



**Stationary Source NO_x and PM Emissions
in the WRAP Region:**

**An Initial Assessment of Emissions, Controls,
and Air Quality Impacts**

Final Report of the WRAP Market Trading Forum

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NOTE: Section VI of this report is bound separately and available
on the WRAP Web site at <http://www.wrapair.org/forums/mtf/nox-pm.html>

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 delegation¹ of federal authority to implement 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 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 which are not present under existing law.

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.

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.

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.

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Prepared by WRAP Staff, the University of California at Riverside, and ENVIRON Corporation

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Prepared by Reaction Engineering Incorporated and Energy & Environmental Strategies

*Section VI Bound separately and available at
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SECTION I: EXECUTIVE SUMMARY

Background and Purpose

The primary purpose of this report is to provide the information necessary for western states and tribes to fulfill the requirements of Section 309(d)(4)(v) of the U.S. Environmental Protection Agency's (EPA) regional haze rule (40 CFR 51.309). Specifically, the rule states:

Provisions for stationary source NOx and PM. The plan submission must include a report which assesses emissions control strategies for stationary source NOx and PM, and the degree of visibility improvement that would result from such strategies. In the report, the State must evaluate and discuss the need to establish emission milestones for NOx and PM to avoid any net increase in these pollutants from stationary sources within the transport region, and to support potential future development and implementation of a multipollutant and possibly multisource market-based program. The plan submission must provide for an implementation plan revision, containing any necessary long-term strategies and BART requirements for stationary source PM and NOx (including enforceable limitations, compliance schedules, and other measures) by no later than December 31, 2008.

The regional haze rule provides the nine western states within the Grand Canyon Visibility Transport Region (GCVTR) an opportunity to submit state implementation plans (SIPs) containing policies and programs recommended in the final report of the Grand Canyon Visibility Transport Commission (June 1996). Such plans must be submitted by December 31, 2003. GCVTR states electing not to submit SIPs under Section 309 must submit SIPs under Section 308 of the regional haze rule in the 2005-07 time frame. Indian tribes have the option to submit tribal implementation plans (TIPs) under either section at any time. Moreover, the TIPs may include reasonably severable elements of the rule. A map of the WRAP region, mandatory federal Class I areas addressed by the regional haze rule, and WRAP state and tribal members is provided in **Figure I-1**.

A major provision of Section 309 is the control of stationary source sulfur dioxide (SO₂) emissions. The provision quoted above – for a report on stationary sources of NOx and PM – is to ensure that states begin the process of evaluating other pollutants from stationary sources. Hence, this report is meant as a starting point for a potentially multi-year process of evaluating stationary sources and designing further control strategies where appropriate. At a minimum, this process must include the determination of best available retrofit technology (BART) for certain sources¹ and the resulting visibility improvements and may include an alternative (e.g., emissions trading) program achieving greater reasonable progress towards the national visibility goal of no man-made impairment.

¹ BART-eligible sources are those which belong to one of 26 industrial categories, have the potential to emit at least 250 tons per year of a visibility-impairing pollutant, and were put into place between 1962 and 1977.

Organization of Report

This report is required for the GCVTR states choosing to submit SIPs under Section 309 of the region haze rule, but since all states must ultimately address stationary source NO_x and PM emissions from BART-eligible and potentially other stationary sources, the scope of this report goes somewhat beyond the nine states in the GCVTR and the limited number of BART-eligible sources in the WRAP region. For example, the air quality modeling evaluates the impact of emission changes within the GCVTR, but at all Class I areas within the contiguous WRAP region. Also, emission control technologies evaluated in Section VI were chosen on the basis of source types throughout the WRAP region, which do not differ substantially from those types within the GCVTR. They were also chosen on the basis of all existing source types, not just BART-eligible source types, partly because sources eligible for BART as a result of pollutants other than SO₂ have not yet been identified² and partly because an alternative program to BART could apply to a much broader universe of sources. By extending the scope of this report beyond the nine GCVTR states and beyond the BART-eligible stationary sources, it not only becomes applicable to a wider range of WRAP members and potential control strategies but serves to coordinate regional development of such strategies. It is also a more cost-effective approach than dealing with the nine GCVTR states separately.

As noted above, this report contains analyses and information to initiate a process for evaluating stationary sources of NO_x and PM – a process required of all states and open to Indian tribes as well. The Executive Summary contains highlights of the report, but it is also where specific issues raised in Section 309(d)(4)(v), such as interpollutant trading, are directly and succinctly discussed. This is intended to help Section 309 states and tribes address the literal requirements of the rule.

Table I-1 shows how analyses within this report were designed to address the specific requirements of the rule. Emissions data can be used to assess emission control strategies and to evaluate the need for milestones by illustrating the relative significance of different source categories to total NO_x and PM emissions, both now and in the future. Ambient monitoring data can be used to assess emission control strategies by illustrating where and how much nitrate and primary PM may contribute to actual visibility impairment. The conceptual model is intended to support this entire assessment and to provide a common, scientifically-founded understanding of western haze and the role of stationary sources in anticipation of a multi-year assessment of their importance and control options. The conceptual model is intended to provide a more complete framework than what can be provided alone by the air quality modeling and other assessments. Air quality modeling is used in a “sensitivity capacity” to assess emission control strategies, their degree of visibility improvement, and the need for milestones to prevent any future increase in emissions. A summary of current NO_x and PM control technologies and their costs, trends, and secondary and multi-pollutant impacts can be used to assess emission control technologies and the need for milestones to support multisource and multipollutant programs. This summary is also a useful starting point for addressing the BART requirements in Section 308 SIPs and Section 309 SIP revisions. All these analyses are expected to be updated and improved by the WRAP before such SIPs are adopted.

² The full universe of BART-eligible sources does not need to be identified until SIPs and SIP revisions are due in 2005-08, although this identification process is expected to begin in 2003.

Table I-1. Analyses Contained in this Report and Their Relation to the Requirements in Section 309(d)(4)(v) of the Regional Haze Rule.

Requirements of 309(d)(4)(v)	Emissions Data	Ambient Data	Conceptual Model	Air Quality Model	Control Technologies
Assess emission control strategies	X	X	X	X	X
Assess degree of visibility improvement that would result from such strategies		X	X	X	
Evaluate and discuss the need to establish milestones to avoid any net increase	X		X	X	
Evaluate and discuss the need for milestones to support potential future development of multipollutant and multisource market-based programs			X		X
Implementation plan revision by December 31, 2008					

Finally, emissions in Alaska are not presented because resources did not permit examination of a second emissions inventory database, nor are air quality modeling results presented for Alaska because the visibility modeling system for Alaska is currently under development. However, ambient monitoring data for Alaska are presented, and the conceptual model and control technology information are applicable as well.

Summary of Findings

Analysis of current and future emissions, ambient monitoring data, and very limited modeling results indicates that stationary source emissions of PM probably cause less than 2 percent of the region's visibility impairment, whereas stationary source NOx emissions result in nitrates³ that probably cause about 2 to 5 percent of the impairment on the Colorado Plateau⁴ and about 10 percent of the impairment in some areas of the Northern Plains, Pacific Northwest, and southern California. These findings may change as emission projections are updated and as ambient monitoring data from new sites is collected and analyzed, and especially as modeling capabilities are improved and as more data become available for the best and worst visibility days.

³ NOx emissions may also increase other PM species.

⁴ Some of the 20 percent haziest days, however, are dominated by nitrate.

Regardless of this or future regional technical analyses, the remedy embodied in reasonably attributable visibility impairment requirements under the regional haze rule is still available where BART-eligible sources of NO_x and PM are found to have direct impact on specific mandatory federal Class I areas. Furthermore, when considering NO_x and PM milestones, attention should be given to the reasonable progress goals in the regional haze rule, which generally entail steady and continuing emission reductions and no degradation on the best visibility days. Where stationary source NO_x emission reductions are appropriate, substantial reduction may be feasible with commercially-available technologies for about \$300 to \$1,200 per ton.

Assessment of Emission Control Strategies for Stationary Sources of NO_x and PM

Since this report is primarily a starting point for addressing stationary source NO_x and PM emissions, the control of which would not be determined until the 2005-08 timeframe, specific emission control strategies including such elements as level of control, applicability, and emissions trading are not addressed. Rather, this report identifies significant issues in assessing and designing such control strategies and provides some preliminary emissions, monitoring, and modeling results.

Stationary source NO_x emissions comprise about 25 percent of the WRAP NO_x emission inventory. One byproduct of NO_x emissions is nitrate aerosols. As described in Section III, during the 20 percent worst days on the Colorado Plateau, nitrate aerosols are responsible for about 6 to 18 percent of the man-made visibility impairment, although on some of these days they are responsible for as much as 40 to 60 percent. At some sites in the Northern Plains, Pacific Northwest, and southern California, nitrate aerosols are responsible for about 40 percent of the man-made visibility impairment during the 20 percent worst days. Assuming the contribution of stationary sources to nitrate is roughly equal to their proportion of the NO_x emission inventory, then stationary source NO_x emissions might be expected to contribute to about 2-5 percent of the Plateau's light extinction and to about 10 percent of the extinction in the Northern Plains, Pacific Northwest, and southern California.

Potentially increasing these contributions is the fact that stationary sources have unique emission characteristics which may disproportionately impact visibility (e.g., stack heights, transport distances, and proximity to Class I areas). Also, NO_x is known to influence the formation of non-nitrate secondary fine particles, to alter the characteristics of primary coarse particles, and its future significance may depend on future changes in sulfur and ammonia emissions. On the other hand, total NO_x emission in the WRAP region are expected to decrease by over 25 percent,⁵ primarily as a result of federal controls on mobile sources, and NO_x reductions may, in isolated instances, lead to local increases in nitrate concentrations.

To determine the effectiveness of stationary source NO_x controls, it is therefore important to have an air quality model that can account for the processes above. The WRAP's current modeling system, while sufficient for analyzing the regional impact of some emission changes, is not predicting nitrate concentrations well enough to support a decision on whether or not

⁵ Future NO_x emissions will, of course, depend on uncertain activity levels (e.g., oil and gas development) and regulatory developments (e.g., new source review reforms).

stationary source NO_x controls are an effective way at achieving reasonable progress – the results are simply too uncertain. Several improvements to the modeling system are underway, but until the model produces better nitrate results, other means of assessment will be necessary to determine the appropriate level of NO_x control in future SIPs.

Given the model's current performance, its use in this report is limited to the summer months (July through September), when it is performing best for nitrate, but also when nitrate concentrations are lowest. Furthermore, its use is limited to two “sensitivity analyses” – a 50 percent stationary source NO_x reduction and a 50 percent stationary source PM₁₀ reduction. The purpose of the sensitivity analyses is to gauge how nitrate and other atmospheric constituents might respond to significant changes in emissions, albeit such responses may be conservative given the model's limited application to the July – September time period. Results are summarized in the next part of this Executive Summary and discussed in more detail in Section V of the report.

As advancements are made towards understanding the air quality impacts of stationary source NO_x emissions, it is appropriate to investigate the potential level of control that can be achieved, and at what cost. Section VI of this report identifies 34 NO_x control technologies. Most of these are commercially available, while others are near-available. Those for coal-fired boilers (by far the largest category of stationary source NO_x emissions) typically achieve 30 to 50 percent NO_x control at a cost of about \$300 to \$1,200 per ton.⁶ Actual costs and emission reductions are highly dependent on boiler type, vintage, and configuration, fuel burned, and existing controls. For these reasons, it is important to have recent, extensive, and reliable data on the emission source population, some of which are lacking in the WRAP inventory, such as current control information, utility boiler heat rates, information on the process producing the emissions (e.g., from natural gas compressor stations), and utilization rates (e.g., from industrial internal combustion engines). Future WRAP emission inventories should include such information.

Visibility impairment may occur when a high portion of the NO_x emissions are in the form of (or converted to) nitrogen dioxide gas (NO₂). This may be important in urban hazes and in some coherent plumes, but is typically negligible for regional haze.⁷ For this reason, NO₂ is not included in the light extinction budget in the EPA's guidance for tracking reasonable progress.

Stationary source PM₁₀ emissions⁸ are currently 6 percent of the WRAP PM₁₀ inventory and may grow slightly to 7 percent by 2018. However, the WRAP inventory does not yet include wind-blown fugitive dust emissions (currently under development), which will tend to decrease the apparent contribution of stationary source PM₁₀ emissions. PM₁₀ accounts for nearly all the man-made light extinction, but the amount attributable to primary stationary source emissions is difficult to determine. Since most of the coarse fraction (between 2.5 and 10 microns) is believed to be primary and only some of the fine fraction is believed to be primary, the percent of visibility impairment attributable to coarse particles should approximate the contribution of

⁶ One exception is selective catalytic reduction (SCR), which is capable of achieving 70 to 90+ percent control at costs of approximately \$1,200 to \$2,000 per ton.

⁷ See, for example, Watson J., *Visibility: Science and Regulation*, J. of Air and Waste Manage. Assoc. 52:628.

⁸ As explained in Section II of this report, the term “PM” used in Section 309(d)(4)(v) of the regional haze rule is construed as primary PM₁₀ emissions.

primary PM₁₀ emissions from all sources. As shown in Section III, this is approximately 10 to 20 percent (on average) across most of the WRAP region, with generally lower percentages in the Pacific Northwest and higher percentages in the southeast part of the region. Assuming the contribution of stationary sources to ambient primary PM₁₀ is roughly equal to their proportion of the PM₁₀ emission inventory, then stationary source PM₁₀ emissions might be expected to contribute to less than 2 percent of the region's light extinction. Coupled with the fact that stationary source PM₁₀ emissions are relatively well controlled in the West, there does not appear to be much potential in a stationary source PM control strategy for purposes of regional haze. PM₁₀ emissions, however, appear to have a greater visibility impact per ton than NO_x emissions, as shown in Section V. Also, some PM₁₀ emission co-benefits may result from multi-pollutant technologies described in Section VI, so reductions in stationary source PM₁₀ emissions could conceivably be part of a broader air quality management strategy and/or part of a broader strategy to achieve reasonable progress under the visibility regulations – e.g., to prevent degradation on the cleanest days.

Finally, the appropriate level of stationary source NO_x and PM control, if any, should be informed by a comprehensive assessment, which may include some non-visibility impacts (to the extent they can be estimated within WRAP resources and with the WRAP's visibility-based tools) and the full costs and benefits of controls, not just those associated with facility compliance and visibility improvements. To this end, the WRAP is completing work on an economic analysis framework to conduct such analyses in a consistent and technically sound manner.

Degree of Visibility Improvement Resulting from Emission Control Strategies for Stationary Sources of NO_x and PM

Due to the complex role of NO_x emissions in the atmosphere, a regional-scale modeling effort is underway to more carefully assess the visibility improvement from potential control strategies. Given the model's current performance, its application in this report is limited to the June-September timeframe – when nitrate performance is best, but also when nitrate concentrations are lowest – and it is only used in a “sensitivity analysis mode”, meaning two scenarios were modeled to gauge how nitrate and other atmospheric constituents might respond to significant changes in emissions: one in which emissions of NO_x are reduced by 50 percent (412,000 tpy) from stationary sources in the GCVTR with emissions of NO_x greater than 100 tpy, and an identical scenario for PM₁₀ (98,000 tpy).

Current modeling results indicate that the stationary source NO_x and PM₁₀ emission reductions described above would reduce regional haze (in Mm⁻¹) by 0.5 percent and 0.4 percent, respectively, when averaged across all sites in the GCVTR over the June-September time period, although some areas would see an improvement of 2 to 5 percent on some days.⁹ On a purely ton-per-ton basis, reductions in stationary source PM₁₀ emissions appear to yield greater regional haze benefits than reductions in NO_x emissions, since they produced almost the same visibility benefit at one-fourth the emission change.

⁹ These results are similar to the more general assessment made in Section IV (see page IV-21).

The NO_x emission reductions had the greatest impact in southern CA, where ammonium nitrate concentrations in Class I areas are predicted to decrease by 0.15 to 0.25 ug/m³. A second area of reductions is predicted in the central-east Rocky Mountains, especially in north-central CO. Although the reductions are not as large as in southern CA (0.04 to 0.11 ug/m³), 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 SO₂ backstop emissions trading program, or Annex. In the case of the Annex, an SO₂ 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 than the sulfate concentrations, but the response of nitrate to NO_x reductions is similar in proportion to the response of sulfate to SO₂ reductions.

NO_x changes appear to 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 SO₂ 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.

The PM₁₀ emission reductions had a maximum impact of about 0.1 to 0.5 ug/m³, or about 4 to 8 percent. Compared to the NO_x reduction scenario, reductions in ambient PM₁₀ are more dispersed, with a greater number of local maximums. This may reflect the fact that there are a fewer number of large PM₁₀ sources than large NO_x sources and that much of the PM₁₀ emissions are coarse particles, with shorter transport distances.

All modeling results in this report are subject to change after the modeling improvements described in Section V are implemented. Results may also change when compiled for the best and worst visibility and nitrate days throughout the year, as opposed to a three-month summer average. For reasons described in Section V, the three-month summer average probably tends to reduce the apparent impact of emission changes.

The Need to Establish Milestones to Avoid Any Net Increase in NO_x and PM Emissions from Stationary Sources

Sensitivity modeling was also done to evaluate the impacts of a 25 percent simultaneous increase in stationary source NO_x and PM₁₀ emissions. The increase in nitrate formation was approximately half the magnitude of the decrease resulting from the NO_x reduction scenario. However, the increase in PM₁₀ (nitrates and primary particulates) and visibility impairment were about the same in the 25 percent increase scenario as in the two 50 percent decrease scenarios because both pollutants were increased simultaneously.

The need to establish milestones to avoid any net increase in NO_x and PM emissions from stationary sources should be determined when more complete and accurate modeling results (and ambient data analyses) are available, prior to submittal of the Section 309 SIP revisions in 2007-08. In addition to the modeling results per se, consideration should be given to meeting the reasonable progress goals of the regional haze rule, which generally imply a steady and continuous reduction in emissions and a prevention of degradation on the best visibility days.

The Need for Milestones to Support Potential Future Development of Multipollutant and Multisource Market-Based Program

Milestones are not absolutely necessary to support potential multipollutant and multisource market-based programs. For example, a group of sources could theoretically comply with an SO₂ milestone by reducing emissions of other pollutants, and/or in other sectors, for which no milestones exist. Regardless, the key issues raised by such programs do not involve the milestones as much as the uncertainties associated with such emissions trading.

As discussed in Section IV, there are a number of issues that must be addressed. Most of these relate to the visibility-improvement value of eliminating a ton of emissions. Different pollutants have different impacts on visibility on a per ton basis. Establishing an “equivalency ratio” to allow X tons of one pollutant to be reduced in lieu of Y tons of another would require significant analysis, and the certainty of such values may be suspect (especially for NO_x) or insufficient to ensure a specific level of visibility improvement. Moreover, the equivalency ratio between two pollutants may vary across the region, between seasons, and possibly over time as the composition of the atmosphere changes. These same uncertainties (involving trades among pollutants) also pertain to trades among a single pollutant, most notably NO_x, as nitrate concentrations are highly variable by season and location.

Trading across emission source categories poses a couple of additional issues. First, all categories would have to have sufficient emissions monitoring to validate emission credits, and monitoring of non-stationary sources is generally less accurate and verifiable than monitoring of stationary sources. Second, concentrated emissions from stacks may have different impacts than diffuse emissions at ground-level.

The uncertainties identified above could be reduced through further research, and the remaining uncertainties could be further addressed by limiting the emission trading markets to certain subregions, pollutants, or seasons where the equivalency ratios are fairly certain and stable. However, such market restrictions could limit the economic benefits the market is intended to provide. In short, some level of multipollutant and/or multisource market based program could be a feasible way of meeting the long-term national visibility goal, and several of the technologies described in Section VI of this report are capable of multipollutant reductions, but substantially more research should be performed before committing to such programs, especially in the 2007-08 timeframe.

Figure I-1. Map of the WRAP Region, Members, and Mandatory Federal Class I Areas.

