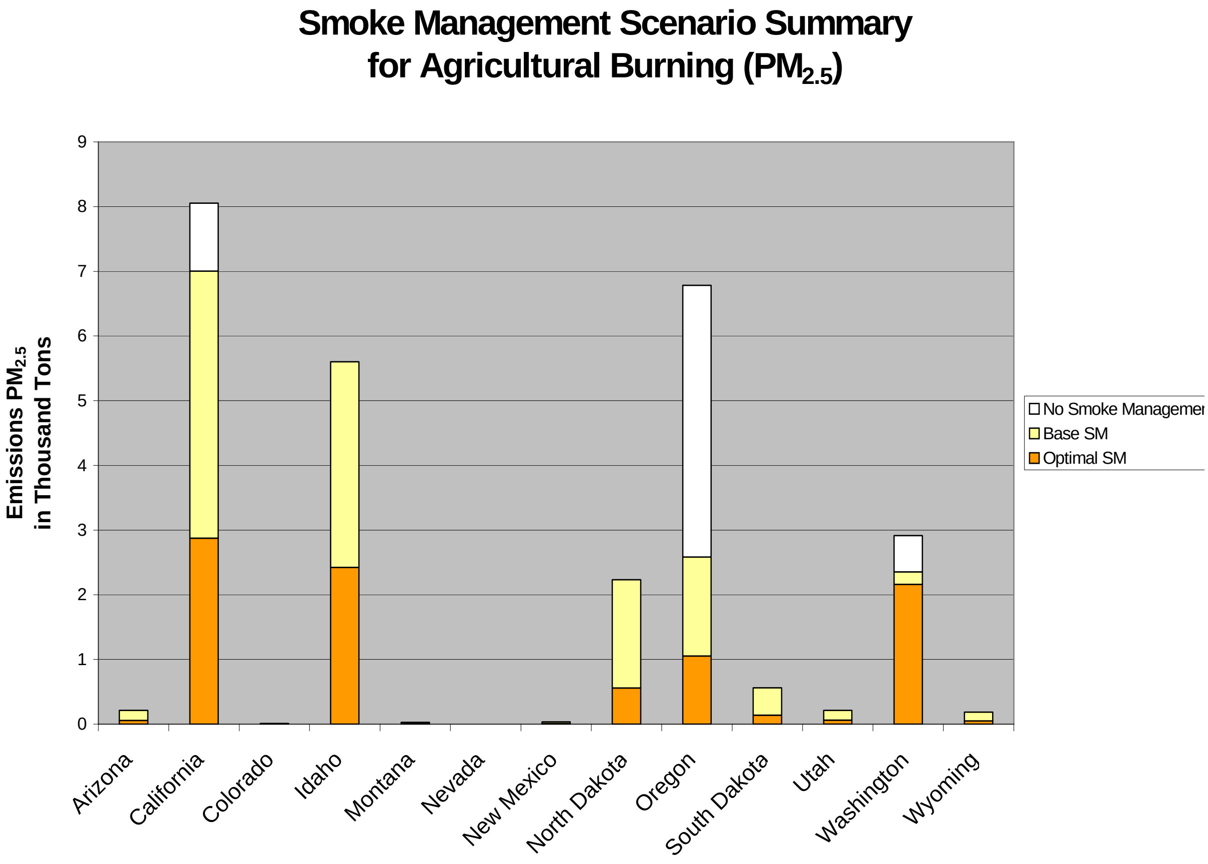
Optimal, or "maximum" control is considered to be the aggressive implementation of emission control measures currently recognized to be effective and available. The FEJF quantified crop-specific emission reduction factors through expert opinion and applied them uniformly across the WRAP region. Reductions to three crop categories were devised under this "maximum" hypothesis. Orchard crops would have a 90 percent reduction in emissions due to utilization of prunings for renewable energy. Cereal crops would experience a 75 percent reduction due to imposed emissions control. Grass seed fields would see a 50 percent reduction via emission controls and increased availability of alternatives to burning. These "rules" were applied to the base scenario by randomly removing fire events (of the appropriate crop-type) until the emission reduction target was reflected in the dataset. The remaining inventory records thereby comprised the 2018 optimal control emissions projection for the WRAP region.

Compared to the base scenario, the optimal smoke management scenario yielded an overall 55 percent decrease in $PM_{2.5}$ emissions. A summary of the $PM_{2.5}$ emissions for agricultural burning by state and smoke management scenario are presented next.

Table 6.1.4.1. Summary of $PM_{2.5}$ emissions from agricultural burning by state and smoke management scenario.

	No Smoke Management		**Base Smoke Management**		**Optimal Smoke Management**	
State	**Absolute (tons x 10^3)**	**Relative (%)**	**Absolute (tons x 10^3)**	**Relative (%)**	**Absolute (tons x 10^3)**	**Relative (%)**
Arizona	0.21	1%	0.21	1%	0.06	1%
California	8.05	30%	7.00	33%	2.87	31%
Colorado	0.01	0%	0.01	0%	0.00	0%
Idaho	5.60	21%	5.60	27%	2.42	26%
Montana	0.03	0%	0.03	0%	0.01	0%
Nevada	0.00	0%	0.00	0%	0.00	0%
New Mexico	0.04	0%	0.04	0%	0.01	0%
North Dakota	2.23	8%	2.23	11%	0.56	6%
Oregon	6.78	25%	2.58	12%	1.05	11%
South Dakota	0.56	2%	0.56	3%	0.14	1%
Utah	0.21	1%	0.21	1%	0.06	1%
Washington	2.91	11%	2.35	11%	2.16	23%
Wyoming	0.19	1%	0.19	1%	0.05	1%
	26.83	**100%**	**21.02**	**100%**	**9.40**	**100%**

Figure 6.1.4.2. Summary of $PM_{2.5}$ emissions from agricultural burning by state and smoke management scenario.



6.2. Tracking fire emissions using the WRAP EDMS

For fire emissions, §309 specifically calls for a statewide inventory and emissions tracking system (spatial and temporal) of VOC, NO_X, EC, OC, and $PM_{2.5}$ emissions from all fire sources. Existing emissions inventories prepared by the Fire Emissions Joint Forum described in this TSD satisfy that requirement, and also inventory SO_2, PM_{10}, CO, and NH_3 emissions. Under §309, states and tribes must identify a method, or a timeline to develop a method, to track fire activity data and calculate the resulting required emissions inventory, in their SIP or TIP. Tracking of fire activity data and calculation of the resulting emissions through the EDMS will provide information critical to the successful implementation of other requirements under §309, including the development, adoption, and implementation of enhanced smoke management programs, the establishment of annual emission goals, and future projections of fire emissions. In order to support the development of an annual emissions goal, the FEJF will provide methods to calculate the benefits of emissions reduction techniques.

The EDMS will track activity data as reported by states and tribes participating in §309, as well as the same type of data provided by other WRAP region state, tribal, and local air agencies, and federal/state/private sources using prescribed and/or agricultural burning techniques. The EDMS will calculate the resulting emissions for fire source types including prescribed fire, wildfire, and agricultural burning. Open burning activities on residential, commercial, or industrial properties are not included in the fire source category, and will be inventoried as area sources by the EDMS. The WRAP Fire Tracking System policy identifies seven essential components of a fire tracking system that represent the minimum spatial and temporal fire activity information necessary to consistently calculate emissions and to uniformly assess impacts on regional haze. These are:

- date of burn
- burn location
- area of burn
- fuel type
- pre-burn fuel loading
- type of burn, and
- anthropogenic or natural classification.

Specifications for calculating emissions from the reported fire activity data will be provided to the Emissions Forum, for use in the EDMS, at a future date by the Fire Emissions Joint Forum. This will allow county/state and tribal reservation tracking of fire emissions, and the expected emissions reductions from the application of emissions reduction techniques.

The EDMS will have the capability to produce a special report in tabular and simple plots (i.e. bar graph and pie chart) formats and to allow queries of the same information including presentation in GIS format. The EDMS to be developed is described in a draft technical report to the Emissions Forum: Needs Assessment for Evaluation and Design of an Emissions Data

Reporting, Management, and Tracking System, (EA Engineering, Science, and Technology, June 26, 2003).

Chapter 7 – Assessment of Road Dust

7.1. Emissions inventories for re-entrained road dust from paved and unpaved roads

Paved and unpaved road dust emissions in the WRAP states were estimated using the methods described in Chapter 1. In brief, paved road dust emissions were estimated using the standard EPA approach, while unpaved road dust emissions were estimated using revised silt contents, revised activity data, and transport fractions. Paved and unpaved road dust PM_{10} and $PM_{2.5}$ emissions by state for 1996 and 2018 are provided in the following tables. Paved road dust emissions increase by about three percent per year from 1996 to 2018, per the increase in vehicle miles traveled. The increase varies by state, with the largest projected growth in vehicle travel in Washington, Idaho, and Utah. Unpaved road dust emissions are projected to decrease between 1996 and 2018, by about 0.75% per year, because of reductions in unpaved road mileage over time as more roads are paved. As a result, unpaved road dust emissions are about 80% of road dust PM_{10} emissions in 1996, and about 65% of road dust PM_{10} emissions in 2018. Overall, road dust PM_{10} emissions increase by about 6% from 1996 to 2018.

Table 7.1.1. 1996 WRAP States Fugitive Road Dust Emissions (TPY)

State	Paved Road Dust		Unpaved Road Dust		Total Road Dust	
	PM_{10}	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
Arizona *	7,318	1,830	18,605	2,791	25,923	4,620
California *	35,643	8,911	86,474	14,090	122,117	23,001
Colorado *	7,897	1,974	30,601	4,590	38,498	6,564
Idaho *	3,502	876	28,304	4,246	31,806	5,121
Montana	2,909	727	15,796	2,369	18,705	3,097
Nevada *	2,528	632	9,460	1,449	11,988	2,081
New Mexico *	5,395	1,349	27,972	4,196	33,367	5,545
North Dakota	2,461	615	34,419	5,163	36,880	5,778
Oregon *	8,067	2,017	19,078	2,862	27,144	4,878
South Dakota	2,296	574	46,199	6,930	48,495	7,504
Utah *	3,680	920	16,040	2,406	19,721	3,326
Washington	7,804	1,951	34,365	5,155	42,169	7,106
Wyoming *	1,823	456	3,449	517	5,271	973
13 states total	91,322	22,831	370,762	56,763	462,084	79,594
* 9 GCVTC States	75,853	18,963	239,983	37,146	315,835	56,109

Table 7.1.2. 2018 WRAP States Fugitive Road Dust Emissions (TPY)

State	Paved Road Dust		Unpaved Road Dust		Total Road Dust	
	PM_{10}	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**	**PM_{10}**	**$PM_{2.5}$**
Arizona *	12,618	3,154	12,976	1,945	25,594	5,099
California *	59,794	14,950	56,447	9,198	116,242	24,148
Colorado *	13,771	3,442	36,956	5,544	50,728	8,986
Idaho *	7,548	1,887	17,976	2,697	25,524	4,584
Montana	4,796	1,201	17,907	2,686	22,703	3,887
Nevada *	5,019	1,256	7,198	1,102	12,217	2,358
New Mexico *	10,198	2,551	32,730	4,909	42,928	7,461

North Dakota	3,723	931	34,255	5,139	37,978	6,070
Oregon *	14,684	3,672	12,158	1,825	26,842	5,497
South Dakota	3,723	931	50,239	7,537	53,962	8,468
Utah *	7,541	1,883	20,487	3,073	28,028	4,957
Washington	18,681	4,668	22,991	3,449	41,672	8,118
Wyoming *	3,019	756	3,719	558	6,738	1,314
13 states total	165,115	41,282	326,040	49,666	491,155	90,947
* 9 GCVTC States	134,192	33,551	200,648	30,853	334,840	64,404

7.2. Road Dust significance analysis for the Colorado Plateau 16 Class I areas

§309 requires the following for Road Dust: *"Area sources of dust emissions from paved and unpaved roads. The plan must include an assessment of the impact of dust emissions from paved and unpaved roads on visibility conditions in the 16 Class I Areas. If such dust emissions are determined to be a significant contributor to visibility impairment in the 16 Class I areas, the State must implement emissions management strategies to address the impact as necessary and appropriate."* As described above, road dust emissions inventories were developed, and the significance of road dust was then tested using the regional air quality model at the Regional Modeling Center, for review by the Air Quality Modeling Forum, and other WRAP Forums and Committees. The modeling results are presented next:

Table 7.2.1. Road Dust Significance Modeling Results

Colorado Plateau Class I Areas	**2018 Base Case (Mm^{-1})**	**2018 No Road Dust (Mm^{-1})**	**EPA *DRAFT default* Natural Conditions Worst 20% Days (Mm^{-1})**	**Bext change No Road Dust (Mm^{-1})**	**Bext change No Road Dust (%)**	**dv Change No Road Dust (dv)**
Arches NP	25.91	25.63	20.12	0.29	1.42	0.14
Black Canyon of Gunnison NP	32.84	32.20	20.26	0.63	3.13	0.31
Bryce Canyon NP	24.24	23.99	20.12	0.25	1.24	0.12
Canyonlands NP	23.89	23.71	20.08	0.18	0.89	0.09
Capitol Reef NP	25.56	25.30	20.18	0.26	1.29	0.13
Flat Tops Wilderness	28.55	28.37	20.28	0.19	0.92	0.09
Grand Canyon NP	27.78	27.53	20.08	0.25	1.22	0.12
Maroon Bells-Snowmass Wilderness	31.78	31.46	20.30	0.32	1.57	0.16
Mesa Verde NP	34.47	34.21	20.18	0.26	1.30	0.13
Mount Baldy Wilderness	41.63	41.26	20.04	0.37	1.87	0.19
Petrified Forest NP	32.46	32.22	20.08	0.24	1.20	0.12
San Pedro Parks Wilderness	28.90	28.65	20.18	0.24	1.21	0.12
Sycamore Canyon Wilderness	35.34	34.95	20.34	0.39	1.92	0.19
West Elk Wilderness	31.15	30.85	20.26	0.30	1.47	0.15
Weminuche Wilderness	29.93	29.77	20.20	0.16	0.80	0.08
Zion NP	25.57	24.95	20.06	0.61	3.05	0.30

In the regional model, the road dust inventory was set to zero for the entire modeling domain, other 2018 base case emissions were included as normal, and the resulting modeled effect of road dust emissions were calculated in terms of the impact on visibility at each of the 16 Colorado Plateau Class I areas, on the predicted worst 20% days. The modeled regional impact of road dust emissions ranged from 0.31 deciviews (3.1% of EPA *DRAFT default* natural conditions to be reached by 2064) at the Black Canyon of the Gunnison National Park to 0.08 deciviews (0.8% of EPA *DRAFT default* natural conditions to be reached by 2064) at the Weminuche Wilderness. While EPA *draft default* natural conditions were used for the purposes of this regional significance analysis, the EPA natural conditions estimates are still in draft form, and do not represent the same levels that WRAP would necessarily use in future analyses. The modeling data were presented and discussed by the Modeling and Mobile Sources Forums, the Oversight Committees, and the Board of Directors, and all agreed that the regional impact of road dust emissions were not significant at the 16 Colorado Plateau Class I areas at this time.

The Board directed the Technical Forums to continue to track and evaluate road dust emissions, as dust aerosols have been shown to be an important contributor to visibility impairment, using IMPROVE aerosol filter data, at many WRAP region Class I areas. The finding of no significance is a rigorous test, as no windblown dust emissions are included in the model, as discussed earlier, so the modeled difference between having road dust in, and road dust out of the model is not masked by a large mass of other dust emissions. The regional model has a grid cell size of $36km^2$, so the impacts of intra-grid cell road dust emissions are not as well characterized. The Air Quality Modeling Forum will be developing a finer grid(s) to better address the localized versus regional impacts road dust and other emissions categories, and other WRAP Forums will review representative natural conditions estimates for individual Class I areas, both for use in the §308 modeling and analysis.

7.3. Tracking road dust emissions using the WRAP EDMS

For road dust, the §309 SIP and TIP submissions must provide for statewide inventories of paved and unpaved road dust; these have been prepared for the years 1996 and 2018, and are described in this TSD.

The EDMS will have the capability to produce the following special report in tabular and simple plots (i.e. bar graph and pie chart) formats and to allow queries of the same information including presentation in GIS format, in addition to the standard reports. The special report would include a comparison of annual WRAP region total emissions of paved and unpaved road dust emissions by state, tribal reservation, as well as the entire region, and the corresponding previous period’s total emissions.

The EDMS to be developed is described in a draft technical report to the Emissions Forum: Needs Assessment for Evaluation and Design of an Emissions Data Reporting, Management, and Tracking System, (EA Engineering, Science, and Technology, June 26, 2003).

Chapter 8 – Assessment of Pollution Prevention

Two key recommendations from the Grand Canyon Visibility Transport Commission (GCVTC) focused on the development of renewable energy sources and promotion of energy conservation. Labeled the 10/20 goals, the recommendation on development of renewable energy sources encouraged states and tribes in the Transport Region to take steps that would increase the use of renewable energy to 10% of the regional power needs by 2005 and 20% of the regional power needs by 2015. For energy conservation, the GCVTC supported the continued development of energy efficiency standards and suggested that the emphasis on energy conservation be maintained within the changing electric power markets. In addition to the 10/20 goals and energy conservation recommendations, the GCVTC suggested that future modeling work be conducted to analyze the potential emission reductions, cost savings, and secondary benefits associated with the use of renewable energy, energy efficiency, and pollution prevention.

The WRAP Air Pollution Prevention Forum has been charged with implementing the air pollution prevention recommendations of the GCVTC. The Air Pollution Prevention Forum commissioned the ICF Consulting Group to analyze the potential emission reductions, costs, and secondary regional economic impacts of meeting the 10/20 goals and energy efficiency recommendations (ICF, 2002). The analysis of this case incorporates the results of the ICF analysis for the Air Pollution Prevention Forum in a scenario that includes 2018 milestone case emission estimates for non-utility point sources.

The estimated SO_2 and NO_x emissions by utility unit for existing facilities, and by State for new sources, were provided by the ICF Consulting Group. The percentage changes in SO_2 and NO_x emissions by unit were applied to the 2018 Milestone Case emissions to estimate air pollution prevention case emissions for this analysis. The ICF model also provided estimated SO_2 and NO_x reductions for new sources. These new source emission reductions were applied to the utility units in each State in proportion to 2018 milestone case emissions. Because of the regional SO_2 trading program, the regional SO_2 emissions total is the same in the air pollution prevention case as it was for the milestone case. There is some shifting of SO_2 emissions among units and States, though. Regional NO_x emissions decline by about 14,000 tons (air pollution prevention case versus milestone case). A State-level summary of utility emission changes by State from the 2018 milestone case is provided below. The tribal new source changes were allocated to Arizona. States not listed had no emissions change.

	Air Pollution Prevention Case Emissions Change	
State	**NO_x tpy**	**SO_2 tpy**
Arizona	-3,267	5,558
Colorado	-1,370	-1,119
Nevada	-430	-307
New Mexico	-7,053	-5,135
Utah	-780	-595
Wyoming	-1,374	1,598
Regional Changes	**-14,274**	**0**

Table 8.1 presents the air pollution prevention case results for utility sources in the GCVTC transport region States. In the air pollution prevention case, GCVTC transport region point source SO_2 emissions are 510,000 tons.

Table 8.1. 2018 Air Pollution Prevention Case Scenario – Utility Point Source Emissions (GCVTC transport region States)

					2018 Emissions (tpy)						
MTF	**Ftype**	**FIPSST**	**State Code**	**State**	**VOC**	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
1	Utility	04	AZ	Arizona	700	91,331	7,205	67,085	3,434	1,659	8
		08	CO	Colorado	602	80,785	7,122	46,918	1,624	1,006	6
		32	NV	Nevada	369	43,825	3,073	19,294	5,607	2,506	3
		35	NM	New Mexico	783	84,762	7,077	65,756	9,161	2,707	4
		41	OR	Oregon	51	10,094	424	3,935	257	177	0
		49	UT	Utah	430	75,229	5,317	23,763	2,561	1,135	3
		56	WY	Wyoming	1,238	102,439	11,346	69,383	11,100	6,612	0
		Totals			**4,173**	**488,465**	**41,564**	**296,134**	**33,744**	**15,802**	**24**

The 22-State region utility criteria pollutant emission summaries for the air pollution prevention case are presented next.

Table 8.2. 2018 Air Pollution Prevention Case Scenario – Utility Emissions by State (22 -State Region)

					2018 Emissions (tpy)						
MTF	**Ftype**	**FIPSST**	**State Code**	**State**	**VOC**	**NO_x**	**CO**	**SO_2**	**PM_{10}**	**$PM_{2.5}$**	**NH_3**
1	Utility	04	AZ	Arizona	700	91,331	7,205	67,085	3,434	1,659	8
1	Utility	05	AR	Arkansas	918	50,964	7,248	71,496	1,654	1,140	98
1	Utility	08	CO	Colorado	602	80,785	7,122	46,918	1,624	1,006	6
1	Utility	19	IA	Iowa	943	76,811	8,537	107,006	3,141	1,803	18
1	Utility	20	KS	Kansas	1,192	91,664	9,207	81,153	2,166	1,370	65
1	Utility	22	LA	Louisiana	1,973	75,803	17,077	75,680	3,116	1,933	925
1	Utility	27	MN	Minnesota	1,007	84,056	7,833	61,025	4,172	2,024	21
1	Utility	29	MO	Missouri	2,053	113,515	13,678	261,759	3,061	2,014	26
1	Utility	30	MT	Montana	405	26,030	3,382	12,862	4,136	2,062	5
1	Utility	31	NE	Nebraska	514	46,631	4,070	45,946	1,014	703	8
1	Utility	32	NV	Nevada	369	43,825	3,073	19,294	5,607	2,506	3
1	Utility	35	NM	New Mexico	783	84,762	7,077	65,756	9,161	2,707	4
1	Utility	38	ND	North Dakota	1,357	108,558	15,808	132,836	3,604	2,095	15
1	Utility	40	OK	Oklahoma	1,614	88,543	15,797	79,824	2,389	1,682	314
1	Utility	41	OR	Oregon	51	10,094	424	3,935	257	177	0
1	Utility	46	SD	South Dakota	130	17,542	615	11,102	55	40	1
1	Utility	48	TX	Texas	11,173	219,850	127,621	471,544	23,362	17,182	2,583
1	Utility	49	UT	Utah	430	75,229	5,317	23,763	2,561	1,135	3
1	Utility	53	WA	Washington	257	19,152	2,133	8,721	2,955	2,033	0
1	Utility	56	WY	Wyoming	1,238	102,439	11,346	69,383	11,100	6,612	0
		Totals			**27,708**	**1,507,582**	**274,569**	**1,717,088**	**88,569**	**51,884**	**4,105**

Table 8.3 shows the electricity generating units in the GCVTC Transport Region with predicted SO_2 and NO_x emission changes in the air pollution prevention case.

Table 8.3. Air Pollution Prevention Case Electricity Generating Unit Emissions

					Percentage Change*		**Milestone Case 2018**		**Pollution Prevention Case 2018**		**Difference**	
State	**County**	**Unit ID**	**ORISID**	**Plant**	**NOx**	**SO_2**	**NOx**	**SO_2**	**NOx**	**SO_2**	**NOx**	**SO_2**
AZ	Navajo	1	113	APS Cholla	-40.52%	-40.51%	2,066	1,050	1,229	625	-837	-425
AZ	Navajo	3	113	APS Cholla	0	344.45	4,081	2,292	4,081	10,189	0	7,896
CO	Montrose	1	527	Nucla	0	-2.36	1,038	1,530	1,038	1,494	0	-36
NM	San Juan	1	2451	San Juan Generating	-36.25	-36.25	6,926	7,170	4,415	4,571	-2,511	-2,599
NM	San Juan	3	2451	San Juan Generating	-40.48	-25.07	9,911	8,459	5,899	6,338	-4,012	-2,121
WY	Sweetwater	BW72	8066	Pacificorp-Jim Bridger	-0.04	55.42	10,171	4,838	10,167	7,519	-4	2,681
							34,193	**25,338**	**26,829**	**30,734**	**-7,364**	**5,396**

*Compared with the 2018 Milestone Case.

These model-estimated changes occur at 6 units at 4 plants in 4 States (Arizona, Colorado, New Mexico, and Wyoming). Expected SO_2 emission increases occur at Cholla #2 and Pacific Corp-Jim Bridger. These emission increases are offset by decreases in SO_2 emissions at Cholla #1, 2 San Juan Generating Station units, and at Nucla. NO_x emissions in the air pollution prevention case are always lower than or equal to those in the milestone case. The largest NO_x emission reductions in the pollution prevention case occur in New Mexico at San Juan Generating Station.

Appendix A: Methods Used to Incorporate State and Local control programs in WRAP Emission Inventories

The purpose of this appendix is to provide a list of state and local emission control programs and assumptions included in the emissions inventories prepared by WRAP contractors for §309. Documentation about the details and assumptions for each emissions inventory are contained in the individual contractors' reports, listed as references in Appendix C of this document. Federal control programs and actions are published in the Federal Register, and are incorporated into EPA emissions models in most cases, and are not listed in this appendix.

A.1. Area Sources

This information is from Chapter IV "Existing Source State Regulation Analyses, Western Regional Air Partnership Emission Forecasts For 2018 - Final Report", E.H. Pechan & Associates, Inc., December 2002, Pechan Rpt. No. 02.12.003/9409.000.

This chapter describes analyses of State and Local regulations affecting criteria pollutant emissions between 1996 and 2018. Results of these analyses are organized by pollutant: PM_{10}, followed by NO_x regulations, followed by SO_2. These analyses were performed in order to update the IAS model control factors so that they would reflect the expected pollution reduction effects of State and local regulations.

PM_{10}

Many PM_{10} nonattainment areas are located in the Western United States. Federal, State, and local air pollution regulations and other initiatives likely to affect point and area PM_{10} sources were analyzed. The focus was on PM_{10} sources in nonattainment areas and the control measures that areas are implementing to bring their areas into attainment. It is not expected that attainment areas would implement post-1996 control measures for PM_{10} and that any pre-1996 regulation effects would already be incorporated in their 1996 emission estimates.

Using EPA's web site *Classifications of PM-10 Nonattainment Areas*, a group of twelve nonattainment areas were selected for analyses (EPA, 2001b). The selected areas included all of the listed serious classification nonattainment areas – Clark County, NV; Coachella Valley, CA; Los Angeles/South Coast Air Basin, CA; Owens Valley, CA; Phoenix, AZ; and San Joaquin Valley, CA . The selected areas also included a sampling of moderate classification nonattainment areas in the WRAP States. For the moderate classification areas, selection was also based on availability of the needed information. The selected moderate classification nonattainment areas included Aspen, CO; Anthony, NM; Klamath Falls, OR; Salt Lake County, UT; Spokane County, WA; and Sheridan, WY.

Area-specific PM_{10} control plans and information were collected and compiled from EPA Regional Offices, and State and local agencies for each of the selected nonattainment areas. Often the information was available via the Internet and the agency was able to provide the web site address. Agency staff were also interviewed to gain insight into an area 's particular nonattainment situation and learn about novel or unique control measures. EPA's web site *Federal Register Notices Related to PM-10 Designations and Classifications* was used to identify recent actions related to the selected nonattainment areas (EPA, 2001c).

Pechan reviewed the gathered documents and prepared a series of tables to summarize the control measure information for each nonattainment area. This information is summarized in Tables IV-3 through IV-9. Each table presents adopted measures for a different source category. Source categories include construction, residential wood combustion, vacant land/unpaved lots, open burning, agricultural tilling, salting/sanding of paved roads, and miscellaneous sources. For use in this analysis, the information about PM_{10} control measures by PM_{10} nonattainment area was translated into a set of PM_{10} control efficiencies by area that were applied as PM_{10} control factors in the 2018 emissions forecast. Each table identifies the nonattainment area and names the types of measures that the area uses to control emissions of PM_{10}. The assumed degree of control of road dust emissions in each PM_{10} nonattainment area is described in the mobile sources emissions inventory report (ENVIRON, 2003). For road dust emissions, PM control measures were applied to fugitive dust emissions from paved and unpaved roads in all PM_{10} nonattainment areas, with the control factors reflecting a higher control level in serious PM_{10} nonattainment areas than was applied in moderate PM_{10} nonattainment areas.

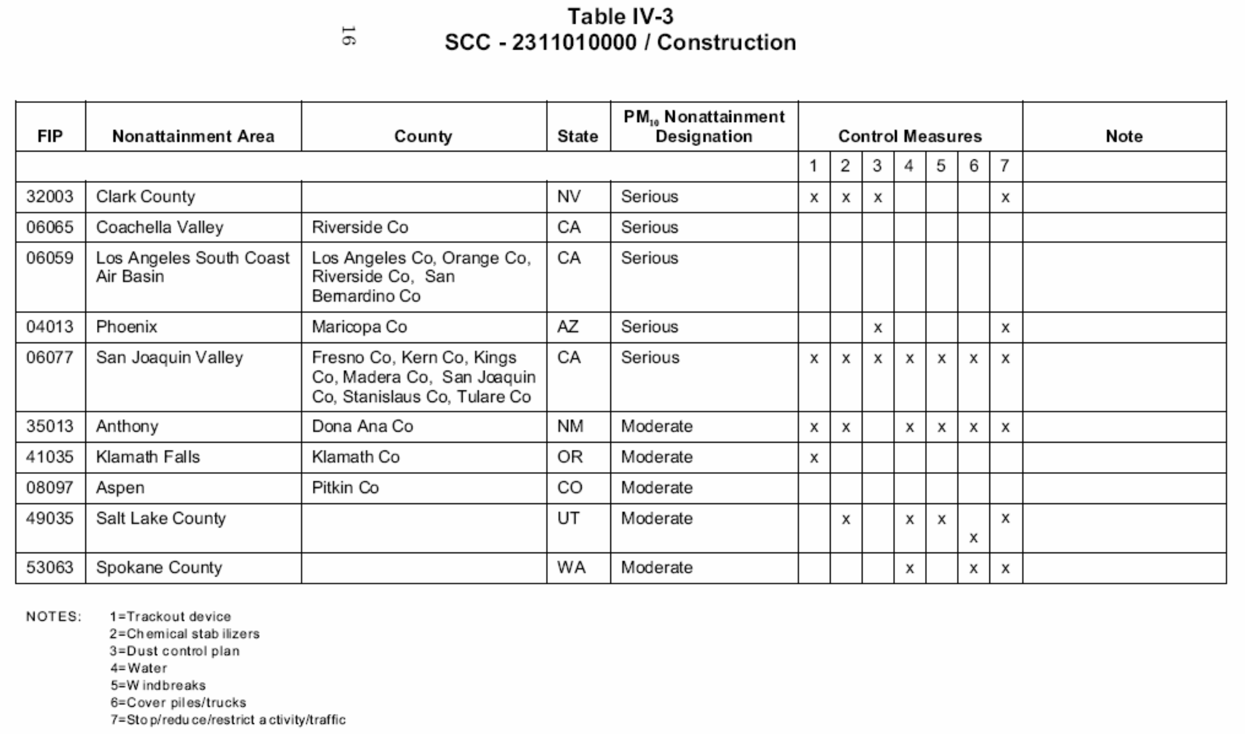


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Table IV-3
SCC - 2311010000 / Construction

FIP	Nonattainment Area	County	State	PM_{10} Nonattainment Designation	Control Measures							Note
					1	2	3	4	5	6	7	
32003	Clark County		NV	Serious	x	x	x				x	
06065	Coachella Valley	Riverside Co	CA	Serious								
06059	Los Angeles South Coast Air Basin	Los Angeles Co, Orange Co, Riverside Co, San Bernardino Co	CA	Serious								
04013	Phoenix	Maricopa Co	AZ	Serious			x				x	
06077	San Joaquin Valley	Fresno Co, Kern Co, Kings Co, Madera Co, San Joaquin Co, Stanislaus Co, Tulare Co	CA	Serious	x	x	x	x	x	x	x	
35013	Anthony	Dona Ana Co	NM	Moderate	x	x		x	x	x	x	
41035	Klamath Falls	Klamath Co	OR	Moderate	x							
08097	Aspen	Pitkin Co	CO	Moderate								
49035	Salt Lake County		UT	Moderate		x		x	x	x	x	
53063	Spokane County		WA	Moderate				x		x	x	

NOTES:
1=Trackout device
2=Chemical stabilizers
3=Dust control plan
4=Water
5=Windbreaks
6=Cover piles/trucks
7=Stop/reduce/restrict activity/traffic

Table IV-4
SCC - 2104008000 / Residential Wood Combustion

FIP	Nonattainment Area	County	State	PM_{10} Nonattainment Designation	Control Measures					Note
					1	2	3	4	5	
04013	Phoenix	Maricopa Co	AZ	Serious	x	x	x			
06077	San Joaquin Valley	Fresno Co, Kern Co, Kings Co, Madera Co, San Joaquin Co, Stanislaus Co, Tulare Co	CA	Serious	x	x	x	x	x	
41035	Klamath Falls	Klamath Co	OR	Moderate			x	x		Woodstove owners must register their stoves. Program to replace woodstoves in place.
08097	Aspen	Pitkin Co	CO	Moderate		x			x	
49035	Salt Lake County		UT	Moderate			x	x		Solid fuel burning devices must be registered. Ban resale of uncertified previously used solid fuel burning devices.
53063	Spokane County		WA	Moderate			x			

NOTES:
1=Ban the sale/installation of uncertified stoves
2=Switch to natural gas
3=No-burn periods
4=Citizen education
5=Limit number of woodburning devices

Table IV-5
Vacant Land, Unpaved Lots

FIP	Nonattainment Area	County	State	PM_{10} Nonattainment Designation	Control Measures							Note
					1	2	3	4	5	6	7	
32003	Clark County		NV	Serious			x	x		x		
06027	Owens Valley	Inyo Co	CA	Serious	x	x					x	Source: Owens dry lake bed, control with shallow flooding
06077	San Joaquin Valley	Fresno Co, Kern Co, Kings Co, Madera Co, San Joaquin Co, Stanislaus Co, Tulare Co	CA	Serious	x	x		x	x	x	x	
35013	Anthony	Dona Ana Co	NM	Moderate	x	x		x	x	x		

NOTES:
1=Re-vegetate/mulch
2=Pave/gravel
3=Prohibit unpaved lots
4=Windbreaks
5=Chemical suppressants
6=Limit use and surface disruption
7=Water

Table IV-6
SCC - 261000000 / Open Burning

FIP	Nonattainment Area	County	State	PM_{10} Nonattainment Designation	Control Measures				Note
					1	2	3	4	
06077	San Joaquin Valley	Fresno Co, Kern Co, Kings Co, Madera Co, San Joaquin Co, Stanislaus Co, Tulare Co	CA	Serious	x	x	x	x	Additional controls - Edu. Program; reduce acres burned, fuel loading, and fuel consumption
41035	Klamath Falls	Klamath Co	OR	Moderate		x			Residential open burning- 2610030000
53063	Spokane County		WA	Moderate	x				

NOTES:
1=Alternatives to burning (use as fuel, removal, chipping, till into soil)
2=Burn ban on no-burn days
3=Require permits
4=Smoke management plan

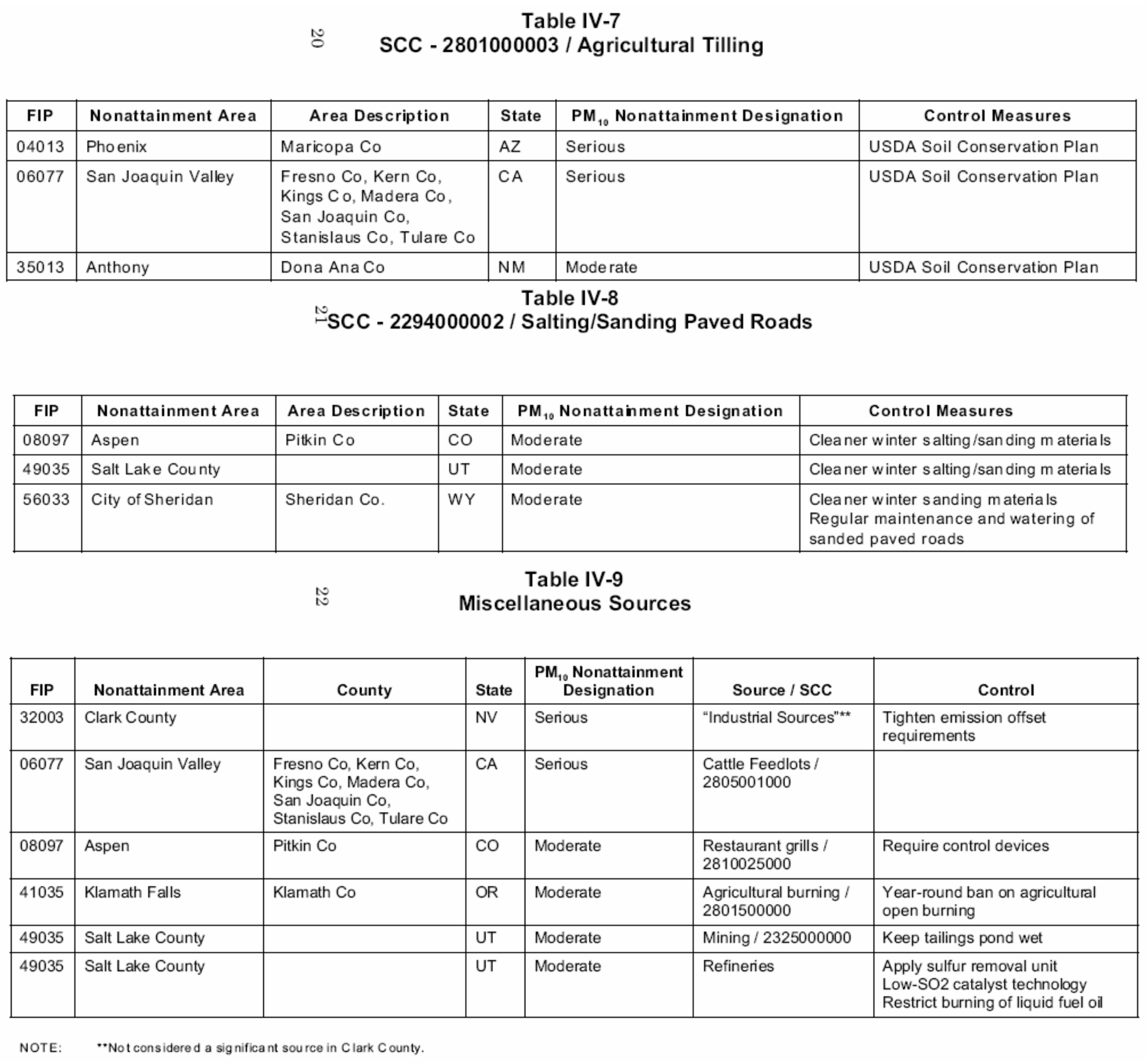


Table IV-7[20]
SCC - 2801000003 / Agricultural Tilling

FIP	Nonattainment Area	Area Description	State	PM_{10} Nonattainment Designation	Control Measures
04013	Phoenix	Maricopa Co	AZ	Serious	USDA Soil Conservation Plan
06077	San Joaquin Valley	Fresno Co, Kern Co, Kings Co, Madera Co, San Joaquin Co, Stanislaus Co, Tulare Co	CA	Serious	USDA Soil Conservation Plan
35013	Anthony	Dona Ana Co	NM	Moderate	USDA Soil Conservation Plan

Table IV-8[21]
SCC - 2294000002 / Salting/Sanding Paved Roads

FIP	Nonattainment Area	Area Description	State	PM_{10} Nonattainment Designation	Control Measures
08097	Aspen	Pitkin Co	CO	Moderate	Cleaner winter salting/sanding materials
49035	Salt Lake County		UT	Moderate	Cleaner winter salting/sanding materials
56033	City of Sheridan	Sheridan Co.	WY	Moderate	Cleaner winter sanding materials Regular maintenance and watering of sanded paved roads

Table IV-9[22]
Miscellaneous Sources

FIP	Nonattainment Area	County	State	PM_{10} Nonattainment Designation	Source / SCC	Control
32003	Clark County		NV	Serious	"Industrial Sources"**	Tighten emission offset requirements
06077	San Joaquin Valley	Fresno Co, Kern Co, Kings Co, Madera Co, San Joaquin Co, Stanislaus Co, Tulare Co	CA	Serious	Cattle Feedlots / 2805001000	
08097	Aspen	Pitkin Co	CO	Moderate	Restaurant grills / 2810025000	Require control devices
41035	Klamath Falls	Klamath Co	OR	Moderate	Agricultural burning / 2801500000	Year-round ban on agricultural open burning
49035	Salt Lake County		UT	Moderate	Mining / 2325000000	Keep tailings pond wet
49035	Salt Lake County		UT	Moderate	Refineries	Apply sulfur removal unit Low-SO2 catalyst technology Restrict burning of liquid fuel oil

NOTE: **Not considered a significant source in Clark County.

Table IV-10 lists the control factors that were applied to the 2018 PM_{10} emissions in the listed PM_{10} nonattainment areas in the Western States. Some of the source categories that are included in the prior tables in this chapter are not included in the control factor file because their PM_{10} emissions are not accounted for in the point and area source inventories.

Table IV-10
Area Source Control File for PM

State ID	County ID	PM_{10} Nonattainment Area	SCC	Control Factors for 2018	
				PM_{10}	$PM_{2.5}$
Construction					
32	003	Clark	2311010000	75	37.5
06	059	LA	2311010000	75	37.5
04	013	Phoenix	2311010000	37.5	18.75
06	077	SJV	2311010000	75	37.5
35	013	Anthony	2311010000	75	37.5
41	035	Klamath	2311010000		
08	097	Aspen	2311010000		
49	035	Salt Lake	2311010000	75	37.5
53	063	Spokane	2311010000		
Agricultural Tilling					
04	013	Phoenix	2801000003	20	20
06	077	SJV	2801000003	20	20
53	063	Spokane	2801000003	20	20

The control efficiencies and rule penetration values shown below are based on control measure evaluations performed by Pechan for EPA's regulatory analysis of the PM National Ambient Air Quality Standard. Control factor development is described by source category below:

Construction Activity - the numerous measures adopted to reduce fugitive dust PM emissions from construction activity were condensed in to two primary measures: a dust control plan and chemical stabilization. A typical dust control plan includes water treatment of disturbed soil and vacuum street sweeping of nearby paved areas. Control efficiency and rule penetration values are as follows:

	PM_{10}		$PM_{2.5}$	
Measure	Control Efficiency	Rule Penetration	Control Efficiency	Rule Penetration
Dust control plan	50%	75%	25%	75%
Chemical stabilization	75%	75%	50%	75%

Agricultural Tilling - the typical measure in the PM_{10} nonattainment area plan s is soil conservation plans. A 20 percent control efficiency is applied to both PM_{10} and $PM_{2.5}$ emissions in areas that have these plans. This 20 percent control efficiency may be conservative for estimating emission reductions for areas like Maricopa County, Arizona where agricultural best management practices have been adopted.

A.2. Prescribed Forest/Range and Agricultural Fire Smoke Management Programs

The following information is from “Integrated Assessment Update and 2018 Emissions Inventory for Prescribed Fire, Wildfire, and Agricultural Burning”, Air Sciences Inc., originally published August 27, 2002, revisions in press, Project # 178-2.

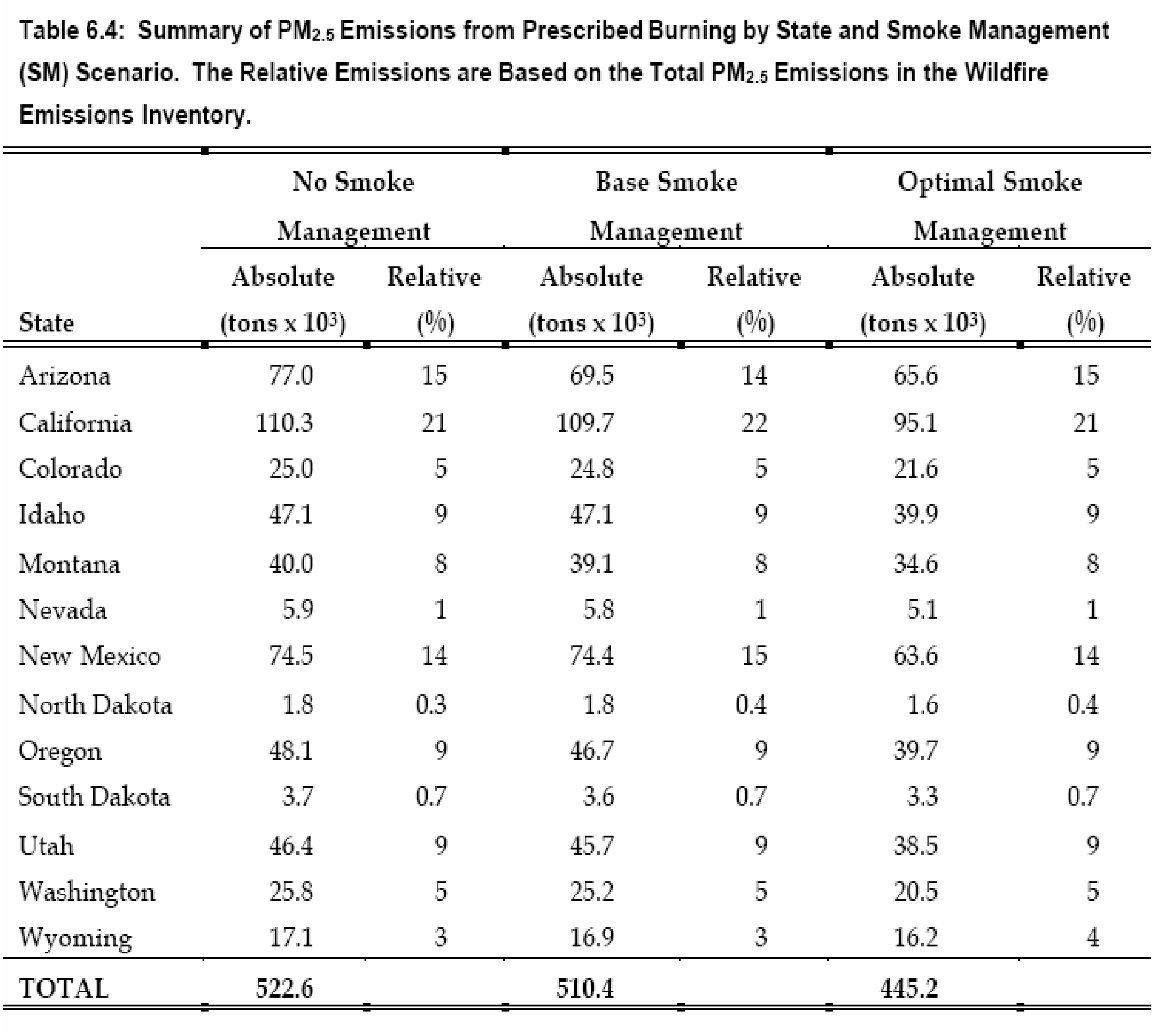


Table 6.4: Summary of $PM_{2.5}$ Emissions from Prescribed Burning by State and Smoke Management (SM) Scenario. The Relative Emissions are Based on the Total $PM_{2.5}$ Emissions in the Wildfire Emissions Inventory.

	No Smoke Management		Base Smoke Management		Optimal Smoke Management	
State	Absolute (tons x 10^3)	Relative (%)	Absolute (tons x 10^3)	Relative (%)	Absolute (tons x 10^3)	Relative (%)
Arizona	77.0	15	69.5	14	65.6	15
California	110.3	21	109.7	22	95.1	21
Colorado	25.0	5	24.8	5	21.6	5
Idaho	47.1	9	47.1	9	39.9	9
Montana	40.0	8	39.1	8	34.6	8
Nevada	5.9	1	5.8	1	5.1	1
New Mexico	74.5	14	74.4	15	63.6	14
North Dakota	1.8	0.3	1.8	0.4	1.6	0.4
Oregon	48.1	9	46.7	9	39.7	9
South Dakota	3.7	0.7	3.6	0.7	3.3	0.7
Utah	46.4	9	45.7	9	38.5	9
Washington	25.8	5	25.2	5	20.5	5
Wyoming	17.1	3	16.9	3	16.2	4
TOTAL	522.6		510.4		445.2	

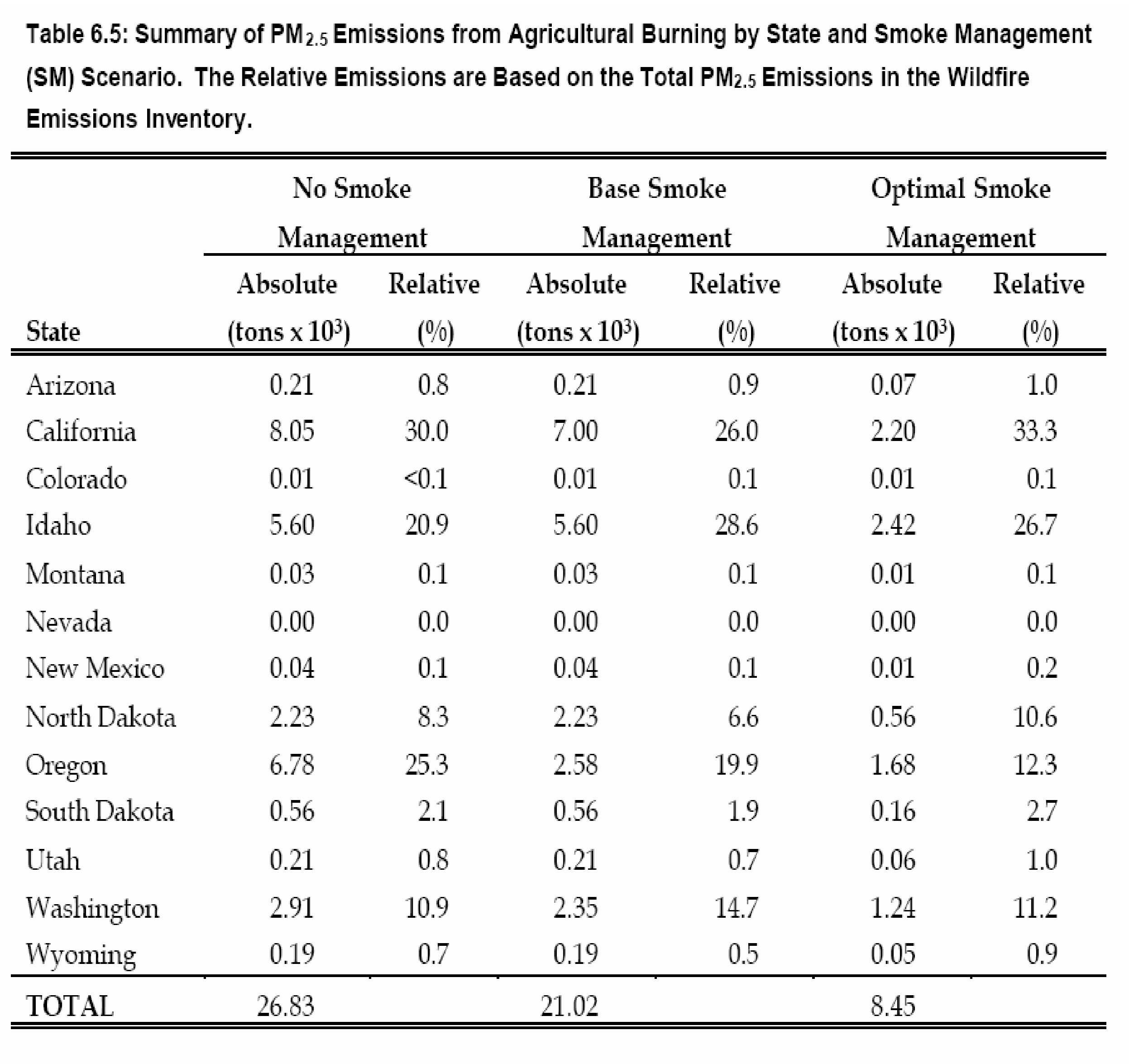


Table 6.5: Summary of $PM_{2.5}$ Emissions from Agricultural Burning by State and Smoke Management (SM) Scenario. The Relative Emissions are Based on the Total $PM_{2.5}$ Emissions in the Wildfire Emissions Inventory.

	No Smoke Management		Base Smoke Management		Optimal Smoke Management	
State	Absolute (tons x 10^3)	Relative (%)	Absolute (tons x 10^3)	Relative (%)	Absolute (tons x 10^3)	Relative (%)
Arizona	0.21	0.8	0.21	0.9	0.07	1.0
California	8.05	30.0	7.00	26.0	2.20	33.3
Colorado	0.01	<0.1	0.01	0.1	0.01	0.1
Idaho	5.60	20.9	5.60	28.6	2.42	26.7
Montana	0.03	0.1	0.03	0.1	0.01	0.1
Nevada	0.00	0.0	0.00	0.0	0.00	0.0
New Mexico	0.04	0.1	0.04	0.1	0.01	0.2
North Dakota	2.23	8.3	2.23	6.6	0.56	10.6
Oregon	6.78	25.3	2.58	19.9	1.68	12.3
South Dakota	0.56	2.1	0.56	1.9	0.16	2.7
Utah	0.21	0.8	0.21	0.7	0.06	1.0
Washington	2.91	10.9	2.35	14.7	1.24	11.2
Wyoming	0.19	0.7	0.19	0.5	0.05	0.9
TOTAL	26.83		21.02		8.45	

A.3. On-Road Mobile Sources

This information is from "Development Of WRAP Mobile Source Emission Inventories", Pollack, 2003, in press.

A.3.1. 1996 Control Programs

MOBILE6/PART5 inputs related to several on-road control programs were also included in the modeling. These control programs are area-specific (i.e., not applied nationally or regionwide), generally based on an area's ozone or CO nonattainment status. These programs include vehicle inspection and maintenance (I/M) programs, oxygenated fuel programs, and Stage II (at-the-pump) vehicle refueling controls. Note that reformulated gasoline is not included in this list because none of the WRAP states had implemented a reformulated gasoline program by 1996. The default control program parameters were those in the 1996 NET. These were updated by the state and local air agencies in some cases. As described in Section 2, federal control programs are included in MOBILE6 and no additional inputs are needed to model these programs.

A.3.2. Inspection and Maintenance (I/M) Programs

I/M program inputs are specific to each state or area implementing such a program. The default I/M program inputs were those from the 1996 NET, converted to MOBILE6 input format, along with the county coverage of these programs in the 1996 NET. Updated information on these programs was provided by Arizona, Colorado, Nevada, Oregon, Utah, and Washington. Table 3-2 lists the counties modeled with an I/M program in place.

Table 3-2. Counties modeled with an inspection and maintenance program in 1996.

State	County
AZ	Maricopa
AZ	Pima
CO	Adams
CO	Arapahoe
CO	Boulder
CO	Douglas
CO	Jefferson
CO	Denver
CO	El Paso
CO	Larimer
CO	Weld
ID	Ada
NM	Bernalillo
NV	Clark
NV	Washoe
OR	Clackamas
OR	Jackson
OR	Multnomah

OR	Washington
UT	Davis
UT	Salt Lake
UT	Weber
UT	Utah
WA	Clark
WA	King
WA	Snohomish
WA	Spokane
WA	Pierce

A.3.3. Oxygenated Fuel

For the WRAP modeling, the program in place in each of the mid-months of the seasons was used (i.e., the program in place in January for the November to February winter season). Table 3-3 lists the counties that were modeled with oxygenated fuels and the inputs used to model these programs. The information in this table includes updated information on these programs provided by the states.

Table 3-3. Oxygenated fuel inputs.

		January Oxygenated Fuel Inputs				**October Oxygenated Fuel Inputs**			
		Market Share (%)		**Oxygen Content (%)**		**Market Share (%)**		**Oxygen Content (%)**	
State	**County**	**Ether Blend**	**Alcohol Blend**	**Ether Blend**	**Alcohol Blend**	**Ether Blend**	**Alcohol Blend**	**Ether Blend**	**Alcohol Blend**
AZ	Maricopa	17	83	2.7	3.5	17	83	2.7	3.5
AZ	Pima *	17	83	2.7	3.5	17	83	2.7	3.5
CO	Adams	25	75	2.7	3.3				
CO	Arapahoe	25	75	2.7	3.3				
CO	Boulder	25	75	2.7	3.3				
CO	Denver	25	75	2.7	3.3				
CO	Douglas	25	75	2.7	3.3				
CO	El Paso	0	100	2.7	2.7	0	100	2.7	2.7
CO	Jefferson	25	75	2.7	3.3				
CO	Larimer	0	100	2.7	2.7	0	100	2.7	2.7
CO	Weld	25	75	2.7	3.3				
MT	Missoula	0	100	2.7	3.5	0	100	2.7	3.5
NV	Clark	24	76	2.7	3.5	24	76	2.7	3.5
NV	Washoe	95	5	2.7	3.5	95	5	2.7	3.5
NM	Bernalillo	15	85	2.7	3.5	15	85	2.7	3.5
OR	Clackamas	0	100	0	3.5	0	100	0	3.5
OR	Jackson	0	100	0	3.5	0	100	0	3.5
OR	Josephine	0	100	0	3.5	0	100	0	3.5
OR	Klamath	0	100	0	3.5	0	100	0	3.5

		January Oxygenated Fuel Inputs				October Oxygenated Fuel Inputs			
		Market Share (%)		Oxygen Content (%)		Market Share (%)		Oxygen Content (%)	
State	**County**	**Ether Blend**	**Alcohol Blend**	**Ether Blend**	**Alcohol Blend**	**Ether Blend**	**Alcohol Blend**	**Ether Blend**	**Alcohol Blend**
OR	Multnomah	0	100	0	3.5	0	100	0	3.5
OR	Washington	0	100	0	3.5	0	100	0	3.5
OR	Yamhill	0	100	0	3.5	0	100	0	3.5
UT	Utah	0	100	0	3.5	0	100	0	3.5
WA	Clark	0	100	0	2.7				
WA	King	0	100	0	2.7				
WA	Pierce	0	100	0	2.7				
WA	Snohomish	0	100	0	2.7				
WA	Spokane	0	100	0	3.2	0	100	0	3.5

* - Pima County inputs were provided by ADEQ. Actual Pima County winter oxygenate is 1.8% rather than 3.5%.

A.3.4. Stage II Refueling Controls

Stage II controls were applied in the following counties: Maricopa County, AZ; Clark and Washoe Counties, NV; Multnomah County, OR; and Clark, King, and Pierce Counties, WA. The Oregon and Washington counties were modeled with a 95 percent Stage II control efficiency for light-duty gasoline vehicles and trucks and an 80 percent Stage II control efficiency for heavy-duty gasoline vehicles. Maricopa County, Clark County (NV), and Washoe County were modeled with a 50 percent control efficiency, 95 percent control efficiency, and 85 percent control efficiency, respectively, applied to both light and heavy vehicles.

A.3.5. Processing of California Data

California has different on-road mobile source control programs from the rest of the country. CARB has its own model that estimates the effects of these control programs. CARB provided 1996 on-road emissions estimates from EMFAC2000 model runs by vehicle class, county, and season, with all applicable controls incorporated.

A.3.6. Future Control Programs for 2003, 2008, 2013, and 2018

The effects of Federal on-road control programs are included in the MOBILE6 and modified PART5 models. The Federal control programs that started in or after 1996 that are treated as defaults in the MOBILE6/PART5 modeling are: National Low Emission Vehicle (NLEV) emission standards starting with the 2001 model year; Tier 2 emission standards starting with the 2004 model year; two phases of new heavy duty vehicle emission standards—one starting in the 2004 model year and the other starting in the 2007 model year; onboard diagnostics; and the Supplemental Federal Test Procedure (SFTP) rule. As discussed above, the low sulfur gasoline fuel corresponding with the Tier 2 emission standards and the low sulfur diesel fuel corresponding with the heavy-duty vehicle 2007 emission standards were also modeled throughout the WRAP region. Also modeled as part of the default conditions in MOBILE6 are estimates of excess NO_x emissions resulting from the use of defeat devices in heavy-duty diesel vehicles as well as the provisions to offset these excess emissions through early pull-ahead of the 2004 heavy-duty diesel emission standards and through low emission rebuilds of existing engines. All of these control programs were modeled using the MOBILE6 defaults and the modified PART5 model defaults, with no additional user input.

In addition to the national on-road control programs, several area-specific control programs were included in the MOBILE6 modeling for the projection years. These include I/M and ATP programs, oxygenated fuel programs, and Stage II refueling control programs. These were modeled as follows:

- I/M and ATP Programs – County coverage of the I/M and ATP programs did not change from the 1996 base year modeling to the projection years. The counties with I/M and/or ATP programs are listed in Table 3-2 (above). The States of Colorado, Oregon, Utah, and Washington provided updates to the I/M or ATP program inputs for the projection years. For the remaining States with I/M or ATP programs modeled in the 1996 base year modeling (Arizona, Idaho, New Mexico, and Nevada), the same I/M and ATP program inputs were modeled in the projection years. It should be noted, however, that these programs did already include projection years in the inputs, with OBD testing starting with the 1996 model year. In both the base year modeling and the projection year modeling, the I/M programs in Washington were only applied to a fraction of the VMT in each of the five counties with an I/M program. These fractions that the I/M emission factors apply to were provided by Washington, and emission factors without I/M programs applied were modeled for the remainder of the VMT in each of these counties.

- Oxygenated Fuel Programs – Table 3-3 (above) lists the counties that were modeled with oxygenated fuel in the 1996 base year, as well as the corresponding inputs used to model the oxygenated fuel program in each county with MOBILE6. Several changes were made to these base year oxygenated fuel inputs for the projection years. For Utah County, Utah, the oxygen content of the oxygenated fuel was changed from 3.5 percent to 2.7 percent. For the counties with oxygenated fuel in Oregon, the oxygenated fuel program was eliminated from the 2008, 2013, and 2018 projection years. In Clark, King, Pierce, and Snohomish Counties, Washington, the oxygenated fuel program was discontinued after 1996, so no oxygenated fuel was modeled for these counties in any of the projection years.

- Stage II Refueling Controls – In the 1996 base year modeling, Stage II controls were applied in the following counties: Maricopa County, AZ; Clark and Washoe Counties, NV; Multnomah County, OR; and Clark, King, and Pierce Counties, WA. The only changes made for the projection year modeling were to add Stage II controls in Clackamas County and Washington Counties, in Oregon. The MOBILE6 inputs for modeling Stage II controls applied to these two counties were the same as those applied to Multnomah County in the 1996 base year modeling - a 95 percent Stage II control efficiency for light-duty gasoline vehicles and trucks and an 80 percent Stage II control efficiency for heavy-duty gasoline vehicles.

A.3.7. Processing of Future California Data

For California, CARB provided on-road emissions estimates from EMFAC2000 model runs for all four future years by vehicle class, county, and season with all applicable control programs incorporated.

A.4. Non-Road Mobile Sources

For non-road sources, 1996 emissions estimates are directly controlled by fuel input, as control technologies were not required for these sources. 1996 state-level off-road fuel sulfur averages are shown below; there are some differences by counties within states and the county-specific sulfur contents were used in developing the 1996 emissions estimates. The fuel sulfur inputs were adjusted to reflect federal rules for gasoline and highway diesel fuels that become effective between 1997 and 2018. No additional control technologies were assumed for 2018.

1996 State Averages

	Gasoline Sulfur (ppm)	Highway Diesel Sulfur (ppm)	Off-Highway Diesel Sulfur (ppm)
Arizona	213	338	2005
California	23	135	135
Colorado	195	335	4100
Idaho	285	380	3075
Montana	375	320	4100
Nevada	91	310	3400
New Mexico	303	310	4100
North Dakota	266	312	4175
Oregon	293	299	3400
South Dakota	238	320	4186
Utah	186	366	3955
Washington	281	301	3400
Wyoming	285	380	4100

California has somewhat different off-road mobile source control programs from the rest of the country, and CARB has its own internal model that estimates the effects of these control programs. CARB provided 1996 off-road emissions estimates from their OFFROAD model by equipment type, county, and season, with all applicable controls incorporated.

A.5. Stationary Sources - Existing Source State Regulation Analyses

This information is from Chapter IV "Existing Source State Regulation Analyses, Western Regional Air Partnership Emission Forecasts For 2018 - Final Report", E.H. Pechan & Associates, Inc., December 2002, Pechan Rpt. No. 02.12.003/9409.000.

A.5.1. NO_x

The analysis of NO_x emission regulations primarily examined ozone nonattainment areas. These are limited to California and Maricopa County (Phoenix), Arizona.

Arizona

Portions of Maricopa County are (were) nonattainment for both ozone and PM_{10}. The primary ozone control measure adopted in Maricopa County was a 15 percent rate VOC emission reduction requirement of the CAA. This emission reduction has no direct impact on SO_2, NO_x and PM_{10} emissions. There are a limited number of NO_x control requirements.

California

In California, the thirty-five (35) air pollution control districts have jurisdiction in imposing emission limits on point sources. The following sections present the district NO_x emission limits for turbines, boilers, internal combustion engines, and petroleum refineries. The fuel combustion sources (boilers, internal combustion engines, and turbines) are of particular interest in this study because they are the largest stationary source NO_x emitters in California.

The impact of these regulatory requirements was estimated as follows. Uncontrolled emission rates were estimated u sing EPA AP-42 uncontrolled emission factors, which are primarily listed in units of pounds per million British thermal units (lbs/MMBtu). EPA guidance was followed to convert these EPA emission factors into parts per million (ppm). This was done for comparison to the California district rules and Maricopa County rules that regulate emissions from these emission units in ppm. This method was used to estimate the likely level of control required by the California Air Pollution Control District (CAPCD) regulations and Maricopa County, Arizona rules. The CAPCD point source regulations also apply to existing units, except as noted. Several CAPCD regulations impose different NO_x limits for units larger than 10 megawatts (MW) depending on whether they have an SCR control device. Since it is not clear whether units in those districts with two sets of rules have installed SCR, to be conservative, the less restrictive emission limit is imposed (assuming no SCR).

Gas Turbines

The first row of Table IV-11 lists the NO_x emission factors for uncontrolled turbine units. They are provided for comparison with emission limits permitted from gas turbines as found by CAPCD. In some cases, CAPCDs impose different NO_x emission limits on units with identical

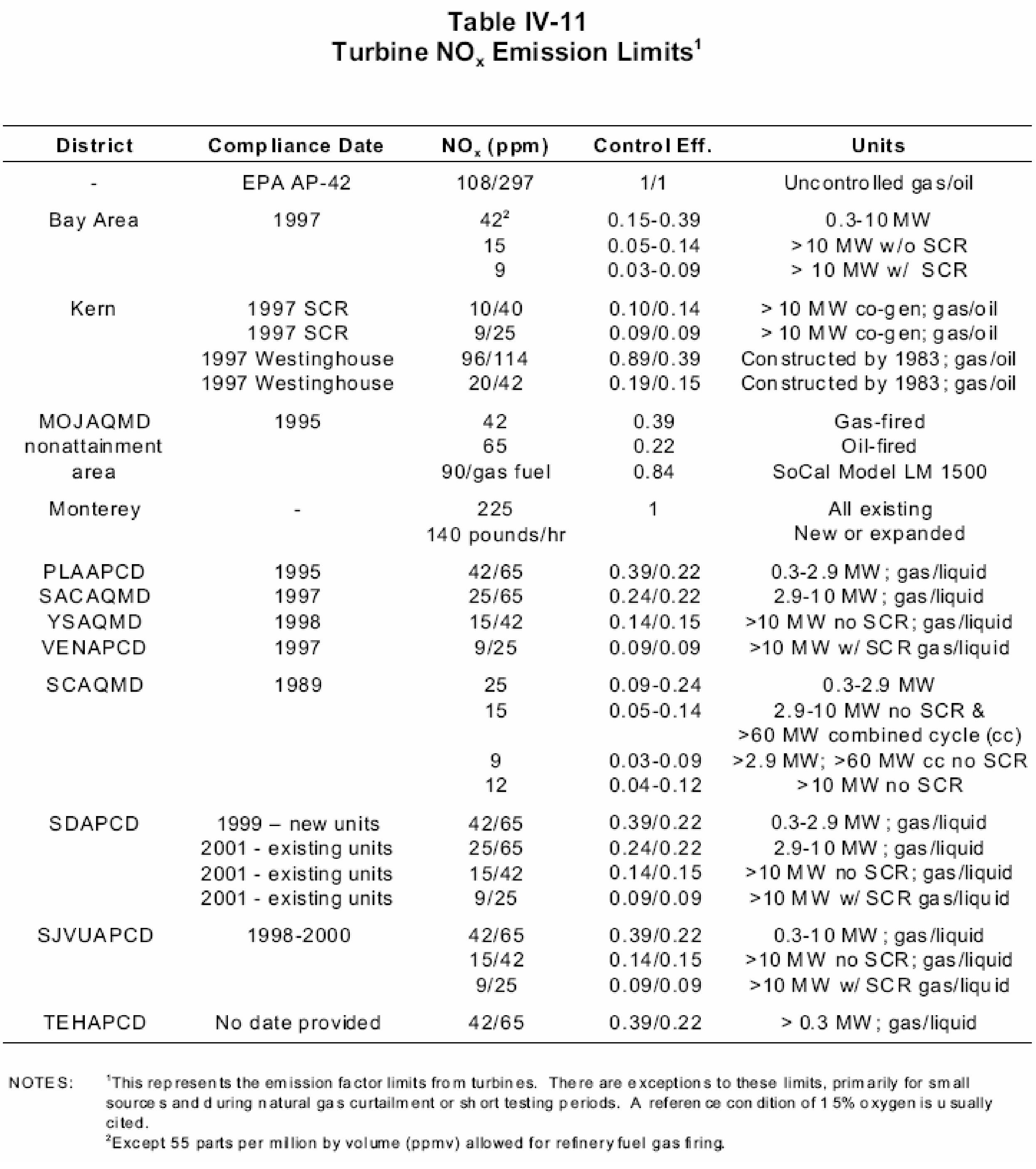


Table IV-11
Turbine NO_x Emission Limits[1]

District	Compliance Date	NO_x (ppm)	Control Eff.	Units
-	EPA AP-42	108/297	1/1	Uncontrolled gas/oil
Bay Area	1997	42[2]	0.15-0.39	0.3-10 MW
		15	0.05-0.14	>10 MW w/o SCR
		9	0.03-0.09	> 10 MW w/ SCR
Kern	1997 SCR	10/40	0.10/0.14	> 10 MW co-gen; gas/oil
	1997 SCR	9/25	0.09/0.09	> 10 MW co-gen; gas/oil
	1997 Westinghouse	96/114	0.89/0.39	Constructed by 1983; gas/oil
	1997 Westinghouse	20/42	0.19/0.15	Constructed by 1983; gas/oil
MOJAQMD nonattainment area	1995	42	0.39	Gas-fired
		65	0.22	Oil-fired
		90/gas fuel	0.84	SoCal Model LM 1500
Monterey	-	225	1	All existing
		140 pounds/hr		New or expanded
PLAAPCD	1995	42/65	0.39/0.22	0.3-2.9 MW; gas/liquid
SACAQMD	1997	25/65	0.24/0.22	2.9-10 MW; gas/liquid
YSAQMD	1998	15/42	0.14/0.15	>10 MW no SCR; gas/liquid
VENAPCD	1997	9/25	0.09/0.09	>10 MW w/ SCR gas/liquid
SCAQMD	1989	25	0.09-0.24	0.3-2.9 MW
		15	0.05-0.14	2.9-10 MW no SCR & >60 MW combined cycle (cc)
		9	0.03-0.09	>2.9 MW; >60 MW cc no SCR
		12	0.04-0.12	>10 MW no SCR
SDAPCD	1999 – new units	42/65	0.39/0.22	0.3-2.9 MW; gas/liquid
	2001 - existing units	25/65	0.24/0.22	2.9-10 MW; gas/liquid
	2001 - existing units	15/42	0.14/0.15	>10 MW no SCR; gas/liquid
	2001 - existing units	9/25	0.09/0.09	>10 MW w/ SCR gas/liquid
SJVUAPCD	1998-2000	42/65	0.39/0.22	0.3-10 MW; gas/liquid
		15/42	0.14/0.15	>10 MW no SCR; gas/liquid
		9/25	0.09/0.09	>10 MW w/ SCR gas/liquid
TEHAPCD	No date provided	42/65	0.39/0.22	> 0.3 MW; gas/liquid

NOTES: [1] This represents the emission factor limits from turbines. There are exceptions to these limits, primarily for small sources and during natural gas curtailment or short testing periods. A reference condition of 15% oxygen is usually cited.

[2] Except 55 parts per million by volume (ppmv) allowed for refinery fuel gas firing.

power ratings that differ only in whether they are equipped with SCR control technology. In all of these cases, those units without SCR control technology are allowed a higher NO_x emission limit. Since it is not clear whether most gas turbines are equipped with SCR or not, to be conservative the less restrictive emission limit assuming no SCR control is being used applies. With this information, the control effectiveness of the NO_x emission limits imposed in each CAPCD is identified. The control effectiveness is obtained by dividing the CAPCD imposed

NO_x emission limits by the corresponding and applicable EPA AP-42 uncontrolled emission factor. The CAPCD turbine regulations also apply to existing units, except as noted.

Industrial Boilers

The IAS separately tracks emissions from industrial coal (incobo), natural gas (inngbo), oil (inoibo), and wood (inwobo) boilers. Table IV-12 lists the EPA NO_x uncontrolled emission factors used for these boilers. Also listed in Table IV-12 are the NO_x emission factor limits imposed on these boilers as found for some CAPCDs. These CAPCD regulations also apply to steam generators and process heaters, except as noted. The control effectiveness of these regulations is obtained by dividing the CAPCD imposed NO_x emission limits by the corresponding and applicable EPA AP-42 uncontrolled emission factor.

Internal Combustion Engines

Table IV-13 lists the NO_x emission factors appearing in EPA AP-42 applicable to uncontrolled internal combustion units. Also listed in Table IV-13 are the emission limits imposed on these units within Maricopa County, Arizona and by CAPCD. With this information, one is able to identify the control effectiveness of the NO_x emission limits imposed within Maricopa County, Arizona and in each CAPCD. The control effectiveness is obtained by dividing the Maricopa County or CAPCD imposed NO_x emission limits by the corresponding and applicable EPA AP-42 uncontrolled emission factor. The CAPCD regulations also apply to existing units, except as noted.

As previously noted, the base case emission inventory for this study is 1996. Because some CAPCD regulations go into effect after 1996, it is expected that these post-1996 regulations will result in a corresponding emission reduction in those areas for these sources relative to 1996. This is captured by reporting the NO_x emission reduction expected in each region relative to 1996, where data are available to perform this task. We have also been able to identify the control effectiveness of the NO_x emission limits imposed in Maricopa County, Arizona and within each CAPCD. The control effectiveness is obtained by dividing the Maricopa County, Arizona and CAPCD imposed NO_x emission limits by the corresponding and applicable EPA AP-42 uncontrolled emission factor. The CAPCD regulations also apply to existing units, except as noted.

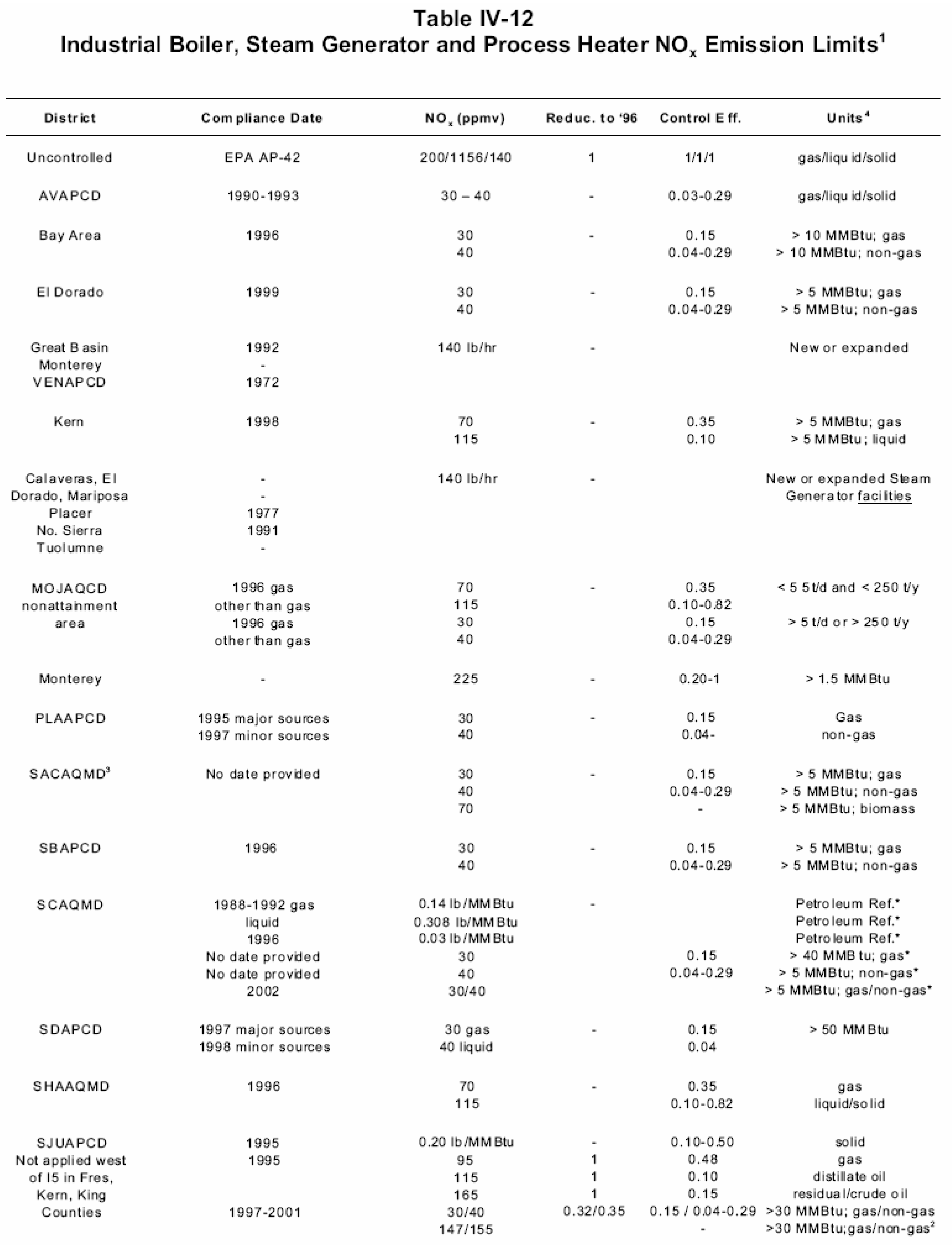


Table IV-12
Industrial Boiler, Steam Generator and Process Heater NO_x Emission Limits[1]

District	Compliance Date	NO_x (ppmv)	Reduc. to '96	Control Eff.	Units[4]
Uncontrolled	EPA AP-42	200/1156/140	1	1/1/1	gas/liquid/solid
AVAPCD	1990-1993	30 – 40	-	0.03-0.29	gas/liquid/solid
Bay Area	1996	30	-	0.15	> 10 MMBtu; gas
		40		0.04-0.29	> 10 MMBtu; non-gas
El Dorado	1999	30	-	0.15	> 5 MMBtu; gas
		40		0.04-0.29	> 5 MMBtu; non-gas
Great Basin	1992	140 lb/hr	-		New or expanded
Monterey	-				
VENAPCD	1972				
Kern	1998	70	-	0.35	> 5 MMBtu; gas
		115		0.10	> 5 MMBtu; liquid
Calaveras, El	-	140 lb/hr	-		New or expanded Steam Generator facilities
Dorado, Mariposa	-				
Placer	1977				
No. Sierra	1991				
Tuolumne	-				
MOJAQCD nonattainment area	1996 gas	70	-	0.35	< 5 5t/d and < 250 t/y
	other than gas	115		0.10-0.82	
	1996 gas	30		0.15	> 5 t/d or > 250 t/y
	other than gas	40		0.04-0.29	
Monterey	-	225	-	0.20-1	> 1.5 MMBtu
PLAAPCD	1995 major sources	30	-	0.15	Gas
	1997 minor sources	40		0.04-	non-gas
SACAQMD[3]	No date provided	30	-	0.15	> 5 MMBtu; gas
		40		0.04-0.29	> 5 MMBtu; non-gas
		70		-	> 5 MMBtu; biomass
SBAPCD	1996	30	-	0.15	> 5 MMBtu; gas
		40		0.04-0.29	> 5 MMBtu; non-gas
SCAQMD	1988-1992 gas	0.14 lb/MMBtu	-		Petroleum Ref.*
	liquid	0.308 lb/MMBtu			Petroleum Ref.*
	1996	0.03 lb/MMBtu			Petroleum Ref.*
	No date provided	30		0.15	> 40 MMBtu; gas*
	No date provided	40		0.04-0.29	> 5 MMBtu; non-gas*
	2002	30/40			> 5 MMBtu; gas/non-gas*
SDAPCD	1997 major sources	30 gas	-	0.15	> 50 MMBtu
	1998 minor sources	40 liquid		0.04	
SHAAQMD	1996	70	-	0.35	gas
		115		0.10-0.82	liquid/solid
SJUAPCD	1995	0.20 lb/MMBtu	-	0.10-0.50	solid
Not applied west of I5 in Fres, Kern, King Counties	1995	95	1	0.48	gas
		115	1	0.10	distillate oil
		165	1	0.15	residual/crude oil
	1997-2001	30/40	0.32/0.35	0.15 / 0.04-0.29	>30 MMBtu; gas/non-gas
		147/155		-	>30 MMBtu;gas/non-gas[2]

Table IV-12 (continued)

District	Compliance Date	NO_x (ppmv)	Reduc. to '96	Control Eff.	Units[4]
SLOAPCD	1993	140 lb/hr	-	-	All facility units
	1995-1997 (1995 new, 1997 existing)	30 or 0.036 lb/MMBtu		0.15	gas
		40 or 0.052 lb/MMBtu		0.04 / 0.29	liquid/solid
TEHAPCD	No date provided	70	-	0.35	gas
		115		0.10-0.82	liquid or solid
VCAPCD	1991-1992	40	-		> 5 MMBtu
	1994-1995	30			1-5 MMBtu
YSAQMD	1998	30	-	0.15	gas
		40		0.04-0.29	non-gas

NOTES:

[1] This represents the emission factor limits from boilers. There are exceptions to these uses, primarily for small and/or emergency uses. A reference condition of 3% oxygen is usually cited.

[2] Box or cabin units.

[3] Boilers only.

[4] MMBtu = MMBtu/hr.

*The Petroleum Ref. applicable section is for boilers and process heaters, the corresponding items for this district do not apply to Petroleum Ref. boilers and process heaters > 40 MMBtu and sulfur plant reaction boilers.

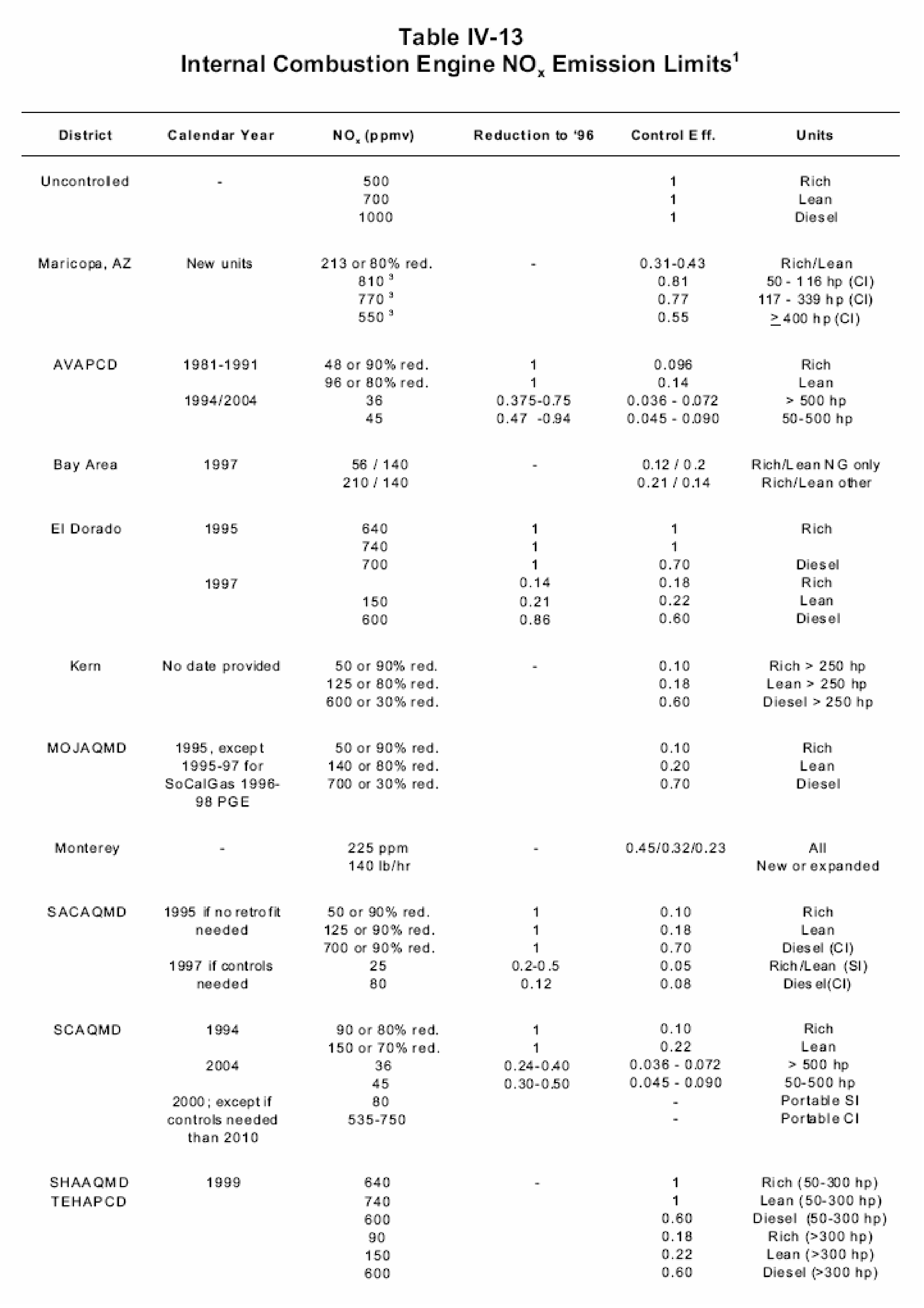


Table IV-13
Internal Combustion Engine NO_x Emission Limits[1]

District	Calendar Year	NO_x (ppmv)	Reduction to '96	Control Eff.	Units
Uncontroled	-	500		1	Rich
		700		1	Lean
		1000		1	Diesel
Maricopa, AZ	New units	213 or 80% red.	-	0.31-0.43	Rich/Lean
		810[3]		0.81	50 - 116 hp (CI)
		770[3]		0.77	117 - 339 hp (CI)
		550[3]		0.55	≥ 400 hp (CI)
AVAPCD	1981-1991	48 or 90% red.	1	0.096	Rich
		96 or 80% red.	1	0.14	Lean
	1994/2004	36	0.375-0.75	0.036 - 0.072	> 500 hp
		45	0.47 -0.94	0.045 - 0.090	50-500 hp
Bay Area	1997	56 / 140	-	0.12 / 0.2	Rich/Lean NG only
		210 / 140		0.21 / 0.14	Rich/Lean other
El Dorado	1995	640	1	1	Rich
		740	1	1	
		700	1	0.70	Diesel
	1997		0.14	0.18	Rich
		150	0.21	0.22	Lean
		600	0.86	0.60	Diesel
Kern	No date provided	50 or 90% red.	-	0.10	Rich > 250 hp
		125 or 80% red.		0.18	Lean > 250 hp
		600 or 30% red.		0.60	Diesel > 250 hp
MOJAQMD	1995, except 1995-97 for SoCalGas 1996-98 PGE	50 or 90% red.		0.10	Rich
		140 or 80% red.		0.20	Lean
		700 or 30% red.		0.70	Diesel
Monterey	-	225 ppm	-	0.45/0.32/0.23	All
		140 lb/hr			New or expanded
SACAQMD	1995 if no retrofit needed	50 or 90% red.	1	0.10	Rich
		125 or 90% red.	1	0.18	Lean
		700 or 90% red.	1	0.70	Diesel (CI)
	1997 if controls needed	25	0.2-0.5	0.05	Rich/Lean (SI)
		80	0.12	0.08	Diesel(CI)
SCAQMD	1994	90 or 80% red.	1	0.10	Rich
		150 or 70% red.	1	0.22	Lean
	2004	36	0.24-0.40	0.036 - 0.072	> 500 hp
		45	0.30-0.50	0.045 - 0.090	50-500 hp
	2000; except if controls needed than 2010	80		-	Portable SI
		535-750		-	Portable CI
SHAAQMD TEHAPCD	1999	640	-	1	Rich (50-300 hp)
		740		1	Lean (50-300 hp)
		600		0.60	Diesel (50-300 hp)
		90		0.18	Rich (>300 hp)
		150		0.22	Lean (>300 hp)
		600		0.60	Diesel (>300 hp)

Table IV-13 (continued)

District	Calendar Year	NO$_x$ (ppmv)	Reduction to '96	Control Eff.	Units
SJVUAPCD	1996	90 or 80% red.	1	0.10	Other Rich
		150 or 70% red.	1	0.22	Lean
		600 or 20% red.	1	0.60	Diesel
	1999/2001	50 or 90% red.[3]	0.56	0.10	Other Rich
		75 or 85% red.[3]	0.50	0.11	Lean
		80 or 90% red.[3]	0.14	0.08	Diesel
SLOAPCD	2000	50 or 90% red.	-	0.10	Rich
		125 or 80% red.		0.18	Lean
		600 or 30% red.		0.60	Diesel
VCAPCD	1994 or 2002	25 or 96% red.	-	0.05	Rich
		45 or 94% red.		0.07	Lean
		80 or 90% red.		0.08	Diesel
		50 or 96% red.		-	Rich-Waste Gas
		125 or 94% red.		-	Lean-Waste Gas
YSAQMD	1995	640 or 9.5 g/hphr	1	1	Rich
		740 or 10.1 g/hphr	1	1	Lean
		700 or 9.6 g/hrhr	1	0.70	Diesel
	1997	90/ 150/ 600	0.15/ 021/ 0.86	0.10/0.22/0.60	Rich/Lean/Diesel

NOTES: [1] Represents emission factor limits from internal combustion engines. Reductions (red.) are from uncontrolled levels. There are exceptions to these limits, primarily for small and/or emergency uses. A reference condition of 15% oxygen is usually cited.
[2] Not applicable to engines owned by public water districts.
[3] Alternatively, a unit with a turbocharger and aftercooler/intercooler or with 4-degree injection timing retard will satisfy Maricopa County, AZ regulations.

Industrial Reciprocating Engines, Including Natural Gas

Table IV-14 lists the NO$_x$ emission factors permitted from natural gas and other fuels used in reciprocating engines as reported by CAPCD. As shown below , only Santa Barbara County and San Diego County Air Pollution Control Districts apply specific NO$_x$ emission factor limits from these types of units.

Table IV-14
Industrial Reciprocating Engine NO$_x$ Emission Limits[1]

District	Compliance Date	NO$_x$ (ppmv)	Control Eff.	Units
Uncontrolled	-	500	1	Rich NG
		625	1	Lean NG
		1000	1	Diesel
Monterey	-	225	0.45/0.36/0.23	All
		140 lb/hr		New or expanded
SBCAPCD	1994	50 or 90% red.	0.10	Rich
		125 or 80% red.	0.20	Lean
		797	0.80	Diesel
SDAPCD	No date provided	50 rich or 90% red.	0.10	Rich NG
		125 lean or 80% red.	0.20	Lean NG
		700 diesel	0.30	Diesel
	2003	25 or 96% red.	0.05	Rich NG
		65 or 90% red.	0.10	Lean NG
		535 or 90% red.	0.535	Diesel

NOTES: [1] This represents the emission factor limits from reciprocating engines. The reference condition used is 15% oxygen content.

Industrial Petroleum Refineries

The California Bay Area District imposed regulations limiting NO_x emissions from boilers, steam generators, and process heaters in petroleum refineries. The limits imposed were 0.2 pounds per MMBtu in 1995 and 0.033 pounds per MM Btu in 1997. In other words, the Bay Area District decreased the allowable NO_x emission factor from petroleum refineries by 83.5 percent from 1995 to 1997 (see Table IV-15).

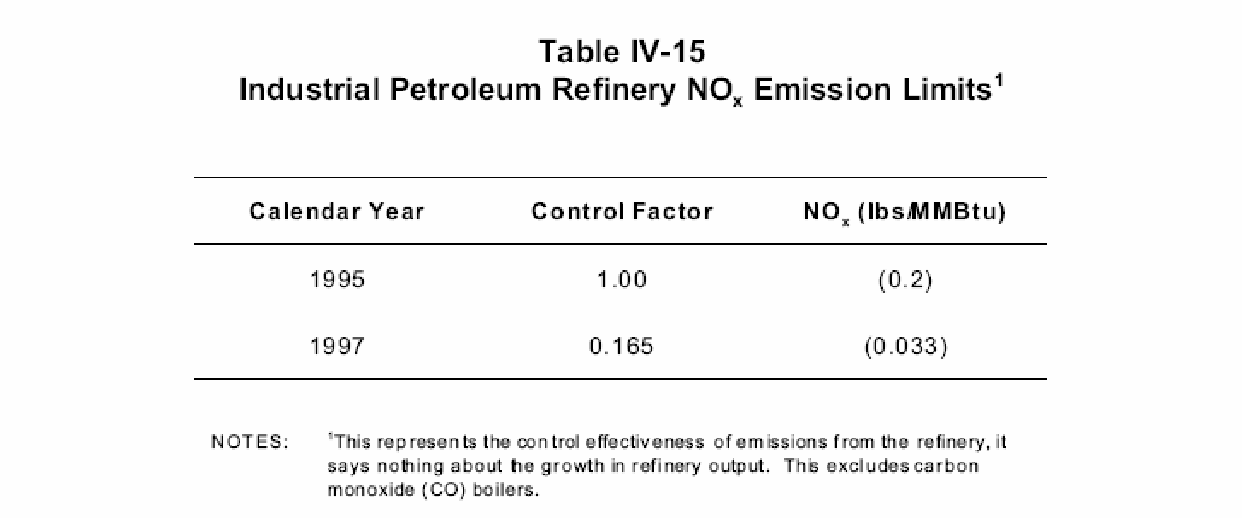


Table IV-15
Industrial Petroleum Refinery NO_x Emission Limits[1]

Calendar Year	Control Factor	NO_x (lbs/MMBtu)
1995	1.00	(0.2)
1997	0.165	(0.033)

NOTES: [1] This represents the control effectiveness of emissions from the refinery, it says nothing about the growth in refinery output. This excludes carbon monoxide (CO) boilers.

Oil and Gas Production Facilities

None of the documents checked on-line included any information about regulated NO_x or PM emissions. The documents related to oil and gas production had to do with leak detection and repair, which affects VOC emissions.

Missouri

Missouri is included in this analysis because its emissions are within the WRAP Region modeling domain. EPA's (1999b) Regional Transport NO_x State Implementation Plan (SIP) proposed to reduce NO_x emissions within many States east of the Rocky Mountains, including Missouri, in an effort to reduce transported ozone concentrations in eastern States. The primary focus for reducing NO_x emissions was from electric generating units (EGUs).

For EGU point sources, base year 1995/1996 NO_x emissions were used to develop an Integrated Planning Model (IPM) Year 2007 emission inventory. For Missouri, the IPM Year 2007 summer emission inventory for EGU point sources equaled 82,097 tons. The EPA 2007 NO_x control case was then developed by unit by applying IPM growth factors to the unit emission rate for the 1995/1996 base year. Emissions from EGUs greater than 25 MW equivalents were then limited to 0.15 lbs NOx/MMBtu. Units 25 MW equivalents or smaller were left at their 2007 base case NO_x emission rate. For Missouri, the resulting IPM NO_x control Year 2007 summer emission inventory for EGU point sources equaled 24,216 tons. Thus, the EPA analysis called for a 70 percent reduction in EGU 2007 NO_x emissions relative to the IPM base case Year 2007 Missouri inventory (see Table IV-16).

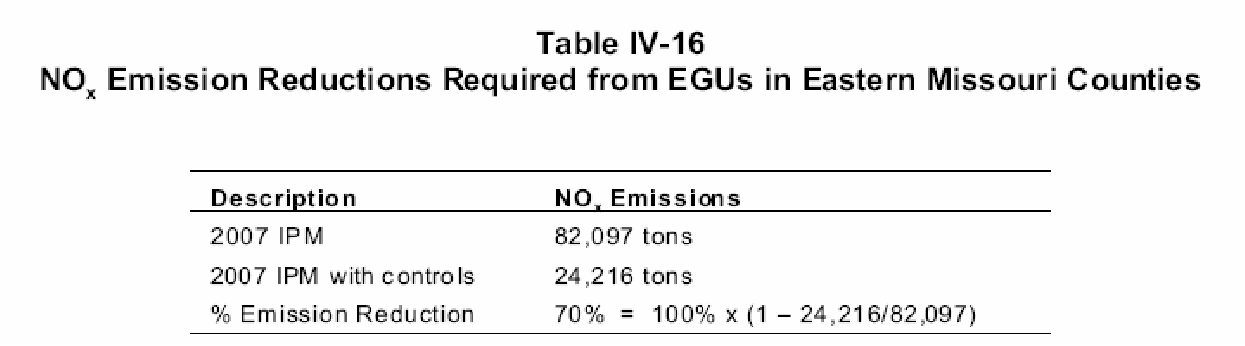


Table IV-16
NO_x Emission Reductions Required from EGUs in Eastern Missouri Counties

Description	NO_x Emissions
2007 IPM	82,097 tons
2007 IPM with controls	24,216 tons
% Emission Reduction	70% = 100% x (1 – 24,216/82,097)

Texas

Texas is included in this analysis because its emissions are within the WRAP Region modeling domain. Recent revisions to the SIPs for the major ozone nonattainment areas in Texas have added many regulations that require stationary source NO_x emitters to reduce their future year emissions.

The Texas SIPs developed by the Texas Natural Resource Conservation Commission (TNRCC) to reduce ozone concentrations in ambient air are very source-specific. There are three ozone nonattainment areas of note in Texas: (1) Beaumont/Port Arthur; (2) Houston/Galveston; and (3) Dallas/Fort Worth. The SIPs developed for these areas require a reduction in NO_x emissions from specific point sources or uniformly across a source category as described below. In addition, TNRCC entered into orders requiring Alcoa and Eastman Chemical to reduce NO_x and VOC emissions for the purpose of revising its SIP for ozone. The effect of these orders in terms of NO_x emission reductions is also included in this analysis. There is also a TNRCC SIP requirement that utility and grandfathered non-utility sources in Eastern and Central counties of Texas reduce emissions. The recommended implementation of this requirement is presented below.

Beaumont/Port Arthur

The Beaumont/Port Arthur ozone nonattainment area includes Hardin, Jefferson, and Orange counties. TNRCC (2000a) believes Tier 1 reductions in NO_x emissions from these three counties will be enough for Beaumont/Port Arthur to attain the 1-hour ozone standard.

The Tier 1 reductions amount to a 40.6 percent, 61.9 percent, and 36.5 percent reduction in NO_x emissions from point sources in Hardin, Jefferson, and Orange counties (see Table IV-17). TNRCC (2000) reports that these reductions are equivalent to requiring a 50 percent emission reduction from utility sources and a 20 percent emission reduction from four (4) refineries and fifteen (15) chemical plants. These NO_x reductions of 40.6 percent, 61.9 percent, and 36.5 percent from point sources in Hardin, Jefferson, and Orange counties were uniformly applied to all point sources in this ozone nonattainment area.

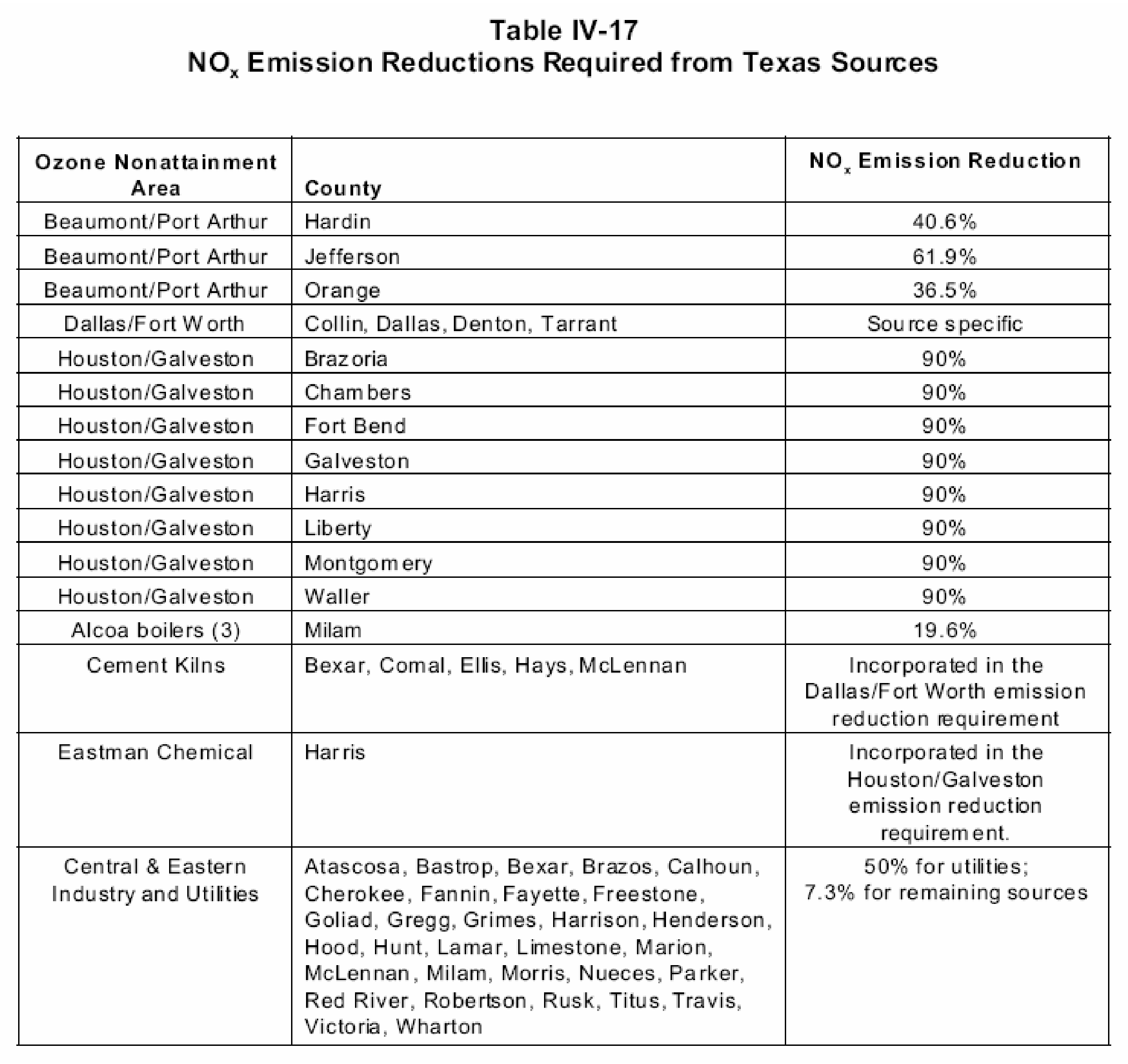


Table IV-17
NO_x Emission Reductions Required from Texas Sources

Ozone Nonattainment Area	County	NO_x Emission Reduction
Beaumont/Port Arthur	Hardin	40.6%
Beaumont/Port Arthur	Jefferson	61.9%
Beaumont/Port Arthur	Orange	36.5%
Dallas/Fort Worth	Collin, Dallas, Denton, Tarrant	Source specific
Houston/Galveston	Brazoria	90%
Houston/Galveston	Chambers	90%
Houston/Galveston	Fort Bend	90%
Houston/Galveston	Galveston	90%
Houston/Galveston	Harris	90%
Houston/Galveston	Liberty	90%
Houston/Galveston	Montgomery	90%
Houston/Galveston	Waller	90%
Alcoa boilers (3)	Milam	19.6%
Cement Kilns	Bexar, Comal, Ellis, Hays, McLennan	Incorporated in the Dallas/Fort Worth emission reduction requirement
Eastman Chemical	Harris	Incorporated in the Houston/Galveston emission reduction requirement.
Central & Eastern Industry and Utilities	Atascosa, Bastrop, Bexar, Brazos, Calhoun, Cherokee, Fannin, Fayette, Freestone, Goliad, Gregg, Grimes, Harrison, Henderson, Hood, Hunt, Lamar, Limestone, Marion, McLennan, Milam, Morris, Nueces, Parker, Red River, Robertson, Rusk, Titus, Travis, Victoria, Wharton	50% for utilities; 7.3% for remaining sources

Houston/Galveston

The Houston/Galveston ozone nonattainment area includes Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. For point sources, TNRCC compiled a 2007 future year NO_x emission inventory equal to 564 and 641 tpy (TNRCC, 2000b) for Phase II and Phase III base cases. TNRCC also compiled a 2007 future year control case NO_x inventory. This control case inventory contained 64 and 67 tpy (TNRCC, 2000b) of point source NO_x emissions, respectively, for Phase II and Phase III scenarios. The difference in the 2007 base case and control case amounts to a 90 percent reduction in NO_x emissions from point sources within Houston/Galveston ozone nonattainment area counties (see Table IV-17). (The 90 percent reduction is calculated from the Phase III scenario as follows: 90 percent = 100 percent x (1 – 67 t/ 641 t).) This 90 percent reduction was applied uniformly to all point sources in the Houston/Galveston area counties shown in Table IV-17.

Dallas/Fort Worth

Appendix F of the Dallas/Fort Worth ozone nonattainment demonstration (TNRCC, 1999a) identifies NO_x control factors proposed for specific industrial boilers and engines and EGUs in that area. These unit specific reductions were applied to estimate 2018 NO_x emissions.

Alcoa

Alcoa operates a plant in Milam County, Texas. A TNRCC order with Alcoa limits future maximum NO_x emissions from Alcoa's 3 boilers to 13,622.4 tpy. This equals a 19.6 percent NO_x emission reduction relative to the emission inventory for these three boilers in the WRAP database for 1996. These reductions were applied in the forecast year.

Cement Kilns

Appendix F of the Dallas/Fort Worth ozone nonattainment demonstration (TNRCC, 1999a) identifies 11 cement kilns modeled as part of the proposed Dallas/Fort Worth NO_x emission reduction strategy. The level of NO_x controls required by TNRCC ranged by unit from 6 to 66 percent. These controls were applied on a unit-by-unit basis as reported by TNRCC. However, one of the four Texas Industries (Ellis County) cement kilns identified by TNRCC as requiring control was not listed in the WRAP 1996 emission inventory. It is unclear whether the WRAP emission inventory missed counting emissions from a cement kiln, or whether there is a typo in the Dallas/Fort Worth ozone SIP strategy.

Eastman Chemical

Eastman Chemical operates a chemical plant in Harris County, Texas. Harris County is part of the Houston/Galveston ozone nonattainment area. A TNRCC order requires this Eastman Chemical plant to reduce NO_x emission s from 14 units by 1,671.5 tpy. Thirteen of the 14 units are to be retired. Because the retirement of these units would also reduce emissions of other pollutants, these specific units in the WRAP database for Eastman Chemical were retired. Because the unit specific codes in the WRAP database and the TNRCC unit identifiers for Eastman Chemical did not match, this required some judgment to determine which units in the WRAP database best matched those identified by TNRCC.

Industry and Utility Units in Central and Eastern Texas

As part of the Houston/Galveston area SIP, TNRCC (1999b) added the following NO_x emission reduction requirements applicable outside the Houston/Galveston area nonattainment counties and within Central and Eastern Texas:

- 50 percent reduction of NO_x emissions from all utility stationary sources, and
- 30 percent reduction of NO_x emissions from remaining grandfathered sources.

The 50 percent reduction was applied uniformly to all utility stationary sources in Central and Eastern Texas. The 30 percent NO_x reduction requirement from grandfathered sources is difficult to simulate, because the identity of the grandfathered sources was not provided by TNRCC. An analysis was made to determine how this information could be adapted and applied uniformly. The analysis made use of a NO_x emissions data file for grandfathered and nongrandfathered sources. The Alcoa boilers (3) mentioned above are thought to represent a part of the non-utility grandfathered sources in Central and Eastern counties of Texas. When the Alcoa boilers emission reduction requirement is removed, the 30 percent reduction required by TNRCC from grandfathered non-utility sources equates to a 7.3 percent emission reduction requirement from all non-utility sources in Central and Eastern Texas. The 7.3 percent reduction was applied uniformly to all non-utility point sources, except for Alcoa.

A.5.2. SO_2

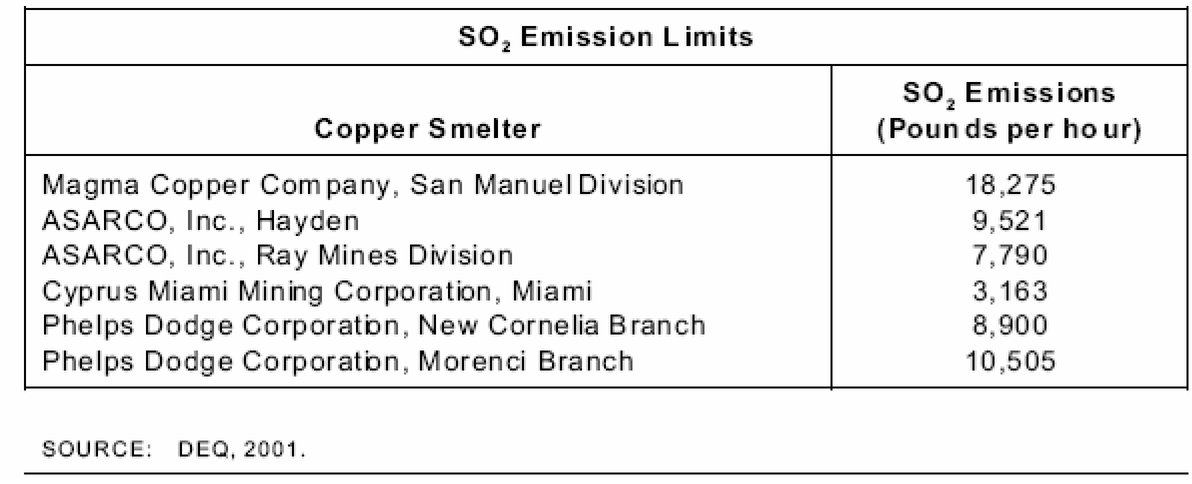
The analysis of existing source State regulations affecting SO_2 emissions in the WRAP States focused on identifying the regulations that were recent enough that existing sources would not have responded to them by 1996. It was also recognized that regulations affecting the largest point source SO_2 emitters would be most important to the forecast. This evaluation focuses on non-utility sources. Utility units are affected by the Federal Acid Rain Program, but as is explained in Chapter VII, future year utility SO_2 and NO_x emission estimates incorporate 2018 utility unit values that were prepared under a separate study. The tables in the following pages report the recent SO_2 emission regulations for the WRAP States that have SO_2 nonattainment areas, or regulations that affect the major sources in their States.

California

Table IV-18 lists the SO_2 emission factor limits found on-line as reported by CAPCD. The emission limits found cover a range of unit operations or in some cases cover all unit operations possible.

Arizona

Arizona air pollution control regulations restrict copper smelter SO_2 emissions by facility as shown below. Of the listed Arizona copper smelters, only ASARCO-Hayden and Phelps Dodge-Miami are currently operating.



SO$_2$ Emission Limits	
Copper Smelter	SO$_2$ Emissions (Pounds per hour)
Magma Copper Company, San Manuel Division	18,275
ASARCO, Inc., Hayden	9,521
ASARCO, Inc., Ray Mines Division	7,790
Cyprus Miami Mining Corporation, Miami	3,163
Phelps Dodge Corporation, New Cornelia Branch	8,900
Phelps Dodge Corporation, Morenci Branch	10,505

SOURCE: DEQ, 2001.

Table IV-18
Point Source SO_2 Emission Limits[1]
State of California

District	Unit Operation	SCC	Year	SO_2
Bay Area	Catalyst Manufacturing		1992	50 lb/hr
Bay Area	Coke calcining kiln		-	400 ppm & 250 lb/hr
AVAPCD			1983	80% red.
SCAQMD			-	
Bay Area	Fluid catalytic cracker		-	1,000 ppmv
SCAQMD			1987	132 lb/1000 barrels feed
Bay Area	Fresh fruit sulfuring		-	20-30 lb/ton of fruit
SDAPCD	Gas turbine		-	150 ppm @15% O_2
AVAPCD	Fuel Combustion	e.g., inxxboxx	1976	0.56 lb/MMBtu solid
Calaveras			-	200 lb/hr steam gener. facility
EDAPCD				
Mariposa				
No. Sierra				
Placer				
Tuolumne				
IMAPCD				500 ppm & 200 lb/hr
SDAPCD				0.8 lb/MMBtu liquid 1.2 lb/MMBtu solid
VENAPCD				300 ppm
Bay Area	Liquid fuel (except in the manufacture of sulfur compounds)		-	0.5% S
IMAPCD				0.5% S*
SCAQMD	Secondary Lead		1977	200 ppm & 2.1 kg/ton processed
Bay Area	Sulfur Recovery Plant/Units[2]	ptescxxx	-	250 ppm @ 0% O_2
SDAPCD				
AVAPCD MOJAQMD				500 ppm & 198 lb/hr
SCAQMD				
IMAPCD				
SLOAPCD				500 ppm & 200 lb/hr
	new or altered units			2000 ppm & 200 lb/hr
AVAPCD	Sulfuric Acid Plant	ptsapxxx	1981	500 ppm & 198 lb/hr
Bay Area			1992	300 ppm @ 15% O_2
IMAPCD			-	500 ppm & 198 lb/hr
MOJAQMD			1976	500 ppm & 198 lb/hr
SLOAPCD				2000 ppm & 200 lb/hr
Bay Area	All other operations not referenced herein	-		300 ppm
IMAPCD				2000 ppm
SLOAPCD				2000 ppm
VENAPCD				500 ppm
Butte	All Operations	-	-	2000 ppm
Colusa			-	
Feather River			1991	
Great Basin			1974	
Monterey			-	
SJUAPCD			1992	
Kern			1972	1000 ppm
Mendocino			-	
No. Sonoma			-	
No. Coast			-	

NOTES:

[1] This represents the emission factor limits.

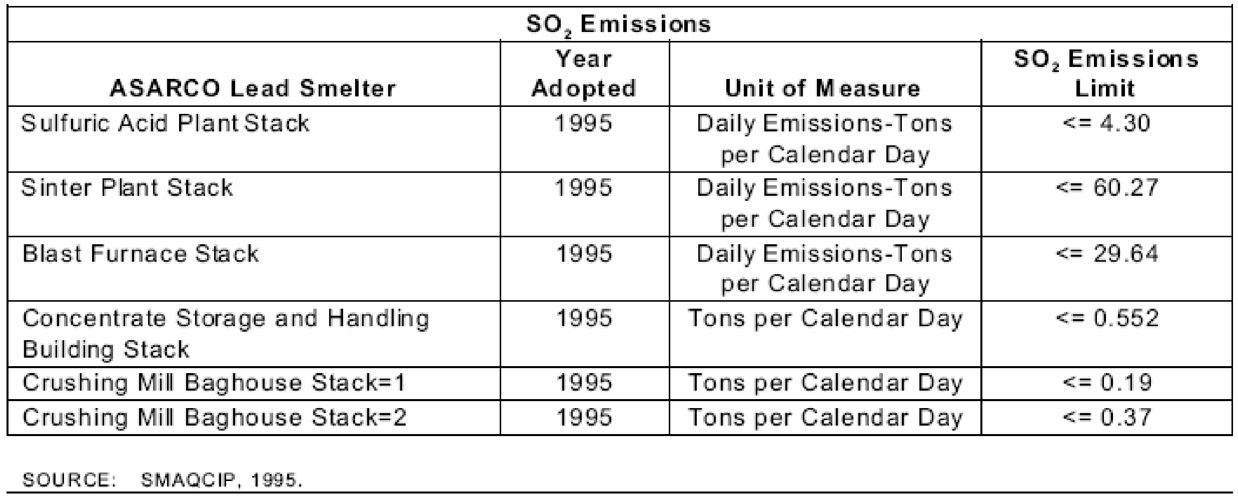
[2] Not in effect for plants which emit less than 100 lb per day of SO_2.

*There are other exceptions not noted.

Montana

Lewis and Clark County (East Helena) (County Code: 30-049)

These SO_2 emission limits were part of the SIP submitted by the State of Montana, and have been included in the Federally (EPA) approved SIP (SMAQCIP, 1995).



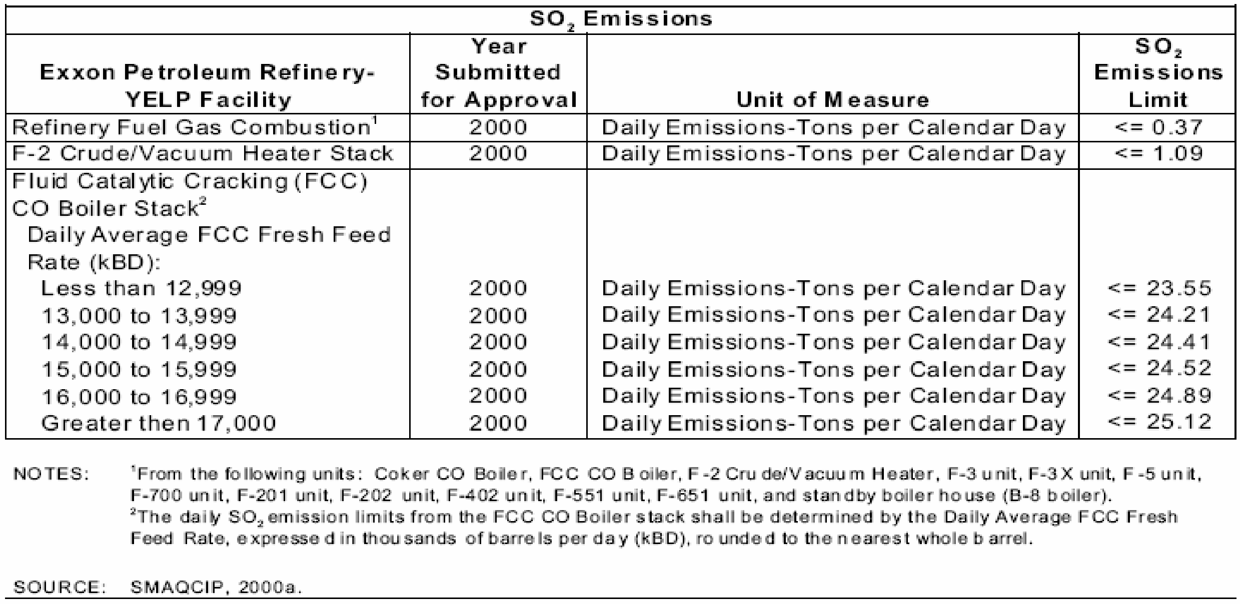
SO_2 Emissions

ASARCO Lead Smelter	Year Adopted	Unit of Measure	SO_2 Emissions Limit
Sulfuric Acid Plant Stack	1995	Daily Emissions-Tons per Calendar Day	<= 4.30
Sinter Plant Stack	1995	Daily Emissions-Tons per Calendar Day	<= 60.27
Blast Furnace Stack	1995	Daily Emissions-Tons per Calendar Day	<= 29.64
Concentrate Storage and Handling Building Stack	1995	Tons per Calendar Day	<= 0.552
Crushing Mill Baghouse Stack=1	1995	Tons per Calendar Day	<= 0.19
Crushing Mill Baghouse Stack=2	1995	Tons per Calendar Day	<= 0.37

SOURCE: SMAQCIP, 1995.

Yellowstone County (County Code: 30-111)

These SO_2 emission limits were part of SIPs submitted by the State of Montana but have not been approved by EPA. Therefore, these limits are State-enforceable only. In addition, the following emission limits will apply whenever the Yellowstone Energy Limited Partnership (YELP) facility receives Exxon Coker unit flue gas, or whenever the Exxon Coker unit is not in operation (SMAQCIP, 2000a).



SO_2 Emissions

Exxon Petroleum Refinery-YELP Facility	Year Submitted for Approval	Unit of Measure	SO_2 Emissions Limit
Refinery Fuel Gas Combustion[1]	2000	Daily Emissions-Tons per Calendar Day	<= 0.37
F-2 Crude/Vacuum Heater Stack	2000	Daily Emissions-Tons per Calendar Day	<= 1.09
Fluid Catalytic Cracking (FCC) CO Boiler Stack[2]			
Daily Average FCC Fresh Feed Rate (kBD):			
Less than 12,999	2000	Daily Emissions-Tons per Calendar Day	<= 23.55
13,000 to 13,999	2000	Daily Emissions-Tons per Calendar Day	<= 24.21
14,000 to 14,999	2000	Daily Emissions-Tons per Calendar Day	<= 24.41
15,000 to 15,999	2000	Daily Emissions-Tons per Calendar Day	<= 24.52
16,000 to 16,999	2000	Daily Emissions-Tons per Calendar Day	<= 24.89
Greater then 17,000	2000	Daily Emissions-Tons per Calendar Day	<= 25.12

NOTES: [1] From the following units: Coker CO Boiler, FCC CO Boiler, F-2 Crude/Vacuum Heater, F-3 unit, F-3X unit, F-5 unit, F-700 unit, F-201 unit, F-202 unit, F-402 unit, F-551 unit, F-651 unit, and standby boiler house (B-8 boiler).
[2] The daily SO_2 emission limits from the FCC CO Boiler stack shall be determined by the Daily Average FCC Fresh Feed Rate, expressed in thousands of barrels per day (kBD), rounded to the nearest whole barrel.

SOURCE: SMAQCIP, 2000a.

SO_2 Emissions			
YELP	Year Submitted for Approval	Unit of Measure	SO_2 Emissions Limit
Boiler stack emissions-when either the Exxon Coker Unit is not operating or the Exxon Coker Unit is operating and YELP is receiving the Exxon Coker flue gas	2000	Daily Emissions-Tons per Calendar Day	8.16
YELP boiler stack emissions-when the Exxon Coker Unit is operating and YELP is not receiving the Exxon Coker flue gas	2000	Daily Emissions-Tons per Calendar Day	5.27

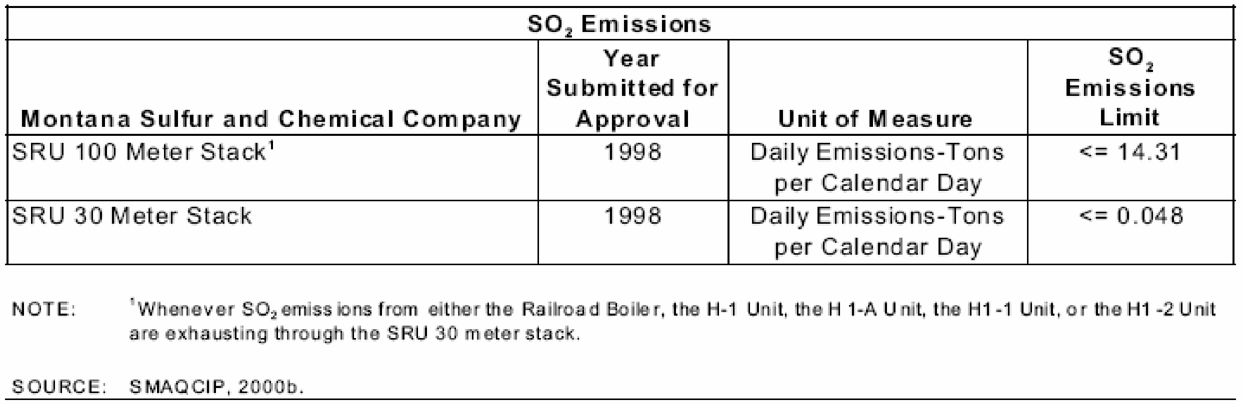
SOURCE: SMAQCIP, 2000a.

SO_2 Emissions			
Cenex Petroleum Refinery	Year Submitted for Approval	Unit of Measure	SO_2 Emissions Limit
FCC Regenerator/CO Boiler Stack	1998	Daily Emissions-Tons per Calendar Day	<= 8.57
Old SRU Tail Gas Oxidizer Stack	1998	Daily Emissions-Tons per Calendar Day	<= 11.66
HDS Complex SRU Stack	1998	Daily Emissions-Tons per Calendar Day	<= 0.17
Emissions from the Combustion Sources (#3, #4, and #5 Boiler Stacks, and Main Crude Heater Stack), Fuel Gas Fired Sources, and the Combustion of Sour Water Stripper Overhead Gases in the Main Crude Heater	1998	Combined Daily Emissions-Tons per Calendar Day	<= 12.06

SOURCE: SMAQCIP, 2000b.

SO_2 Emissions			
Conoco Petroleum Refinery	Year Submitted for Approval	Unit of Measure	SO_2 Emissions Limit
Main Boiler House Stack	1998	Daily Emissions-Tons per Calendar Day	<= 3.86
FCC Stack	1998	Daily Emissions-Tons per Calendar Day	<= 3.95
Jupiter Sulfur SRU Stack	1998	Daily Emissions-Tons per Calendar Day	<= 0.30
Process Heaters (#1, #2, #4, #5, #10, #11, #12, #13, #14, #15, #16, #17, #18, #19, #20, #21, #22, #23, #24), Coker Heater, Fractionator Feed Heater, and Recycle Hydrogen Heater	1998	Combined Daily Emissions-Tons per Calendar Day	<= 0.35

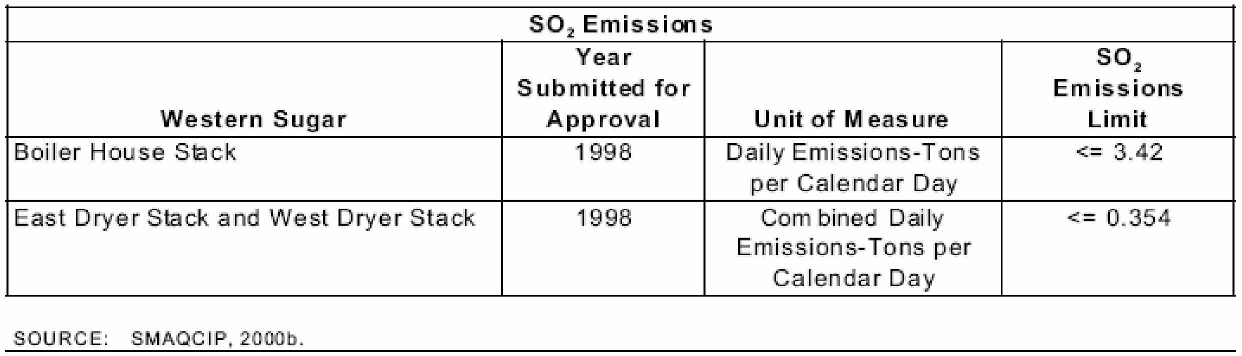
SOURCE: SMAQCIP, 2000b.



SO_2 Emissions			
Montana Sulfur and Chemical Company	**Year Submitted for Approval**	**Unit of Measure**	**SO_2 Emissions Limit**
SRU 100 Meter Stack[1]	1998	Daily Emissions-Tons per Calendar Day	<= 14.31
SRU 30 Meter Stack	1998	Daily Emissions-Tons per Calendar Day	<= 0.048

NOTE: [1] Whenever SO_2 emissions from either the Railroad Boiler, the H-1 Unit, the H 1-A Unit, the H1-1 Unit, or the H1-2 Unit are exhausting through the SRU 30 meter stack.

SOURCE: SMAQCIP, 2000b.

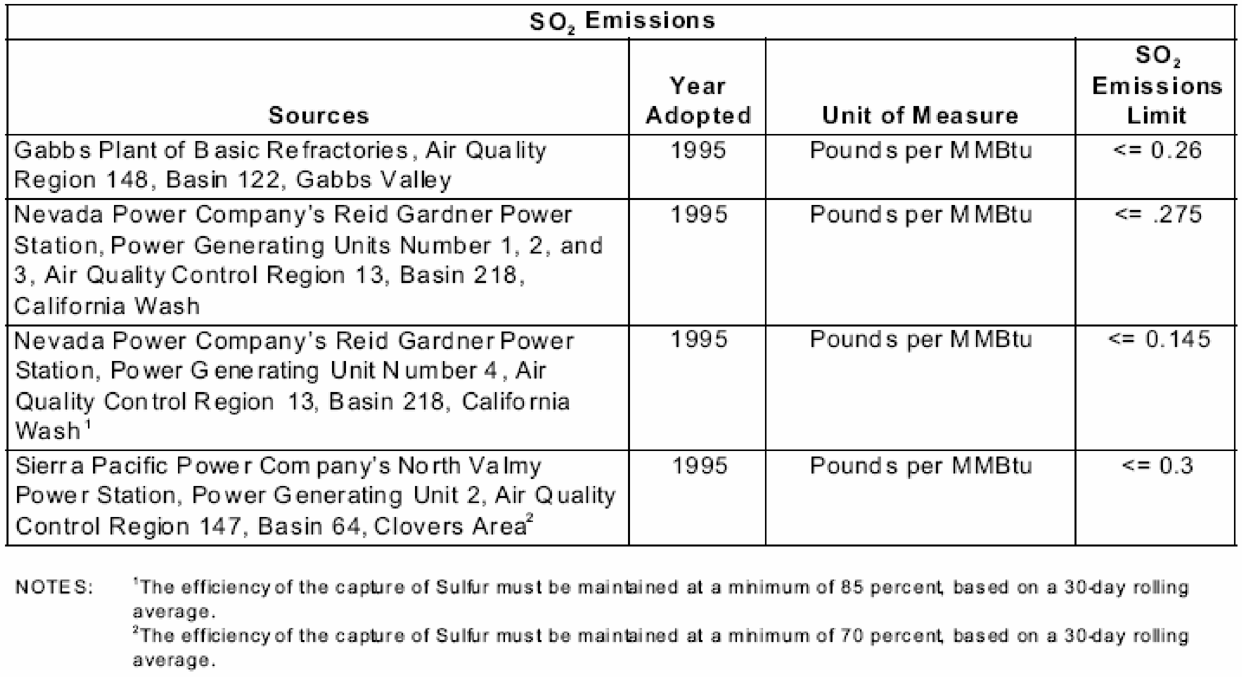


SO_2 Emissions			
Western Sugar	**Year Submitted for Approval**	**Unit of Measure**	**SO_2 Emissions Limit**
Boiler House Stack	1998	Daily Emissions-Tons per Calendar Day	<= 3.42
East Dryer Stack and West Dryer Stack	1998	Combined Daily Emissions-Tons per Calendar Day	<= 0.354

SOURCE: SMAQCIP, 2000b.

Nevada

Nevada State SO_2 regulations were summarized as follows:

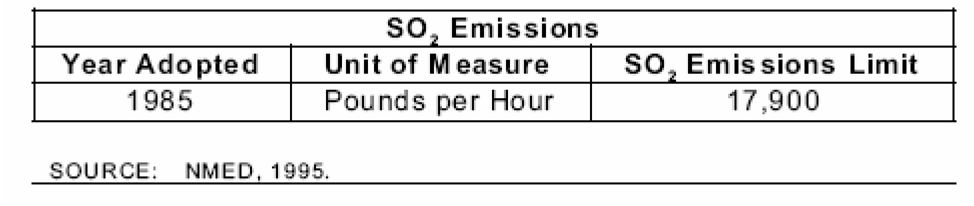


SO_2 Emissions			
Sources	**Year Adopted**	**Unit of Measure**	**SO_2 Emissions Limit**
Gabbs Plant of Basic Refractories, Air Quality Region 148, Basin 122, Gabbs Valley	1995	Pounds per MMBtu	<= 0.26
Nevada Power Company's Reid Gardner Power Station, Power Generating Units Number 1, 2, and 3, Air Quality Control Region 13, Basin 218, California Wash	1995	Pounds per MMBtu	<= .275
Nevada Power Company's Reid Gardner Power Station, Power Generating Unit Number 4, Air Quality Control Region 13, Basin 218, California Wash[1]	1995	Pounds per MMBtu	<= 0.145
Sierra Pacific Power Company's North Valmy Power Station, Power Generating Unit 2, Air Quality Control Region 147, Basin 64, Clovers Area[2]	1995	Pounds per MMBtu	<= 0.3

NOTES: [1] The efficiency of the capture of Sulfur must be maintained at a minimum of 85 percent, based on a 30-day rolling average.
[2] The efficiency of the capture of Sulfur must be maintained at a minimum of 70 percent, based on a 30-day rolling average.

New Mexico

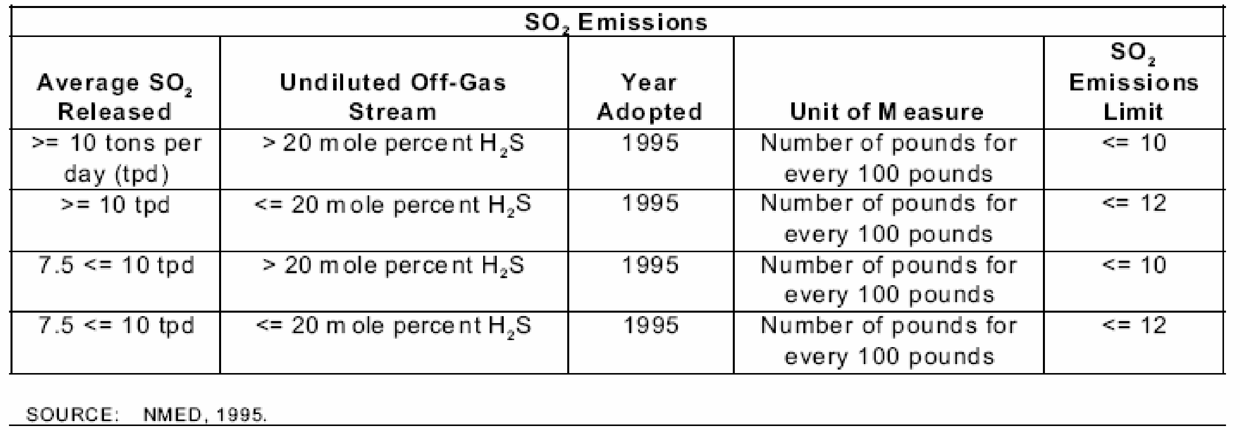
Coal Burning Equipment (After December 31, 1984, the owner or operator of a coal burning station that has two or more units o f existing coal burning equipment that have a rated heat capacity greater than 250 MMBtus per hour has an SO2 emission limit of 17,900 pounds per hour, which is averaged over any three-hour period and determined on a total station basis (NMED, 1995).)



SO_2 Emissions		
Year Adopted	Unit of Measure	SO_2 Emissions Limit
1985	Pounds per Hour	17,900

SOURCE: NMED, 1995.

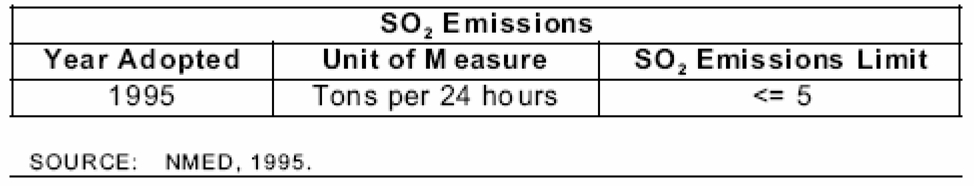
Natural Gas Processing Plants



SO_2 Emissions				
Average SO_2 Released	Undiluted Off-Gas Stream	Year Adopted	Unit of Measure	SO_2 Emissions Limit
>= 10 tons per day (tpd)	> 20 mole percent H_2S	1995	Number of pounds for every 100 pounds	<= 10
>= 10 tpd	<= 20 mole percent H_2S	1995	Number of pounds for every 100 pounds	<= 12
7.5 <= 10 tpd	> 20 mole percent H_2S	1995	Number of pounds for every 100 pounds	<= 10
7.5 <= 10 tpd	<= 20 mole percent H_2S	1995	Number of pounds for every 100 pounds	<= 12

SOURCE: NMED, 1995.

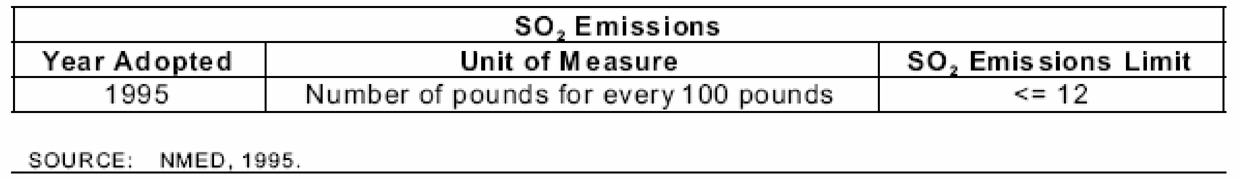
Petroleum Refineries



SO_2 Emissions		
Year Adopted	Unit of Measure	SO_2 Emissions Limit
1995	Tons per 24 hours	<= 5

SOURCE: NMED, 1995.

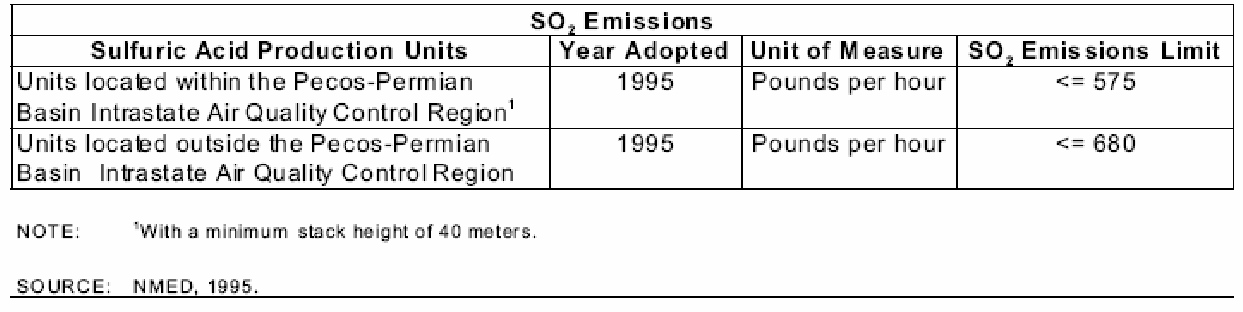
Sulfur Recovery Plants (This limit applies to plants where fabrication, erection, or installation commenced before August 14, 1974.



SO_2 Emissions		
Year Adopted	Unit of Measure	SO_2 Emissions Limit
1995	Number of pounds for every 100 pounds	<= 12

SOURCE: NMED, 1995.

Sulfuric Acid Production Units

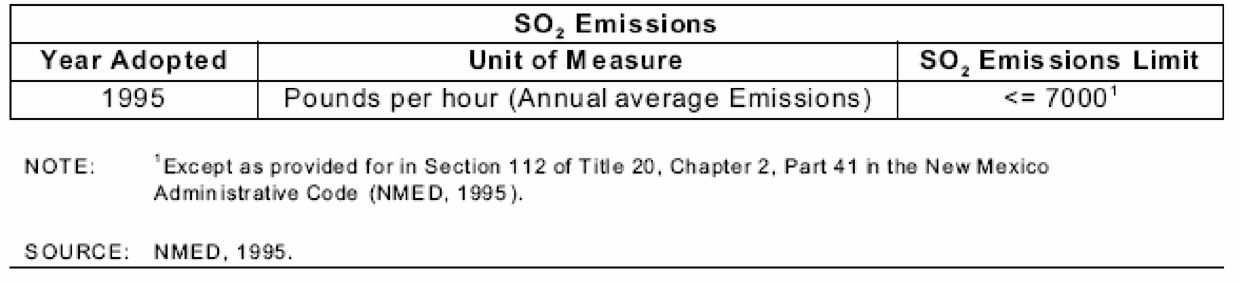


SO$_2$ Emissions			
Sulfuric Acid Production Units	Year Adopted	Unit of Measure	SO$_2$ Emissions Limit
Units located within the Pecos-Permian Basin Intrastate Air Quality Control Region[1]	1995	Pounds per hour	<= 575
Units located outside the Pecos-Permian Basin Intrastate Air Quality Control Region	1995	Pounds per hour	<= 680

NOTE: [1] With a minimum stack height of 40 meters.

SOURCE: NMED, 1995.

Nonferrous Smelters



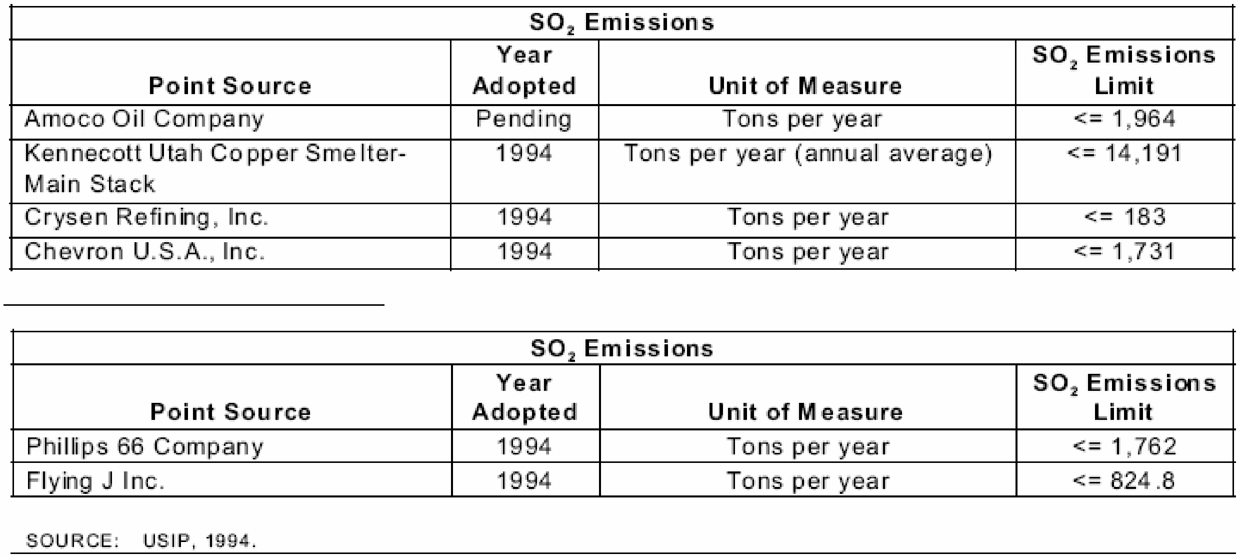
SO$_2$ Emissions		
Year Adopted	Unit of Measure	SO$_2$ Emissions Limit
1995	Pounds per hour (Annual average Emissions)	<= 7000[1]

NOTE: [1] Except as provided for in Section 112 of Title 20, Chapter 2, Part 41 in the New Mexico Administrative Code (NMED, 1995).

SOURCE: NMED, 1995.

Utah

The SIP for Utah was last approved by EPA on July 8, 1994, except for the Amoco Oil Company submission.



SO$_2$ Emissions			
Point Source	Year Adopted	Unit of Measure	SO$_2$ Emissions Limit
Amoco Oil Company	Pending	Tons per year	<= 1,964
Kennecott Utah Copper Smelter-Main Stack	1994	Tons per year (annual average)	<= 14,191
Crysen Refining, Inc.	1994	Tons per year	<= 183
Chevron U.S.A., Inc.	1994	Tons per year	<= 1,731

SO$_2$ Emissions			
Point Source	Year Adopted	Unit of Measure	SO$_2$ Emissions Limit
Phillips 66 Company	1994	Tons per year	<= 1,762
Flying J Inc.	1994	Tons per year	<= 824.8

SOURCE: USIP, 1994.

After gathering the above information about State regulations, the SO$_2$ emission limits were compared with the SO$_2$ emissions in the WRAP 1996 point source file for affected facilities. In all cases, it was found that emission points/facilities were in compliance with these SO$_2$ regulations. Therefore, no additional SO$_2$ controls were placed on point sources in the 2018 emission forecast.

A.6. Stationary Sources – Retirement Factors, Unit Lifetime Analysis

This information is from Chapter V "Retirement Factors – Unit Lifetime Analysis, Western Regional Air Partnership Emission Forecasts For 2018 - Final Report", E.H. Pechan & Associates, Inc., December 2002, Pechan Rpt. No. 02.12.003/9409.000.

In the original IAS model, future year forecasts of electric utility emissions used estimates of the date of initial operation and expected unit lifetimes in years to determine when existing source emission rates were likely to be replaced with new source emission rates. So, for example, if an oil-fired utility boiler began operating in 1970, it would be expected to be replaced by a new boiler that emits at NSPS/BACT level emission rates in 2000 at the end of its 30-year lifetime. For non-utility units, the IAS model includes the effects of retirements using an annual rate. So, each unit in any source category has the same annual retirement rate applied. For example, the annual retirement rate for industrial boilers in the IAS model has been 0.6 percent per year. If this retirement rate were applied to the 1996 to 2018 forecast horizon that is being used for this project, then 12.4 percent of industrial boiler capacity would be retired during this 22-year period. One of the objectives of this project was to establish projection methods for the largest non-utility units that parallel those used for utilities. This requires gathering and using information about the year of initial operation for individual non-utility units and expressing non-utility unit lifetimes in years. The year of initial operation data gathering activity is described in Chapter II. This chapter describes the effort to establish appropriate lifetime estimates for the source categories (scc_ ids) in the IAS model.

A.6.1. Industrial Sources

This section deals with estimating the lifetimes of the IAS industrial sources listed in Table V-1. The IAS annual retirement rates for each sector were converted into the lifetime years listed above by the following formula:

$$\frac{1}{\text{Retirement Rate}} = \text{Years}$$

We consulted several other data sources, such as Internal Revenue Service Publications, Bureau of Economic Analysis (BEA) depreciation schedules, other industry publications, and estimates provided by authorities in different sectors, to estimate the actual lifetimes of the different industrial sector units or plants. The following sub sections describe how the lifetimes of the different industrial sector units or plants were calculated or estimated.

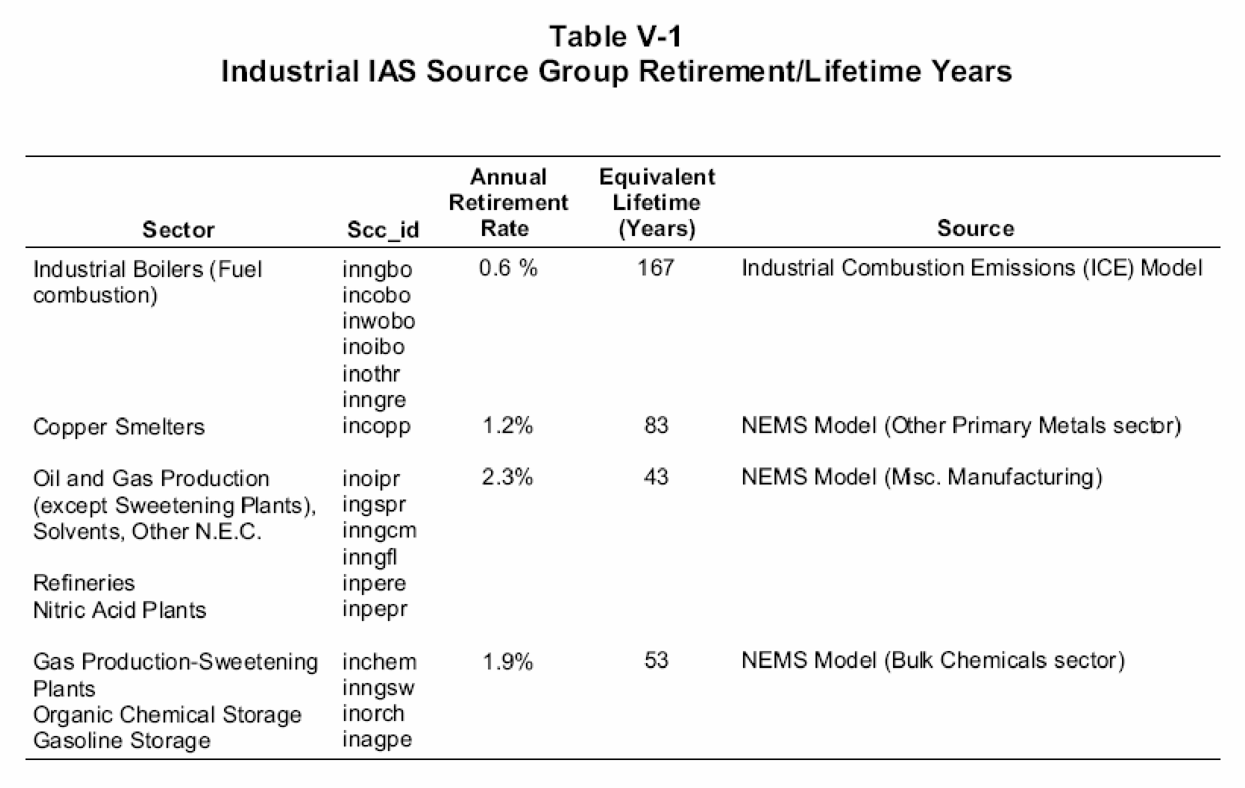


Table V-1
Industrial IAS Source Group Retirement/Lifetime Years

Sector	Scc_id	Annual Retirement Rate	Equivalent Lifetime (Years)	Source
Industrial Boilers (Fuel combustion)	inngbo incobo inwobo inoibo inothr inngre	0.6 %	167	Industrial Combustion Emissions (ICE) Model
Copper Smelters	incopp	1.2%	83	NEMS Model (Other Primary Metals sector)
Oil and Gas Production (except Sweetening Plants), Solvents, Other N.E.C.	inoipr ingspr inngcm inngfl	2.3%	43	NEMS Model (Misc. Manufacturing)
Refineries	inpere			
Nitric Acid Plants	inpepr			
Gas Production-Sweetening Plants	inchem inngsw	1.9%	53	NEMS Model (Bulk Chemicals sector)
Organic Chemical Storage	inorch			
Gasoline Storage	inagpe			

A.6.2. Industrial Boilers

The annual retirement rates used in the original IAS model for industrial fuel combustors or industrial boilers are taken from a U.S. energy model named the ICE model. The ICE model was developed and applied as part of the National Acid Precipitation Assessment Program (NAPAP) emission and control techniques evaluation process. The assumed IAS annual industrial boiler retirement rate of 0 .6 percent converts into a lifetime of 167 years. However, other data sources present boiler lifetimes that are much lower, and these estimates are presented next.

According to *Steam/its generation and use*, the degree of pressure and heat associated with a boiler, along with its design, function, and operation affect boiler lifetime. Industrial boilers operating at pressures above 1,200 psi (pounds per square inch, absolute or difference) and 900 F (482 C) final steam temperature undergo more complicated aging mechanisms than lower temperature boilers (Stultz, 1992). The high pressures and associated high furnace wall temperatures make these units more susceptible to water side corrosion. Table V-2 presents the component replacement sequence for a typical high pressure, high temperature boiler (Stultz, 1992).

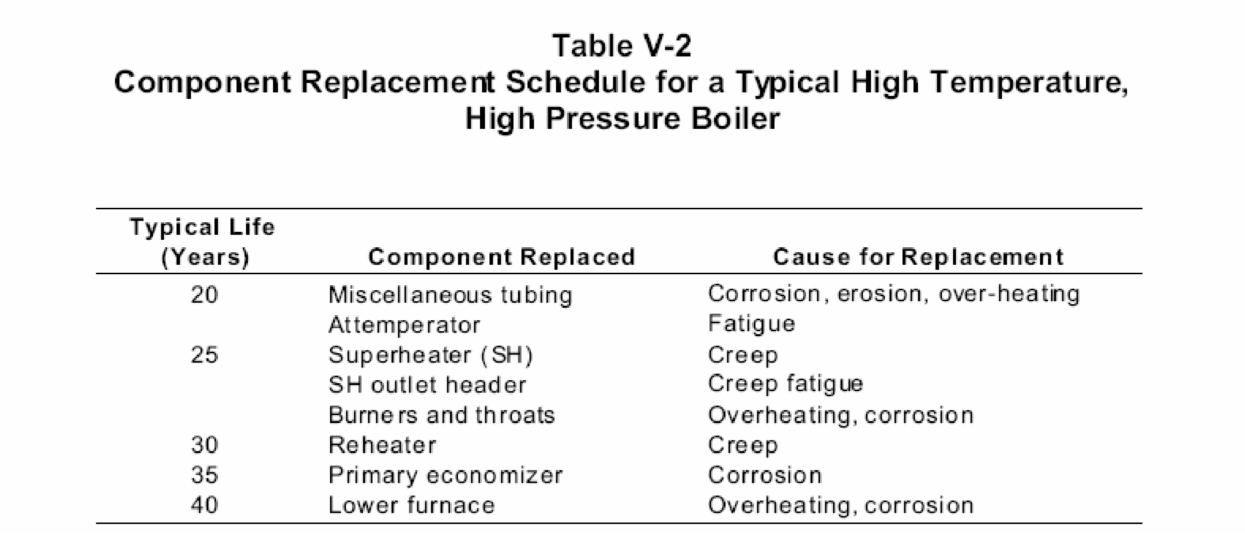


Table V-2
Component Replacement Schedule for a Typical High Temperature, High Pressure Boiler

Typical Life (Years)	Component Replaced	Cause for Replacement
20	Miscellaneous tubing	Corrosion, erosion, over-heating
	Attemperator	Fatigue
25	Superheater (SH)	Creep
	SH outlet header	Creep fatigue
	Burners and throats	Overheating, corrosion
30	Reheater	Creep
35	Primary economizer	Corrosion
40	Lower furnace	Overheating, corrosion

In the case of a typical high temperature, high-pressure boiler, most boiler pressure part components have been replaced after 40 years of operation. However, the aging process and rate of component degradation differ from boiler to boiler. Moreover, the actual component life of a boiler is highly variable depending on the specific design, operation, maintenance, and fuel (Stultz, 1992). In another analysis, Teknekron Research Inc. assumed a 30-year boiler lifetime when calculating the retirement rate of a boiler in its report “Review of Modeling Activities Related to New Source Performance Standards for Industrial Boilers” (Placet, 1980). However, it was also found that some boilers over 70 years old were still in use, with no plans to retire them. Therefore, Teknekron suggested an approximate boiler lifetime of 40 years as a reasonable estimate of the lifetime of an industrial boiler (Placet, 1980).

The Internal Revenue Service’s “Publication 946: How to Depreciate Property” lists lifetimes of industrial boilers from a depreciation point of view. The IRS uses a system called Modified Accelerated Cost Recovery System (MACRS) to depreciate assets. According to this system, a class life of 28 years is estimated for the asset category “Central Steam Utility Production and Distribution.” In addition, 20-year and 28-year recovery periods are estimated for the General Depreciation System (GDS) and Alternative Depreciation System (ADS), respectively (IRS, 2000). The lifetime years used in the depreciation schedules in this publication may not be directly representative of the actual lifetime of a boiler. Therefore, we presume that these lifetimes represent a minimum lifetime estimate for industrial boilers. This same issue arose in interpreting the BEA ’s depreciation schedules. These schedules estimate a service life of 32 years for “Steam Engines and Turbines” (Fraumeni, 1997). Again, since this depreciation lifetime may not directly represent the actual lifetime of a boiler, these lifetimes might represent a minimum lifetime estimate for industrial boilers.

Discussions were held with Bob Bessette of the Council of Industrial Boiler Owners (CIBO), Randall Rawson of the American Boiler Manufacturers Association, Ian Lutes of Foster Wheeler Corporation, and Brian Moore of the Hartford Steam Boiler Company. The opinion among this group was that while industrial boiler lifetimes could range from 30 to 100 years, the majority of these boilers stay in service from 35 to 60 years. Industrial boilers generally have less focus on maintenance than utility boilers. Utility boilers, as a rule, are optimally maintained. In some cases, industrial boiler owners are reticent to perform maintenance on their units for fear of triggering new source review. Therefore, it would be expected that the average lifetime of an industrial boiler would be less than that of a comparable utility boiler. There are exceptions, of course, especially when industrial boilers are well maintained and operated at lower pressures. Field erected units tend to have higher lifetimes than package boilers for a variety of reasons. Through discussions with staff at the U.S. Department of Energy, it was determined that the most comprehensive data source about expected unit lifetimes by source type was Energy and Environmental Analysis's Industrial Sector Technology Use Model (ISTUM). The estimated lifetimes by industrial sector technology from ISTUM (EEA, 2001) range from 20 years for refinery heaters and distillation units to 30 years for industrial boilers. However, there is evidence that the equipment turnover in these industries is not nearly as rapid as ISTUM predicts.

Pechan's recommendation based on the evidence provided by the boiler industry representatives is that a 45-year lifetime be used for all industrial boilers in the emission forecasts to 2018. This is 1.5 times the lifetime used by the ISTUM model. It is also recommended that the IAS model lifetimes for other industrial sector technologies be 1.5 times the ISTUM values. This makes the lifetimes for most refinery equipment 30 years, and makes the cement kiln lifetimes 37.5 years. Making these changes provides a more conservative estimate of future year WRAP State emissions. A summary of estimated unit lifetimes by industrial source category is provided in Table V-3.

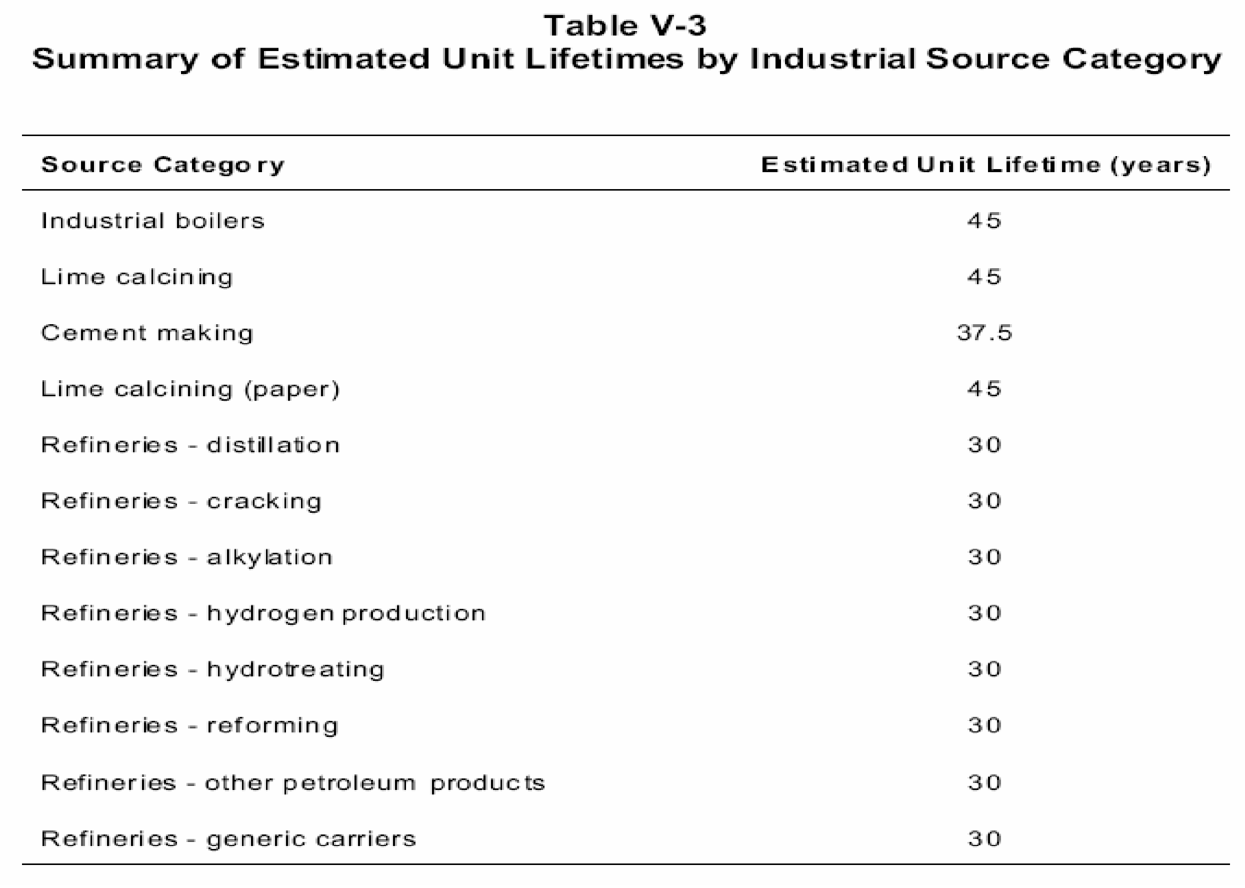
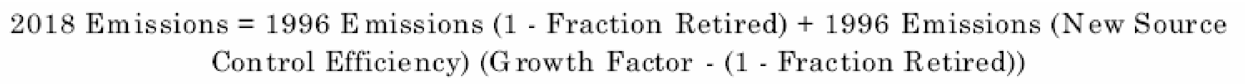


Table V-3
Summary of Estimated Unit Lifetimes by Industrial Source Category

Source Category	Estimated Unit Lifetime (years)
Industrial boilers	45
Lime calcining	45
Cement making	37.5
Lime calcining (paper)	45
Refineries - distillation	30
Refineries - cracking	30
Refineries - alkylation	30
Refineries - hydrogen production	30
Refineries - hydrotreating	30
Refineries - reforming	30
Refineries - other petroleum products	30
Refineries - generic carriers	30

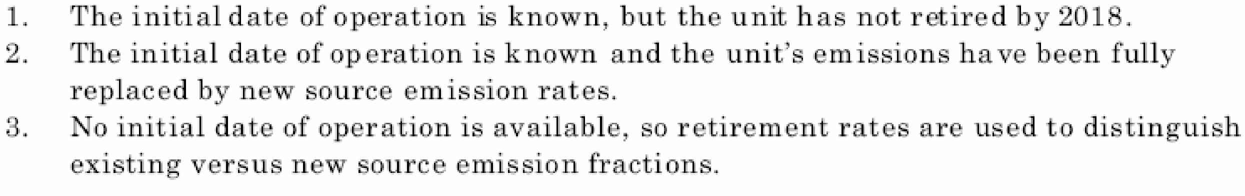
Example Calculations

The IAS model algorithms are applied to estimate 2018 emissions given the primary variables affecting emissions in that year, which are: 1996 emissions, unit date of initial operation, expected unit lifetime or retirement rate, new source control efficiency, and growth rates/factors. The base IAS algorithm for performing emission forecasts to 2018 at the unit level is shown in the equation below.



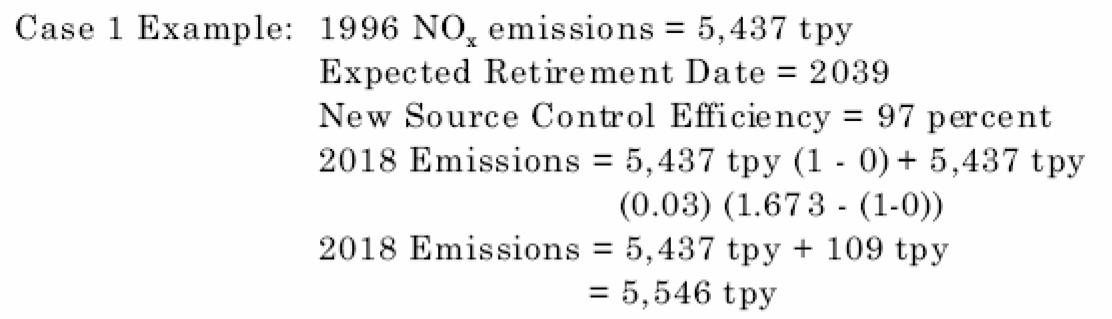
2018 Emissions = 1996 Emissions (1 - Fraction Retired) + 1996 Emissions (New Source Control Efficiency) (Growth Factor - (1 - Fraction Retired))

In the point source emission projections, there are three cases that all of the sources fall into. These three cases are listed below:



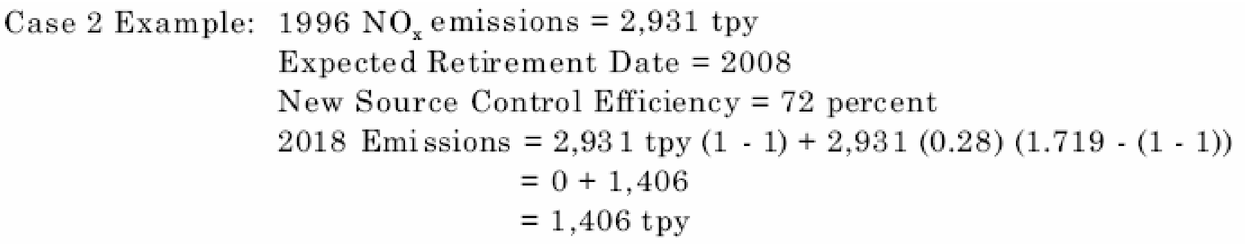
1. The initial date of operation is known, but the unit has not retired by 2018.
2. The initial date of operation is known and the unit's emissions have been fully replaced by new source emission rates.
3. No initial date of operation is available, so retirement rates are used to distinguish existing versus new source emission fractions.

Example calculations of 2018 emissions are provided below for each of these three cases:



Case 1 Example: 1996 NO_x emissions = 5,437 tpy
Expected Retirement Date = 2039
New Source Control Efficiency = 97 percent
2018 Emissions = 5,437 tpy (1 - 0) + 5,437 tpy (0.03) (1.673 - (1-0))
2018 Emissions = 5,437 tpy + 109 tpy
= 5,546 tpy

In this example, because the unit is expected to still be operating in 2018, the existing source portion of the SO_2 emissions (5,437 tpy) remains the same as in 1996. Any increase in activity at this facility is estimated to occur at new source emission rate levels, which are 3 percent of existing source rates.



Case 2 Example: 1996 NO_x emissions = 2,931 tpy
Expected Retirement Date = 2008
New Source Control Efficiency = 72 percent
2018 Emissions = 2,931 tpy (1 - 1) + 2,931 (0.28) (1.719 - (1 - 1))
= 0 + 1,406
= 1,406 tpy

Because this unit has an expected retirement date before 2018, all of the 2018 emissions are at new source rates, which are 28 percent of existing source rates. The growth factor that is applied to the new source emission rates incorporates 1996 activity, plus expected activity increases from 1996 to 2018.

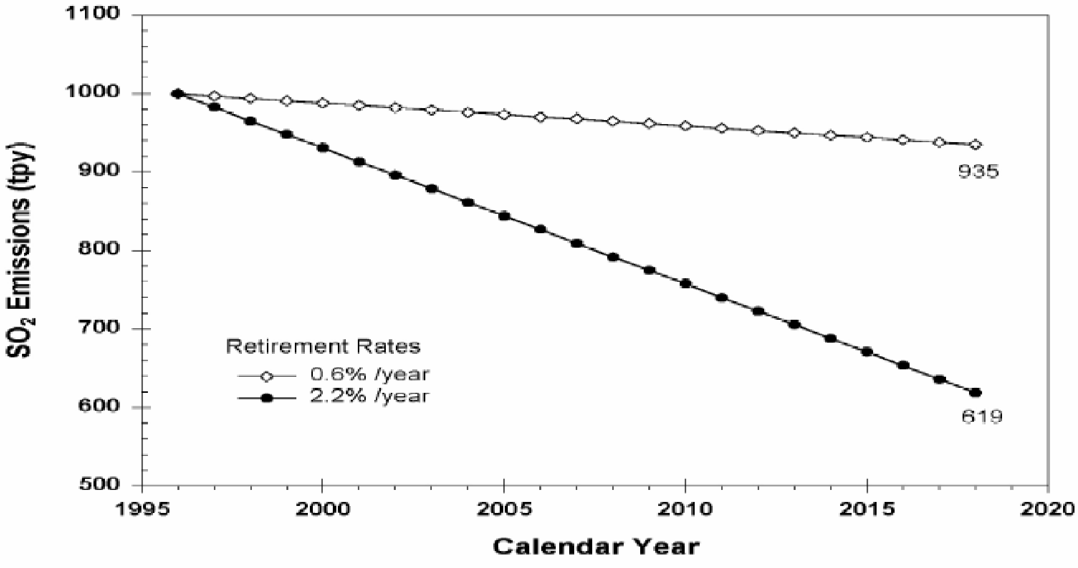
Case 3 Example: No Specific Start Date/Retirement Date
New Source Control Efficiency = 60 percent
2018 Emissions = 2,743 tpy (1 - .7333) + 2,743 (0.4) (1.634 - (1 - .7333))
= 732 + 1,500 tpy
= 2,232 tpy

With no specific start date/retirement date available, the retirement rate is applied in a way to capture the percentage of existing capacity in this industry that is expected to retire each year over the 22-year forecast horizon. In this example, 73 percent of the 1996 capacity is estimated to have been retired by 2018. While, in reality, units do not retire a fraction of their capacity each year, this calculation is expected to provide a reasonable simulation of existing source retirement, new source growth when spread over a broad geographic region, like the WRAP States.

Implications of Retirement Assumptions in IAS

The practical result of using the revised estimates of unit lifetimes by source category and technology is that future emissions are lower for source categories with significant differences between new and existing source emission rates. Figure V-1 presents an example 1996 to 2018 SO_2 emissions path using the previous industrial boiler IAS retirement rate of 0.6 percent per year compared with the new retirement rate of 2.2 percent per year. This is a source category where the new source SO_2 control efficiency is 90 percent, so the faster the existing units retire, the more rapid the decline in future SO_2 emissions. A 2.0 percent per year new source growth rate is used in this example. So, a 1,000 tpy SO_2 source in 1996 would be estimated to have 2018 emissions of 936 tpy if the prior IAS retirement rate was used. The emission forecasting methods applied in this study yield a 2018 emissions estimate of 619 tpy. This is a significant reduction in future emissions from this source category compared with prior methods.

Figure V-1
Industrial Boiler Lifetime Effects on Emission Forecasts



Appendix B: Use of EPA Guidance and best practices

The WRAP and its contractors followed EPA emissions inventory guidance and best emissions inventory development practices, EPA modeling guidance, and used professional judgment in preparing technical analyses for §309. Specific references to EPA guidance documents are listed throughout the earlier chapters, usually as web addresses and report titles, as well as in Appendix M of this document.

Appendix C: 1996 Base Case Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 1996 base case modeling run. These are not the emissions used in the 1996 base case model performance evaluation run, where the model-predicted results are compared to monitoring data. The emissions following are used as the basis of “projected visibility improvement”, requirement of §309, for the 16 Colorado Plateau Class I areas. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire.

The 1996 base case modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/1996_Base_Case_Final.xls .

Appendix D: 2018 Base Case Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 2018 base case modeling run. The emissions following are based on “rules and regulations on the books” as of 2001. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire.

The 2018 base case modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/2018_Base_Case_Final.xls .

Appendix E: 2018 Scenario 1 Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 2018 Scenario 1 modeling run. The emissions following are based on "rules and regulations on the books" from the 2018 base case, plus adoption of the SO_2 Annex Milestones and Pollution Prevention programs across the Grand Canyon Visibility Transport Commission 9-state region. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire. Scenario 1 is the first of two projections of visibility improvement from implementation of §309 programs.

The 2018 Scenario 1 modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/2018_Scenario_1_Final.xls .

Appendix F: 2018 Scenario 2 Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 2018 Scenario 2 modeling run. The emissions following are based on “rules and regulations on the books” from the 2018 base case, adoption of the SO_2 Annex Milestones and Pollution Prevention programs across the Grand Canyon Visibility Transport Commission 9-state region, as well as adoption of the Enhanced Smoke Management Programs across the Grand Canyon Visibility Transport Commission 9-state region, based on the 2018 Optimal Smoke Management emissions inventories for forest/range prescribed fire and agricultural fire. Typical wildfire emissions were used in this scenario. Scenario 2 is the second of two projections of visibility improvement from implementation of §309 programs.

The 2018 Scenario 2 modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/2018_Scenario_2_Final.xls .

Appendix G: 2018 BART with Uncertainty Scenario Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 2018 BART with Uncertainty Scenario modeling run. The emissions following are based on analyses described in Chapter 1 of this document. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire. The BART with Uncertainty Scenario was compared using air quality modeling to the SO_2 Annex Milestones Scenario, and the results are discussed in Chapter 4 of this document.

The 2018 BART with Uncertainty Scenario modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/2018_BARTwUncertainty_Final.xls .

Appendix H: 2018 SO_2 Annex Milestones Scenario Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 2018 SO_2 Annex Milestones Scenario modeling run. The emissions following are based on analyses described in Chapter 1 of this document. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire. The SO_2 Annex Milestones Scenario was compared using air quality modeling to the BART with Uncertainty Scenario, and the results are discussed in Chapter 4 of this document.

The 2018 SO_2 Annex Milestones Scenario modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/2018_SO2_Annex_Milestones_Final.xls .

Appendix I: 2018 Stationary Source 50% NO_x Reduction Scenario Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 2018 Stationary Source 50% NO_x Reduction Scenario modeling run. The emissions following are based on analyses described in Chapter 4 of this document. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire. The 2018 Stationary Source 50% NO_x Reduction Scenario was modeled to satisfy requirement of §309, and the results are discussed in Chapter 4 of this document.

The 2018 Stationary Source 50% NO_x Reduction Scenario modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/2018_NOx_50percent_Decrease_Stationary_Sources_Final.xls .

Appendix J: 2018 Stationary Source 50% PM_{10} Reduction Scenario Emissions Used in Air Quality Modeling

The following spreadsheet details emissions used in the 2018 Stationary Source 50% PM_{10} Reduction Scenario modeling run. The emissions following are based on analyses described in Chapter 4 of this document. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire. The 2018 Stationary Source 50% PM_{10} Reduction Scenario was modeled to satisfy requirement of §309, and the results are discussed in Chapter 4 of this document.

The 2018 Stationary Source 50% PM_{10} Reduction Scenario modeling run emissions spreadsheet is found on the WRAP website at:

http://wrapair.org/309/documents/FinalDocs/2018_PM10_50percent_Decrease_Stationary_Sources_Final.xls .

Appendix K: 2018 Stationary Source Simultaneous 25% NO_x and 25% PM_{10} Increase Scenario Emissions Used in Air Quality Modeling

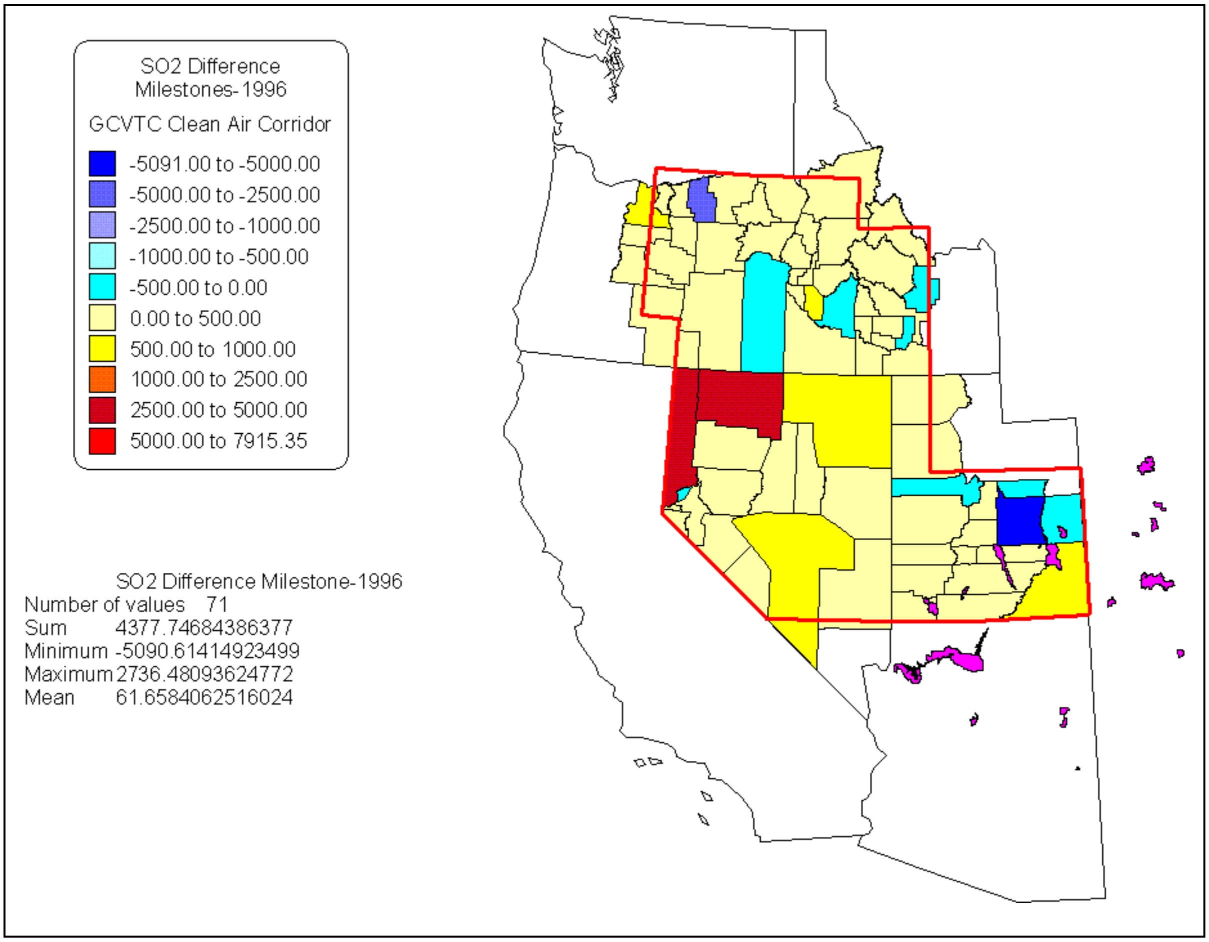
The following spreadsheet details emissions used in the 2018 Stationary Source Simultaneous 25% NO_x and PM_{10} Increase Scenario modeling run. The emissions following are based on analyses described in Chapter 4 of this document. Fire emissions in the spreadsheet below are typical wildfire, and the 2018 base case emissions for forest/range prescribed fire and agricultural fire. The 2018 Stationary Source Simultaneous 25% NO_x and PM_{10} Increase Scenario was modeled to satisfy requirement of §309, and the results are discussed in Chapter 4 of this document.

The 2018 Stationary Source Simultaneous 25% NO_x and PM_{10} Increase Scenario modeling run emissions spreadsheet is found on the WRAP website at:

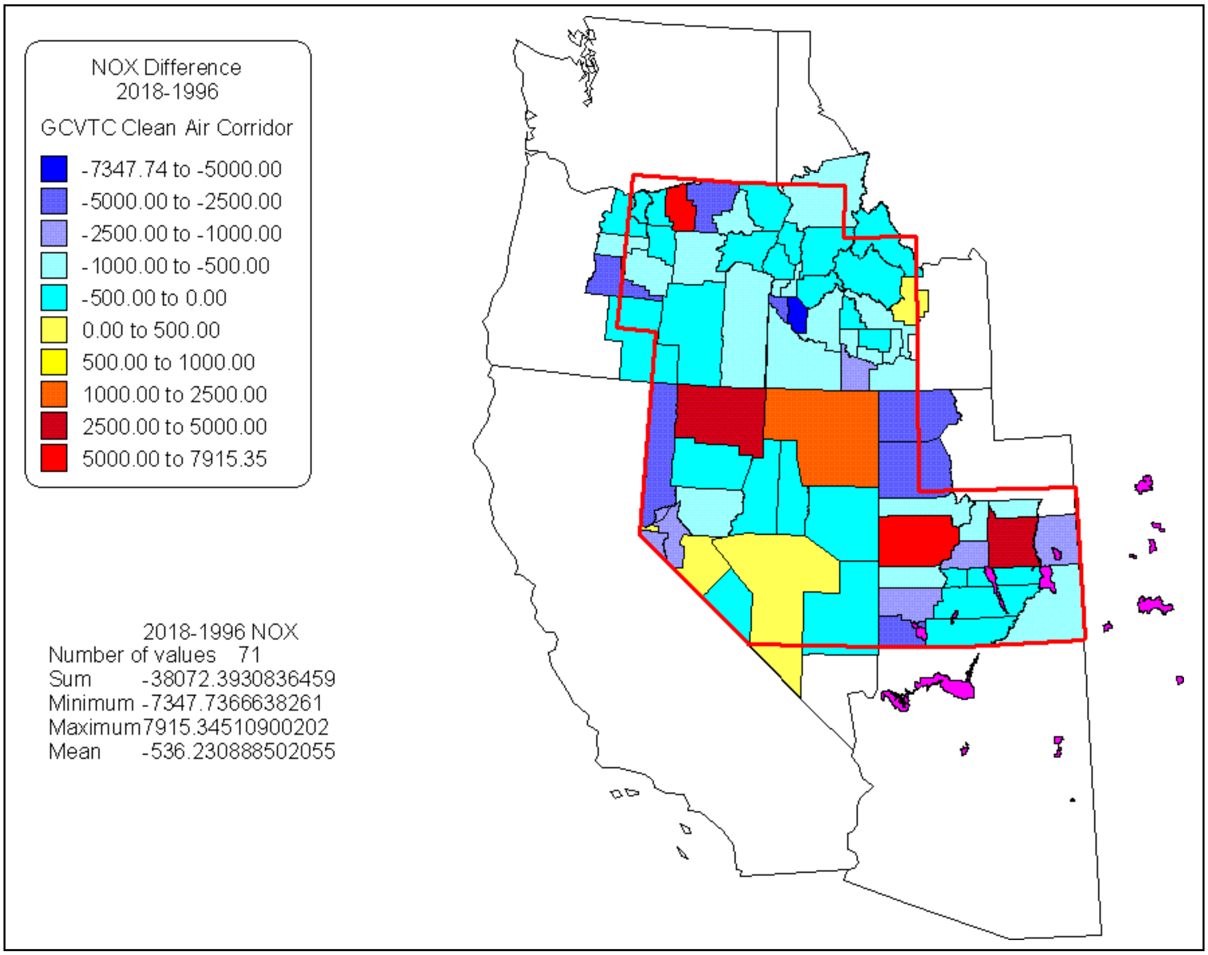
http://wrapair.org/309/documents/FinalDocs/2018_PM10_25percent_and_NOx_25percent_Increase_Stationary_Sources_Final.xls .

Appendix L: Clean Air Corridor Change in Emissions 1996 to 2018

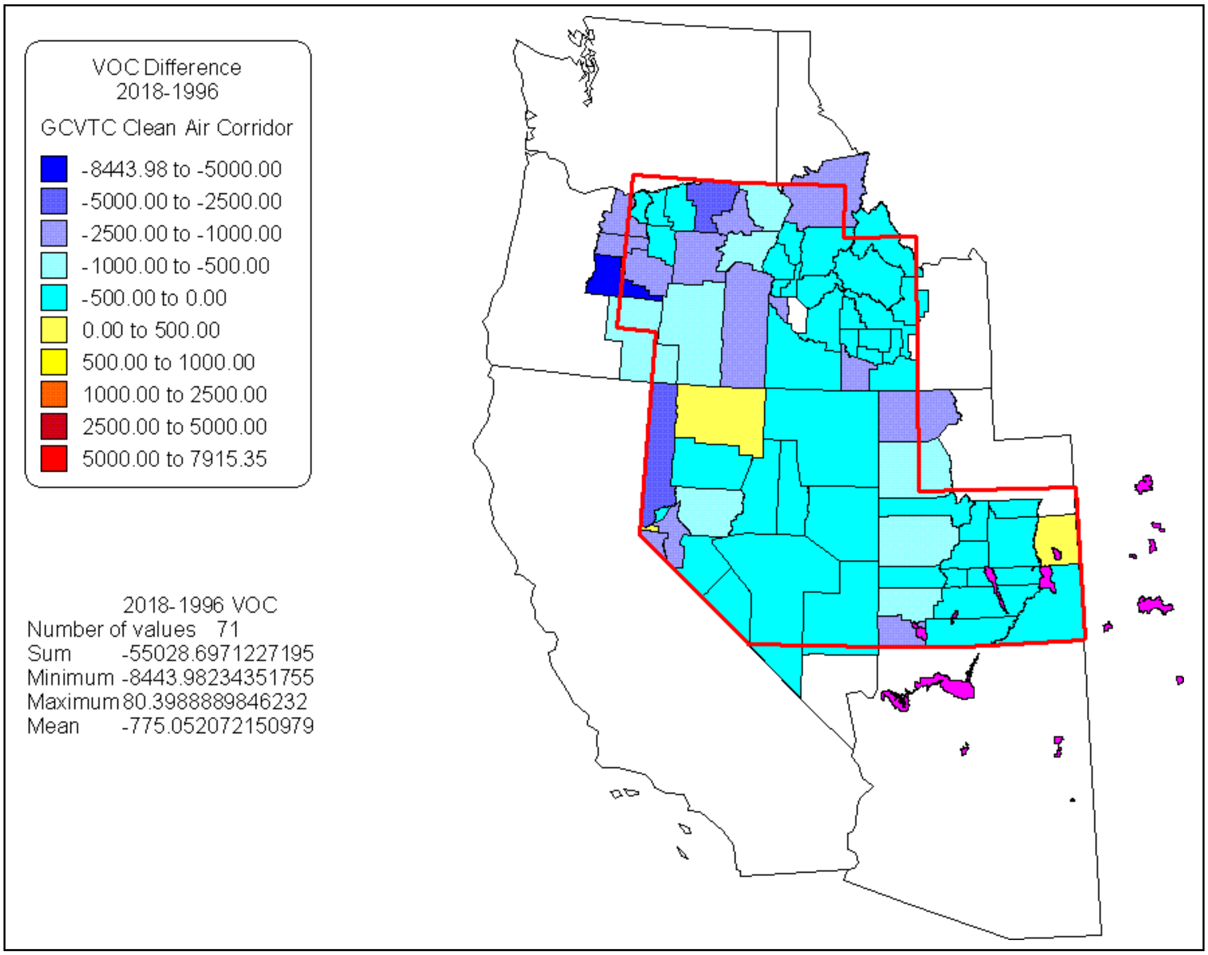
The projected changes in emissions, within the clean air corridor, are show spatially in the following figures for SO_2, NO_2, VOC, PM_{10}, and $PM_{2.5}$.



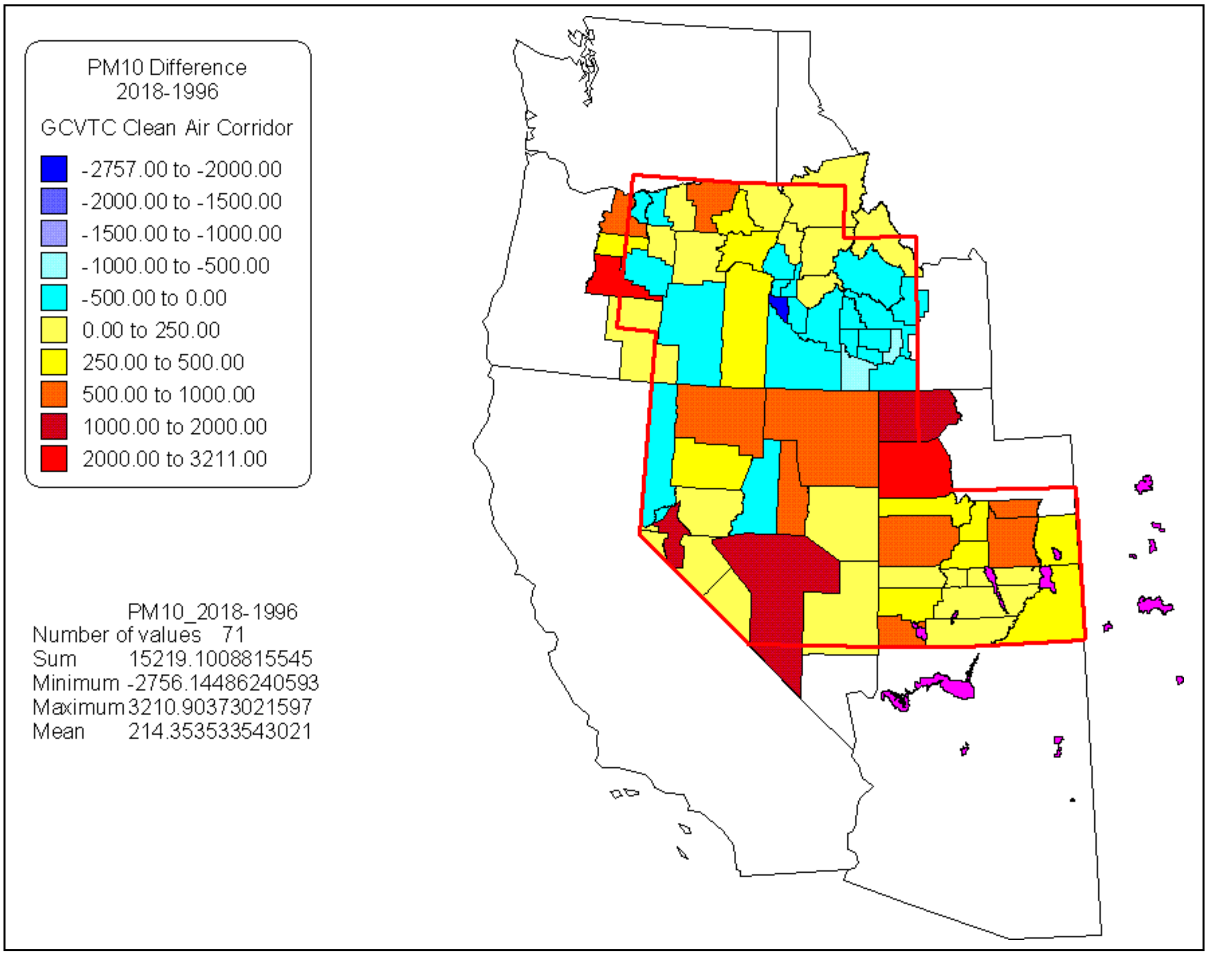
SO_2 emission difference, by county, 2018 projections with WRAP SO_2 Annex Milestones and 1996 base.



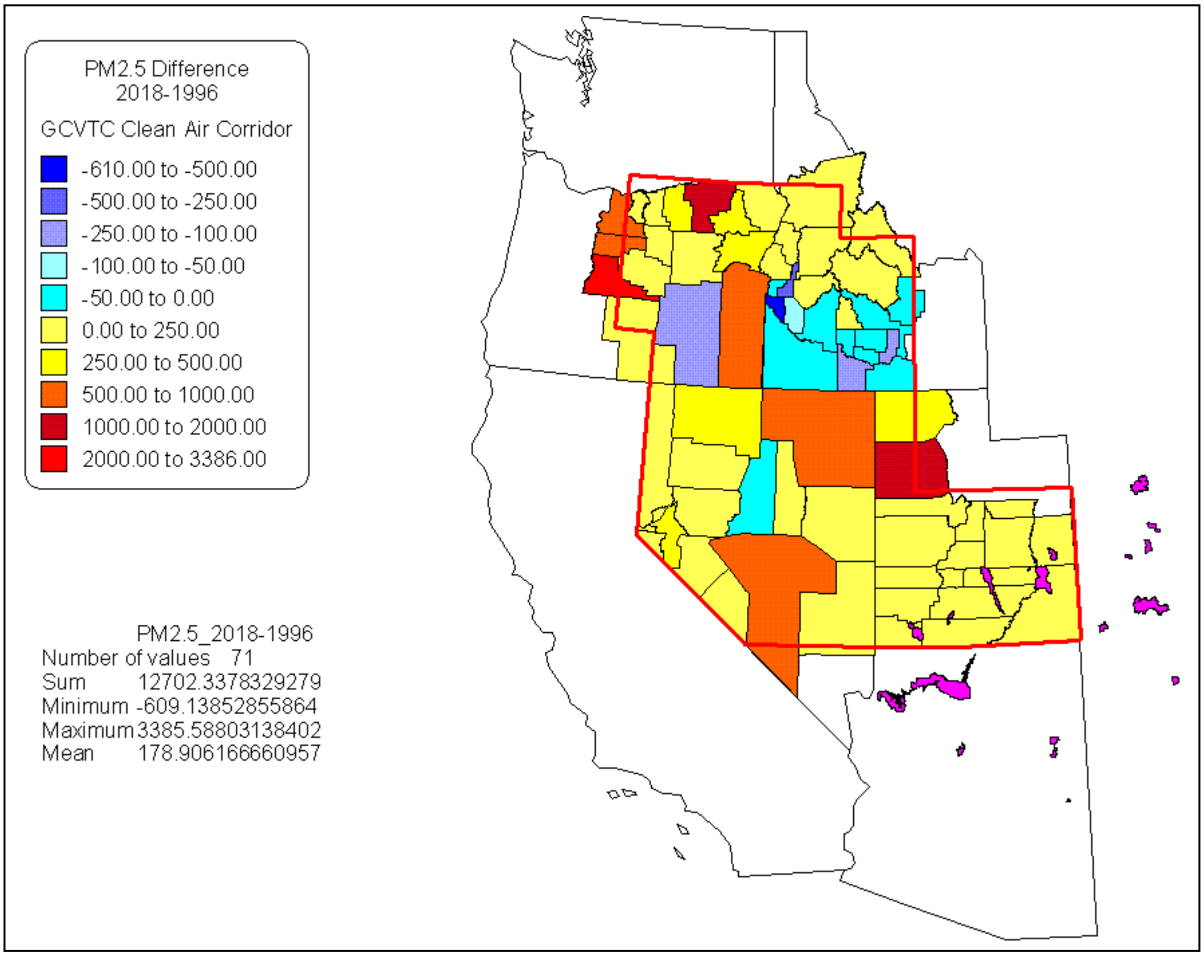
NO_X emission difference, by county, 2018 projections and 1996 base



VOC emission difference, by county, 2018 projections and 1996 base



PM_{10} emission difference, by county, 2018 projections and 1996 base



PM$_{2.5}$ emission difference, by county, 2018 projections and 1996 base

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Glossary (after Malm, W. C., Introduction to Visibility, National Park Service, May 1999)

absorption: a class of processes by which one material is taken up by another.

absorption coefficient: a measure of the ability of particles or gases to absorb photons; a number that is proportional to the number of photons removed from the sight path by absorption per unit length.

aerosol: a dispersion of microscopic solid or liquid particles in a gaseous medium, such as smoke and fog.

air parcel: a volume of air that tends to be transported as a single entity.

anthropogenic: produced by human activities.

apportionment: to distribute or divide and assign proportionately.

attenuation: the diminuation of quantity. In the case of visibility, attenuation or extinction refers to the loss of image-forming light as it passes from an object to the observer.

coagulation: the process by which small particles collide with and adhere to one another to form larger particles.

condensation: the process by which molecules in the atmosphere collide and adhere to small particles.

condensation nuclei: the small nuclei or particles with which gaseous constituents in the atmosphere (e.g., water vapor) collide and adhere.

deciview: a unit of visibility proportional to the logarithm of the atmospheric extinction, an index of haziness. Under many circumstances a change in one deciview will be perceived to be the same on clear and hazy days.

extinction: the attenuation of light due to scattering and absorption as it passes through a medium.

extinction coefficient: a measure of the ability of particles or gases to absorb and scatter photons from a beam of light; a number that is proportional to the number of photons removed from the sight path per unit length. See absorption.

haze: an atmospheric aerosol of sufficient concentration to be visible. The particles are so small that they cannot be seen individually, but are still effective in visual range restriction. See visual range.

homogenous nucleation: process by which gases interact and combine with droplets made up of their own kind. For instance, the collision and subsequent adherence of water vapor to a water droplet is homogenous nucleation. See nucleation.

hydrocarbons: compounds containing only hydrogen and carbon. Examples: methane, benzene, decane, et cetera.

hygroscopic: readily absorbing moisture, as from the atmosphere.

IMPROVE: Interagency Monitoring of PROtected Visual Environments.

isopleth: a line drawn on a map through all points having the same numerical value.

LAC: See Light-Absorbing Carbon.

light-absorbing carbon: carbon particles in the atmosphere that absorb light. Black carbon.

light extinction budget: the percent of total atmospheric extinction attributed to each aerosol and gaseous component of the atmosphere.

micron: a unit of length equal to one millionth of a meter; the unit of measure for wavelength.

nitrogen dioxide: a gas (NO2) consisting of one nitrogen and two oxygen atoms. It absorbs blue light and therefore has a reddish-brown color associated with it.

NO_2: See nitrogen dioxide.

nucleation: process by which a gas interacts and combines with droplets. See homogenous nucleation.

Perceived Visual Air Quality (PVAQ): an index that relates directly to how human observers perceive changes in visual air quality.

photon: a bundle of electromagnetic energy that exhibits both wave-like and particle-like characteristics.

plume blight: visual impairment of air quality that manifests itself as a coherent plume.

point source: 1) generally, any stationary source for which individual records are maintained for emission inventory purposes; distinguished from area source, often by a criterion involving emission rate, such as 100 tons per year. 2) A source of pollution that is point-like in nature. An example is the smoke stack of a coal-fired power plant or smelter. See source.

precursor emissions: emissions from point or regional sources that transform into pollutants with varied chemical properties.

Rayleigh scattering: the scattering of light by particles much smaller than the wavelength of the light. In the ideal case, the process is one of a pure dipole interaction with the electric field of the light wave.

relative humidity: the ratio of the partial pressure of water to the saturation vapor pressure, also called saturation ratio; often expressed as a percentage.

scattering (light): an interaction of a light wave with an object that causes the light to be redirected in its path. In elastic scattering, no energy is lost to the object.

scattering coefficient: a measure of the ability of particles or gases to scatter photons out of a beam of light; a number that is proportional to the amount of photons scattered per unit length.

secondary aerosols: aerosol formed by the interaction of two or more gas molecules and/or primary aerosols.

SO_2: See sulfur dioxide.

source: in atmospheric chemistry, the place, places, group of sites, or areas where a substance is injected into the atmosphere. Can include point sources, elevated sources, area sources, regional sources, multiple sources, et cetera.

sulfates: those aerosols that have origins in the gas-to-aerosol conversion of sulfur dioxide; of primary interest are sulfuric acid and ammonium sulfates.

sulfur dioxide: a gas (SO_2) consisting of one sulfur and two oxygen atoms. Of interest because sulfur dioxide converts to an aerosol that very efficiently scatters light. Also, it can convert into acid droplets consisting primarily of sulfuric acid.

visual range: the distance at which a large black object just disappears from view.

VOC: Volatile Organic Compound - gaseous hydrocarbon.