National Park Service
U.S. Department of the Interior

Natural Resource Program Center

# Federal Land Managers' Air Quality Related Values Work Group (FLAG)

## *Phase I Report—Revised (2010)*

Natural Resource Report NPS/NRPC/NRR—2010/232

**ON THE COVER**

Courthouse Towers, Arches National Park, Utah.
Photo by Debbie Miller.

**THIS PAGE:**

Jumping Cholla, Superstition Wilderness, Arizona.
Photo by Steve Boutcher

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This guidance document was jointly prepared by the National Park Service, U.S. Forest Service, and the U.S. Fish and Wildlife Service, in collaboration with the Environmental Protection Agency. Guidance contained herein has been reviewed by subject matter experts and the general public through formal public review and comment period. This guidance document provides information for Federal Land Managers, permitting authorities, and permit applicants to use when assessing air quality impacts to air quality related values. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

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**NPS 999/105412, October 2010**

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, D.C. 20240

OCT -7 2010

Dear FLAG User:

We are pleased to provide the final revised FLAG report (FLAG 2010). FLAG was formed at the request of permit applicants and State permit review authorities to develop a more consistent and objective approach for the Federal Land Managers (FLMs), *i.e.*, National Park Service, U.S. Fish and Wildlife Service, and U.S. Department of Agriculture Forest Service, to evaluate air pollution effects on their Air Quality Related Values (AQRVs). The FLAG effort focused on how air pollutants – primarily particulate matter, nitrogen dioxide, sulfur dioxide, nitrates, sulfates, ozone – affect the health and status of resources in areas managed by the three agencies. FLAG subgroups concentrated on four key issues: (1) visibility; (2) aquatic and terrestrial effects of wet and dry pollutant deposition; (3) terrestrial effects of ozone; and (4) process and policy issues. In December 2000, the FLMs published a final Phase I report (FLAG 2000). Based on knowledge gained and regulatory developments since FLAG 2000, the FLMs believe certain revisions to FLAG 2000 are now appropriate. The final revised FLAG 2010 report reflects those changes.

The FLAG 2010 report contains a wealth of information and should continue to be a very useful tool; we support its recommendations. The FLAG report is guidance and reflects agency direction, but it is not a rule. Nevertheless, we encourage all FLMs, permitting authorities, permit applicants, and other interested parties to take advantage of the helpful information contained in the FLAG report when assessing air pollution impacts on AQRVs.

We want to thank the many people who contributed to this important and worthwhile project.

Sincerely,

Thomas L. Strickland
Assistant Secretary for Fish and Wildlife and Parks
Department of the Interior

Sincerely,

Harris Sherman, Under Secretary
Natural Resources and the Environment
Department of Agriculture

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# Preface to this Edition of the FLAG Phase I Report (New)

Under the Clean Air Act, the Federal Land Manager (FLM) and the Federal official with direct responsibility for management of Federal Class I parks and wilderness areas (i.e., Park Superintendent, Refuge Manager, Forest Supervisor) have an affirmative responsibility to protect the air quality related values (AQRVs) (including visibility) of such lands, and to consider whether a proposed major emitting facility will have an adverse impact on such values. The FLM's decision regarding whether there is an adverse impact is then conveyed to the permitting authority – usually a State agency – for consideration in its determinations regarding the permit. The permitting authority's determinations generally consider a wide range of factors, including the potential impact of the new source or major modification on the AQRVs of Class I areas, if applicable.

Both State permitting agencies and permit applicants requested that the FLMs provide better consistency pertaining to their role in the review of new source permit applications near Federal Class I areas. To address this concern, the FLMs formed the Federal Land Managers' Air Quality Related Values Work Group (FLAG). The official "FLM" is the Secretary of the department with authority over the Federal Class I areas (or the Secretary's designee). For the Department of the Interior, the Secretary has designated the Assistant Secretary for Fish and Wildlife and Parks as the FLM, whereas the Secretary of Agriculture has delegated the FLM responsibilities to the Regional Forester, and in some cases, the Forest Supervisor.

The purpose of FLAG is twofold: (1) to develop a more consistent and objective approach for the FLMs to evaluate air pollution effects on public AQRVs in Class I areas, including a process to identify those resources and any potential adverse impacts, and (2) to provide State permitting authorities and potential permit applicants consistency on how to assess the impacts of new and existing sources on AQRVs in Class I areas, especially in the review of Prevention of Significant Deterioration (PSD) of air quality permit applications. Under the Clean Air Act, the FLM formal "affirmative responsibility" role in the permitting process is limited to the extent a proposed new or modified source may affect AQRVs in a Class I area.[1]


**Adult Brown Pelicans on Breton Island National Wildlife Refuge, Louisiana.**
Credit: USFWS

FLAG members include representatives from three of the federal land management agencies that administer Federal Class I areas: the U.S. Forest Service (USFS), under the Department of Agriculture, and the National Park Service (NPS) and U.S. Fish and Wildlife Service (FWS) under the Department of the Interior, hereafter referred to as "the Agencies" or the "FLMs." In addition, five Tribal governments each administer their redesignated Class I areas, and the Bureau of Land Management (BLM) jointly administers four mandatory Federal Class I areas with the USFS. BLM is not a member of FLAG. However, because BLM does manage federal PSD Class I lands, as well as large amounts of acres in the vicinity of many FLAG Agencies' Class I areas, they may apply, when appropriate, the assessment methodologies outlined in the FLAG report. Applicants with the potential to adversely impact visibility or other AQRVs at PSD Class I areas administered by the BLM should contact that agency directly to discuss their considerations. The Agencies review permit applications for projects that may impact their areas, and make recommendations to their respective FLM as to whether or not those impacts might be considered adverse. The FLM will then make the final decision regarding the nature of the potential impacts to AQRVs, which is then conveyed to the permitting authority for its consideration.

In December 2000, after undergoing a public review and comment process that included a 90 day public comment period announced in the *Federal Register* and a public meeting, the FLMs published a *FLAG Phase I Report* (FLAG 2000), along with an accompanying "Response to Public Comments" document. The FLAG 2000 report described the work accomplished in Phase I of the FLAG effort. FLAG 2000 provided State permitting authorities and potential permit applicants a consistent methodology for conducting Class I area impact analyses. At that time, the Agencies envisioned a FLAG Phase II to address unresolved issues

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[1] Nevertheless, the FLMs are also concerned about resources in Class II parks and wilderness areas because they have other mandates to protect those areas as well. The information and procedures outlined in this document are generally applicable to evaluating the effect of new or modified sources on the AQRVs in both Class I and Class II areas, including the evaluation of effects as part of Environmental Assessments and/or Environmental Impact Statements under the National Environmental Policy Act (NEPA). However, FLAG does not preclude more refined or regional analyses being performed under NEPA or other programs.

including those that will require research and the collection of new data. However, resource constraints have prevented the Agencies from embarking on a formal FLAG Phase II process, but the Agencies have made significant progress in obtaining effects-based information as part of their resource-protection responsibilities. This information is included in this revised report.

The Agencies formed three separate subgroups to deal with area specific technical and policy issues associated with visibility impairment, ozone effects on vegetation, and effects of pollutant deposition on soils and surface waters. FLAG 2000 consolidated the results of those three subgroups.

FLAG 2000 included recommendations for completing and evaluating New Source Review (NSR) projects that may affect federally protected areas. It was intended to be a screening tool to help the Agencies and permit applicants determine whether impacts would be negligible. It was not intended to provide a bright-line test that would allow one to determine whether or not a proposed source of air pollution would cause or contribute to an adverse impact on AQRVs. That determination remains a project-specific management decision of the FLM. Among other factors, the FLMs' assessment of whether or not an adverse impact would occur is based on the sensitivity of the AQRVs at the particular federally protected area under consideration, and the magnitude, frequency, duration, timing, and geographic extent of the estimated new source impacts. This report (FLAG 2010) reaffirms these intentions.

FLAG 2000 has been a useful tool to the Agencies, State permitting authorities, and permit applicants. It was intended to be a working document that would be revised as necessary as the Agencies learn more about how to better assess the health and status of AQRVs. Based on knowledge gained and regulatory developments since FLAG 2000, the Agencies believe certain revisions to FLAG 2000 are now appropriate. This revised report (FLAG 2010) reflects those changes. However, it is important to emphasize that in this revision the Agencies have made certain changes to update specific information and data, but retain intact much of the background and general information contained in FLAG 2000 (e.g., Appendices A through H). Therefore, while this version replaces FLAG 2000, FLAG 2010 does not constitute a comprehensive update of all the information and material contained in FLAG 2000. Instead, the Agencies have focused their efforts on those areas of FLAG 2000 that have received the most attention and concern from permit applicants and permitting authorities. In that regard, the Agencies have included substantial changes to the visibility analysis sections, as well as included a more detailed discussion of the factors that the FLMs will use in the decision making process for an adverse impact determination. The Agencies have also taken this opportunity to discuss some key regulatory developments since FLAG 2000, as well as update some information in the FLAG 2000 deposition and ozone sections. To aid the FLAG user wanting to focus on the most recent changes, the Agencies have identified those new and revised sections throughout the FLAG 2010 report.

The most significant changes in this FLAG 2010 revision are summarized as follows:

- Adopts similar criteria derived from EPA's 2005 Best Available Retrofit Technology (BART) guidelines for the Regional Haze Rule to screen out from AQRV review those sources with relatively small amounts of emissions located a large distance from a Class I area (i.e., Q/D ≤ 10, for sources located greater than 50 km away).
- Utilizes the most recent EPA estimates to determine annual average or 20% best natural visibility conditions for Class I areas, using the new EPA-approved visibility algorithm.
- Adopts criteria derived from the 2005 BART guidelines that utilizes monthly average relative humidity adjustment factors to minimize the effects of weather events (i.e., short-term meteorological phenomena) on modeled visibility impacts.
- Adopts criteria derived from the 2005 BART guidelines that sets a 98th percentile value to screen out roughly seven days of haze-type visibility impairment per year.
- Includes deposition analysis thresholds and concern thresholds for nitrogen and sulfur deposition impacts on vegetation, soils, and water.
- Increases transparency and consistency of factors considered for adverse impact determinations.

A comparison of these FLAG 2010 changes to information contained in FLAG 2000 is provided in Table 1:

Other changes of note included in FLAG 2010 are:

- Clarifies the near field visibility analysis techniques for analyzing plumes or layers viewed against a background;
- Expands discussion of "Critical Loads" to reflect some significant developments in this area since FLAG 2000;
- Updates ozone sensitive species lists contained in Appendix 3.A of the FLAG 2000 report, but now includes that information on individual agency web sites rather than in the FLAG 2010 report;
- Replaces Appendix 3.B of FLAG 2000 (W126 and N100 ozone values) with current information on the individual agency web sites;
- Updates the information contained in Table D-2 of FLAG 2000 to reflect current information, but now includes that information on individual agency web sites rather than in the FLAG 2010 report;
- Replaces the dated sulfate, nitrate, and ammonium ion concentration maps (Figures D-2, D-3, and D-4 of FLAG 2000), with a reference to the NADP site for current trends data.

**Table 1. FLAG 2000 vs. FLAG 2010 Analyses**

| | FLAG 2000 | FLAG 2010 |
|---|---|---|
| Annual emissions/Distance (Q/D) screening criteria. (Not applicable for Class I increment analyses). | None | ≤10 (sum of certain pollutant emissions (TPY) divided by distance (km) from Class I area; applies to all AQRVs, not just visibility. See section 3.2. |
| Background Visibility Conditions. | Based on annual average natural, using NAPAP estimates. | Based on annual average natural, or 20% best natural, using EPA data from Regional Haze Rule development. See section 3.3.3. |
| Relative Humidity Adjustment Factor (f(RH)). | Hour-by-hour (with RH capped at 98%). | Monthly average (with RH capped at 95%). See section 3.3.3. |
| First Level Screening Model. | CALPUFF or CALPUFF-lite. | CALPUFF only. See section 3.3.3. |
| Visibility Assessment Criteria. | Maximum modeled value. | 98th percentile modeled value at any receptor. See section 3.3.3. |
| Deposition Analysis Thresholds/ Concern Thresholds | None | Provided for nitrogen and sulfur deposition. See section 3.5.6. |
| Adverse Impact Determination Criteria. | "Likely to Object" if 10% threshold exceeded; regulatory factors implicitly considered. | Adverse impact determination process more explicit; considers regulatory and other factors. See sections 4.2-4.4 |

# Executive Summary (Revised)

The Federal Land Managers' Air Quality Related Values Work Group (FLAG) formed to develop a more consistent approach for the Federal Land Managers (FLMs) to evaluate air pollution effects on resources. As discussed in the Preface, the *FLAG Phase I Report* (FLAG 2000) is being revised in part at this time. The primary—but not sole—focus of FLAG is the New Source Review (NSR) program, especially in the review of Prevention of Significant Deterioration (PSD) of air quality permit applications. The goals of FLAG have been to provide consistent policies and processes both for identifying air quality related values (AQRVs) and for evaluating the effects of air pollution on AQRVs, primarily in Federal Class I air quality areas, but also in some instances, in other national parks, national forests, national wildlife refuges, wilderness areas, and national monuments. Federal Class I areas are defined in the Clean Air Act as national parks over 6,000 acres and wilderness areas and memorial parks over 5,000 acres, established as of 1977. All other FLM areas are designated Class II. Maps of the Agencies' Federal Class I areas are provided in Appendix E.

FLMs have an "affirmative responsibility" to protect AQRVs. In this respect, the FLM role consists of considering whether emissions from a new or modified source may have an adverse impact on AQRVs and providing comments to permitting authorities (States or EPA). FLMs have no permitting authority under the Clean Air Act, and they have no authority under the Clean Air Act to establish air quality-related rules or standards. It is important to emphasize that the FLAG report only explains factors and information the FLMs expect to use when carrying out their consultative role. It is separate from Federal regulatory programs.

FLAG members include representatives from the three primary agencies that administer the nation's Federal Class I areas: the U.S. Forest Service (USFS), the National Park Service (NPS), and the U.S. Fish and Wildlife Service (FWS). (Subsequently in this report, these three agencies collectively will be referred to as "the Agencies" or the "FLMs." Class I and Class II air quality areas are called "FLM areas" in this report.) Appendix F contains a list of participants that worked on the original FLAG 2000 report.

This report describes the work accomplished in Phase I of the FLAG effort as revised to reflect current developments. That work includes identifying policies and processes common to the FLMs (herein called "commonalities") and developing new policies and processes using readily available information. This report provides State permitting authorities and potential permit applicants a consistent and predictable process for assessing the impacts of new and existing sources on AQRVs, including a process to identify those AQRVs and potential adverse impacts. The report also discusses considerations unrelated to new source review and managing emissions in Federal areas. If and when the Agencies embark on Phase II, FLAG will address unresolved issues including those that will require research and the collection of new data.

**Marble Mountain Wilderness, California.**
Credit: Steve Boutcher

This revised *FLAG Phase I Report* consolidates the results of the FLAG Visibility, Ozone, and Deposition subgroups. The chapters prepared by these subgroups contain issue-specific technical and policy analyses, recommendations for evaluating AQRVs, and information for completing and evaluating NSR permit applications. This information and the associated recommendations are intended for use by the FLMs, permitting authorities, NSR permit applicants, and other interested parties. The report includes background information on the roles and responsibilities of the FLMs under the NSR program.

This document includes recommendations for completing and evaluating NSR applications that may affect Class I FLM areas. This information can also be used to evaluate impacts on Class II parks and wilderness areas. It does not provide a universal formula that would, in all situations, allow one to determine whether or not a source of air pollution causes or contributes to an adverse impact. That determination remains a project-specific management decision, the responsibility for which remains with the FLM, as delegated by Congress. The FLM's assessment of whether or not an adverse impact would occur is based on the sensitivity of the AQRVs at the particular FLM area under consideration, as well as the consideration of several other factors, including the magnitude, frequency, duration, timing, and geographic extent of the new source's impacts.

To provide information for the FLM's assessment of adverse impacts on AQRVs, the permit applicant should identify the potential impacts of the source on all applicable AQRVs of that area. An FLM may ask that an applicant address any or all of the areas of concern. The primary areas of concern to the FLMs with respect to air pollution emissions are visibility impairment, ozone effects on vegetation, and effects of pollutant deposition on soils and surface waters.

The *FLAG Phase I Report* also describes the FLAG effort, including the FLAG approach, organization, and plans for future FLAG work. Appendix A of the report contains a glossary of technical terms, abbreviations, and acronyms used in the report along with associated definitions. Appendix G provides a list of all references cited in the FLAG report.

The key recommendations developed by the Visibility, Ozone, and Deposition subgroups are summarized below, and updated in part in this FLAG 2010 revision. However, for all three subject matter areas, FLAG recommends that the permit applicant consult with the appropriate permitting authority and with the FLM for the affected area(s) for confirmation of preferred procedures. This consultation should take place in the early stages of the permit application process.

## Recommendations for Evaluating Visibility Impacts (Revised)

FLAG provides recommendations, specific procedures, and interpretation of results for assessing visibility impacts of new or modified sources on Class I area resources.[2]

FLAG addresses assessments for sources proposed for locations near (generally within 50 km) and at large distances (greater than 50 km) from these areas. The key components of the recommendations are highlighted below.

In general, FLAG recommends that an applicant:

- Apply the Q/D test (see "INITIAL SCREENING TEST" below) for proposed sources greater than 50 km from a Class I area to determine whether or not any further visibility analysis is necessary.
- Consult with the appropriate regulatory agency and with the FLM for the affected Class I area(s) or other affected area for confirmation of preferred visibility analysis procedures.
- Obtain FLM recommendation for the specified reference levels (estimate of natural conditions) and, if applicable, FLM recommended plume/observer geometries and model receptor locations.
- Apply the applicable EPA Guideline, steady-state models for regions within the Class I area that are affected by plumes or layers that are viewed against a background (generally within 50 km of the source).
    - Calculate hourly estimates of changes in visibility, as characterized by the change in the color difference index ($\Delta E$) and plume contrast (C), with respect to natural conditions, and compare these estimates with the thresholds given in section 3.3.3.
- For regions of the Class I area where visibility impairment from the source would cause a general alteration of the appearance of the scene (generally 50 km or more away from the source or from the interaction of the emissions from multiple sources), apply a non-steady-state air quality model with chemical transformation capabilities (refer to EPA's *Guideline on Air Quality Models*), which yields ambient concentrations of visibility-impairing pollutants. At each Class I receptor:
    - Calculate the change in extinction due to the source being analyzed, compare these changes with the reference conditions, and then compare these results with the thresholds given in section 3.3.3.
    - Utilize estimates of annual average natural visibility conditions for each Class I area as presented in Table 6, unless otherwise recommended by the FLM or permitting authority. Alternative estimates of visibility conditions are provided in Table 5 for consistency with State agencies that elected to use 20% best visibility for regional haze or BART implementations, or when FLMs recommend using the 20% best visibility as natural background.
- If first-level modeling results are above levels of concern, continue to consult with the Agencies to discuss other considerations (e.g., possible impact mitigation, more refined analyses).

This review process for distant/multi-source applications is portrayed schematically in Figure 1.

## Recommendations for Evaluating Ozone Impacts (Revised)

- FLM actions or specific requests on a permit application will be based on the existing air pollution situation at the area they manage. These conditions include (1) whether or not actual ozone damage has occurred in the area, and (2) whether or not ozone exposure levels occurring in the area are high enough to cause damage to vegetation (i.e., phytotoxic $O_3$ exposures). Figure 2 shows the FLM review process to assess ozone impacts for a project that exceeds the initial annual emissions over distance (Q/D) screening criteria. As noted in Figure 2, ambient ozone concentrations are considered along with data from exposure response studies (EPA 2007b) to determine whether a source will cause or contribute to phytotoxic

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[2] Nevertheless, the FLMs are also concerned about resources in Class II parks and wilderness areas because they have other mandates to protect those areas as well. The information and procedures outlined in this document are generally applicable to evaluating the effect of new or modified sources on the AQRVs in both Class I and Class II areas, including the evaluation of effects as part of Environmental Assessments and/or Environmental Impact Statements under the National Environmental Policy Act (NEPA). However, FLAG does not preclude more refined or regional analyses being performed under NEPA or other programs.

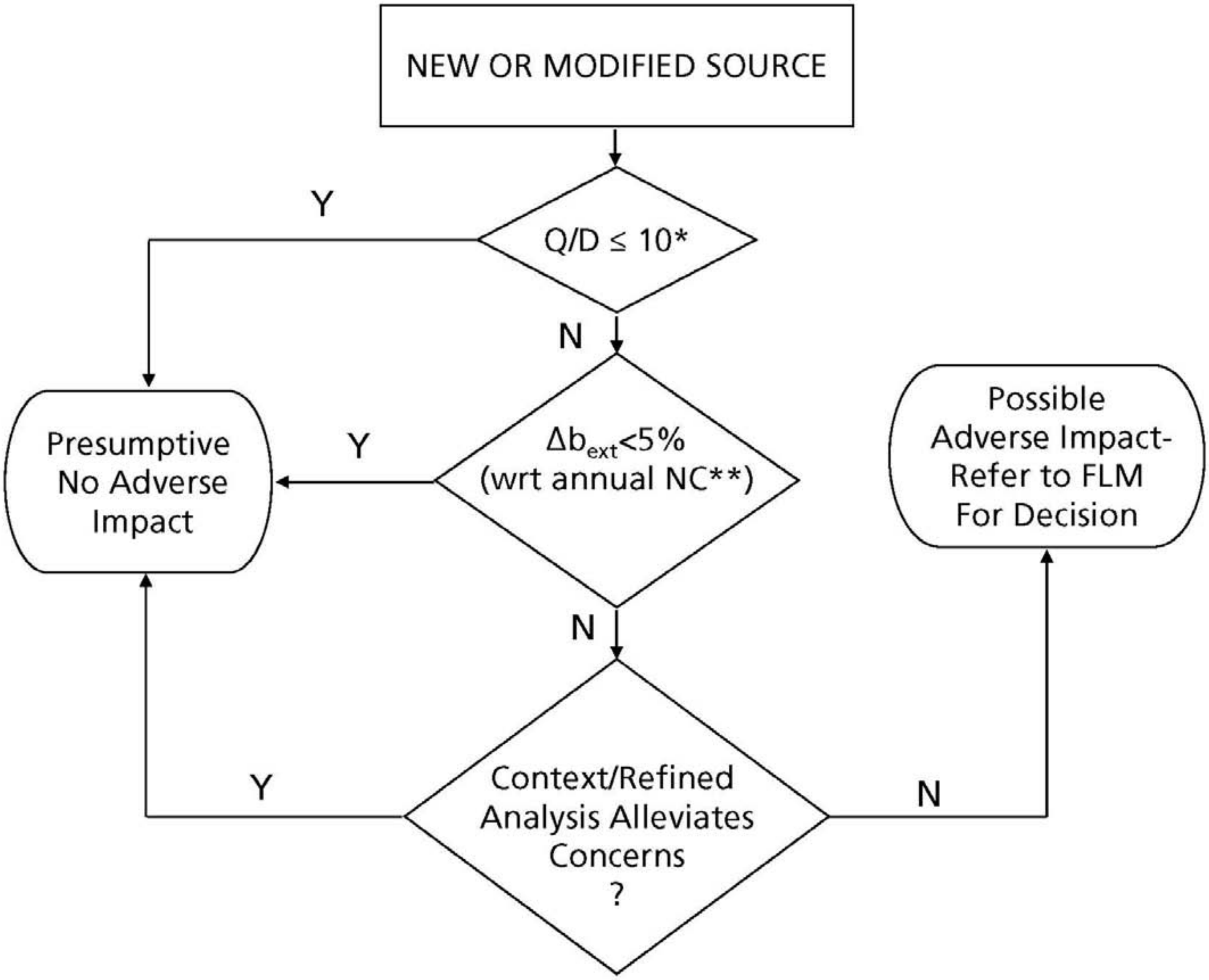

**Figure 1. Procedure for Visibility Assessment for Distant/Multi-Source Applications (Revised)**
*Q/D test only applies to sources located greater that 50 km from a Class I area.
**Difference Change in the 98th percentile with respect to (wrt) the annual average Natural Condition (NC). Applicant should use the 20th percentile best natural condition background if recommended by the FLM or permitting authority.

ozone levels (i.e., levels toxic to plants) at the affected site. The FLM may ask the applicant to calculate the ozone exposure values if these data are not already available. Ozone damage to vegetation is determined from field observations at the impacted site.

- Oxidant stipple necrosis on plant foliage and ozone-induced senescence infer adverse physiological or ecological effects, and are considered to be damage if they are determined to have a negative impact on aesthetic value.
- Established ozone metrics to describe ozone exposure are referenced.
- $NO_x$ and VOC emissions are of concern because they are precursors of ozone. Current information indicates most FLM areas are $NO_x$ limited. Until we determine the VOC or $NO_x$ status of each area, we will focus on $NO_x$ emission sources.

## Recommendations for Evaluating Deposition Impacts (Revised)

For a project that exceeds the initial annual emissions over distance (Q/D) screening criteria, the permit applicant should consult with the appropriate regulatory agency and FLM for the affected area(s) to determine if a deposition impact analysis should be done (i.e., expected sulfur and/

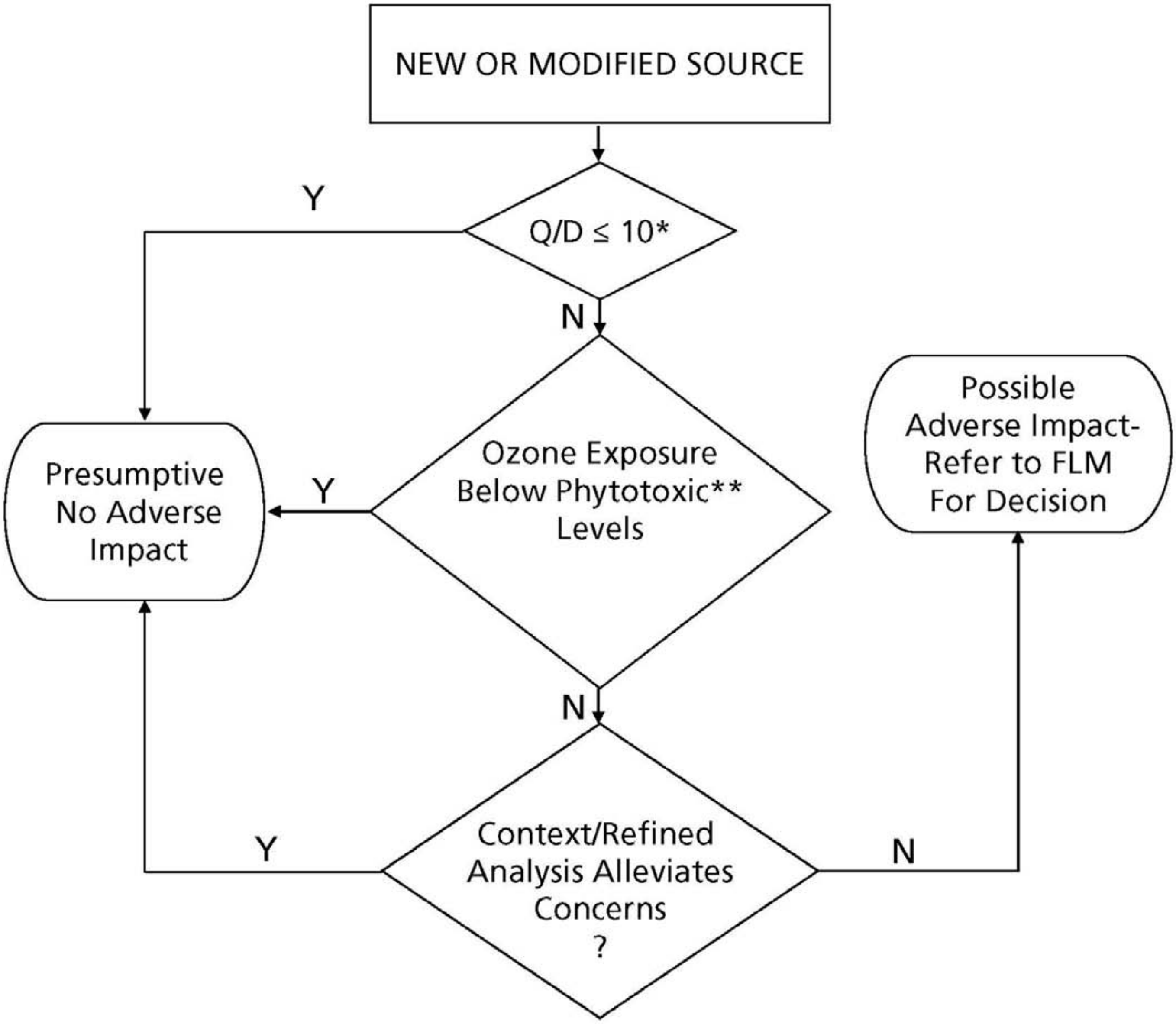

**Figure 2. FLM Assessment of Potential Ozone Effects from New Emissions Source (Revised)**
*Q/D test only applies to sources located greater that 50 km from a Class I area.
**Note: Ambient ozone concentrations are considered along with data from exposure response studies (EPA 2007b) to determine whether a source will cause or contribute to phytotoxic ozone levels (i.e., levels toxic to plants) at the affected site.

or nitrogen deposition impacts are above the Deposition Analysis Threshold (DAT) or concern threshold (see section 3.5.6). Please note that although mercury and other toxic emissions are of interest to the FLM, the deposition impact analyses discussed here applies only to nitrogen and sulfur emissions. If an analysis is advised, the permit applicant should obtain available information on Class I AQRVs, critical loads, and concern thresholds from the FLM. In addition, the applicant should refer to section 3.5.6 'Recommendations for Evaluating Potential Effects from Proposed Increases in Deposition to an FLM Area' section of the Deposition Chapter. The following steps summarize that process.

- From the respective Agency web sites, identify available on-site or representative wet and dry deposition data for the FLM area.
- Estimate the future deposition rate by adding the existing rate, the new emissions' contribution to deposition, and the contribution of sources permitted but not yet operating, while subtracting emission reductions that will occur before the proposed source begins operation. Modeling of new, reduced, and permitted but not yet operating emissions' contribution to deposition should be conducted following EPA recommendations.
- Compare the future deposition rate with the recommended screening criteria (e.g., critical load,

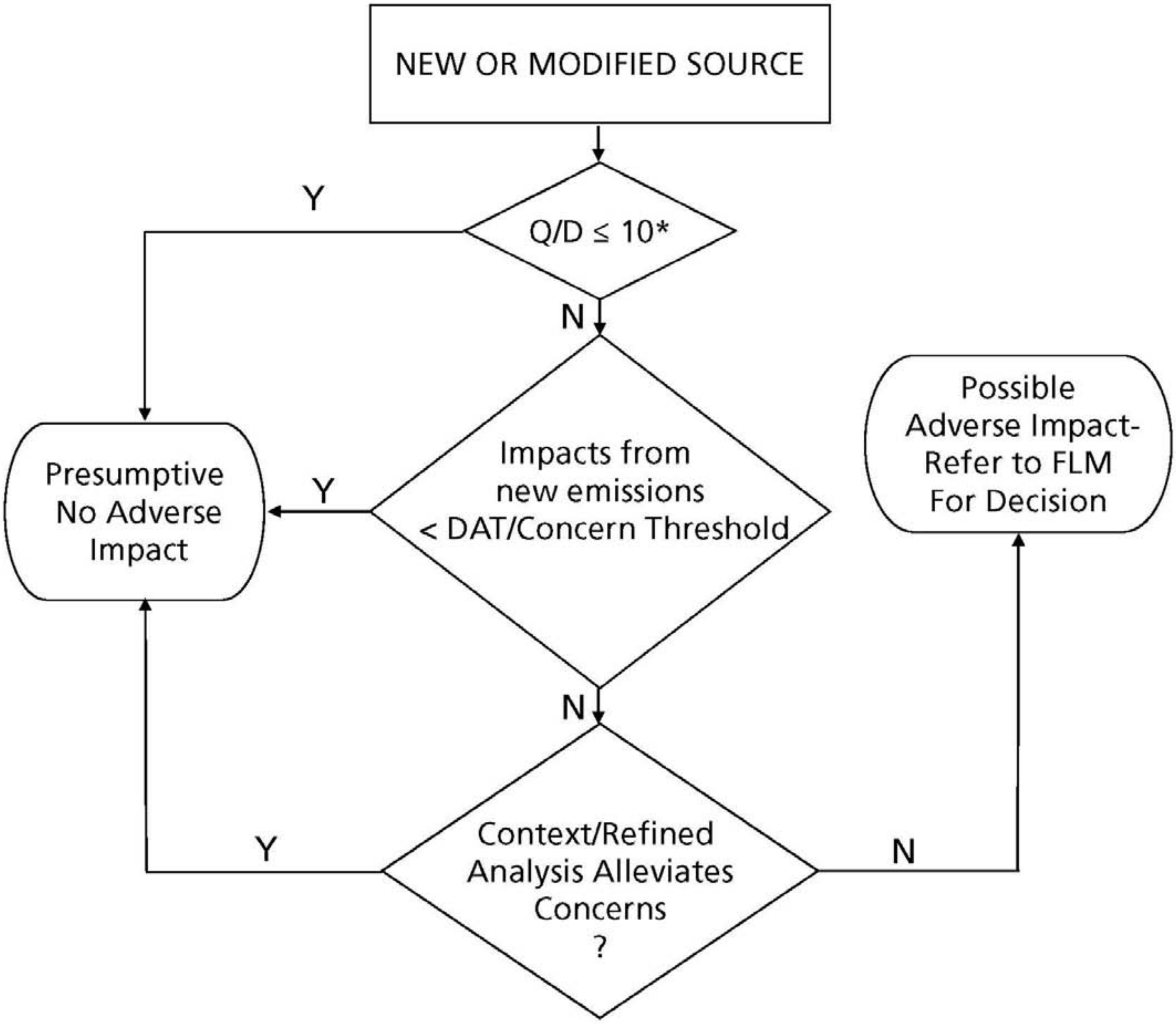

**Figure 3. FLM Assessment of Potential Deposition Effects from New Emissions Sources (Revised)**
*Q/D test only applies to sources located greater that 50 km from a Class I area.

concern threshold, or screening level value) for the affected FLM area. A list of documents summarizing these screening criteria, where available, can be found in Appendix G.

  - Information for USFS Class I areas is also available at: http://www.fs.fed.us/air
  - NPS and FWS Class I area information is available at: http://www.nature.nps.gov/air

- Figure 3 shows the FLM review process to assess deposition impacts from new emission sources.

# 1. Background

## 1.1. History (Revised)

The Clean Air Act Amendments of 1977 give Federal Land Managers (FLMs) an "affirmative responsibility" to protect the natural and cultural resources of Class I areas from the adverse impacts of air pollution (see Appendix B: 'Legal Framework for Managing Air Quality and Air Quality Effects on Federal Lands'). FLM responsibilities include the review of air quality permit applications from proposed new or modified major pollution sources near these Class I areas. If, in its permit review, an FLM demonstrates that emissions from a proposed source will cause or contribute to adverse impacts on the air quality related values (AQRVs) of a Class I area, the permitting authority, typically the State, can deny the permit.

The FLMs' role in the reviewing of permit applications focuses on impacts to Class I areas.[3] Individually, FLMs have developed different approaches to identifying AQRVs and defining adverse impacts on AQRVs in Class I areas. For example, in 1988, the U.S. Department of Agriculture Forest Service (USFS) conducted a national screening process to identify the AQRVs for each of its Class I areas. Using this national process as a starting point, each USFS Region refined the screening parameters and identified sensitive AQRVs for many Class I areas. However, this resulted in differences in the approaches and levels used by USFS Regions. The U.S. Department of the Interior National Park Service (NPS) and the U.S. Fish and Wildlife Service (FWS) have adopted a case-by-case approach to permit review, considering the most recent information available for each area. NPS and FWS have included lists of sensitive AQRVs for their Class I areas in their Air Resources Information System (ARIS) database.

### 1.1.1. FLAG Approach (Revised)

Air resource managers from the USFS, NPS, and FWS recognized the need for a more consistent approach among their agencies with respect to their efforts to protect AQRVs. In April 1997, an interagency Work Group was formed whose objective was "to achieve greater consistency in the procedures each agency uses in identifying and evaluating AQRVs." The Work Group named itself the Federal Land Managers' Air Quality Related Values Work Group, or FLAG. Although FLAG membership comprises air resource managers and subject matter experts from the three agencies, representatives from the Bureau of Land Management, the U.S. Environmental Protection Agency (EPA), U.S. Geological Survey, and State air agencies have also participated in FLAG efforts.

**UL Bend National Wildlife Refuge, Montana.**
Credit: Maribeth Oaks/The Wilderness Society

FLAG participants have collaborated to:

- define sensitive AQRVs,
- identify the critical loads (or pollutant levels) that would protect an area and identify the criteria that define adverse impacts, and
- standardize the methods and procedures for conducting AQRV analyses.

To accomplish its objective, FLAG started with (and will continue to build on) the procedures, terms, definitions, and screening levels common to the three agencies. Many such "commonalities" were identified early in the FLAG planning sessions (see section 1.4, 'Commonalities Among Federal Land Managers').

FLAG's "Action Plan" stipulates a phased approach. Phase I addressed issues that could be resolved without research or the collection of new data. When the Agencies embark on FLAG Phase II, they will address the more complex and unresolved issues from Phase I that may require additional data collection (see section 5, 'Future FLAG Work').

The FLAG effort focuses on the effects of the air pollutants that could affect the health of resources in Class I areas, primarily pollutants such as ozone, particulate matter, nitrogen dioxide, sulfur dioxide, nitrates, and sulfates. In Phase I, FLAG concentrated on four issues: (1) terrestrial effects of ozone; (2) aquatic and terrestrial effects of wet and dry pollutant deposition; (3) visibility impairment; and (4) process and policy issues. Four subgroups, one for each of

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[3] Nevertheless, the FLMs are also concerned about resources in Class II parks and wilderness areas because they have other mandates to protect those areas as well. The information and procedures outlined in this document are generally applicable to evaluating the effect of new or modified sources on the AQRVs in both Class I and Class II areas, including the evaluation of effects as part of Environmental Assessments and/or Environmental Impact Statements under the National Environmental Policy Act (NEPA). However, FLAG does not preclude more refined or regional analyses being performed under NEPA or other programs.

these issues, were formed and charged with developing a set of recommendations for consistent policies and processes.

FLAG 2000's findings and technical recommendations underwent scientific peer review, as well as review by agency decision-makers such as Class I area Park Superintendents, Refuge Managers, and Forest Supervisors; Regional Foresters; and the Assistant Secretary for Fish and Wildlife and Parks. (Note: USFS has designated the FLM as the Regional Foresters and, in some cases, Forest Supervisors.) FLAG products have also undergone public review and comment. A "notice of availability" of the draft FLAG 2000 report was published in the *Federal Register*, and the FLMs conducted a public meeting to discuss the draft FLAG report and provided a 90 day public comment period. For the FLAG 2010 revisions, the FLMs announced the availability of the draft report in the *Federal Register* and provided a 60 day public comment period. There was not sufficient public interest to conduct a public meeting to discuss the proposed revisions to the FLAG report.

### 1.1.2. FLAG Organization

In addition to the four subgroups (policy, deposition, ozone, and visibility), the FLAG organization included Leadership and Coordinating Committees and a Project Manager. The Leadership Committee, which includes the air quality program chiefs from the three FLM agencies, was responsible for providing direction to the Work Group and the resources necessary for FLAG to accomplish its objective. The Coordinating Committee, which also includes representatives from each agency, was responsible for communications within the Work Group, including coordination among the agencies and subgroups. The FLAG Project Manager coordinated FLAG activities, served as a single point-of-contact for the subgroups, and performed other administrative functions.

## 1.2. Overview of Resource Issues (Revised)

Research conducted on Federal lands by FLMs and others has characterized natural resource effects associated with air pollution, and has helped identify those particular resources that are vulnerable to pollution in different areas. This effort does not address the impacts from air pollution on cultural resources. Documented effects include impairment of visibility, injury and reduced growth of vegetation, and acidification and fertilization of soils and surface waters. Air pollution effects on resources have been identified in a number of FLM areas; a few examples are provided below. It is important to note that similar, or even more serious, air pollution effects may be occurring on all Federal lands, but FLMs have not had the financial resources to perform the inventorying, monitoring, and/or research necessary to document such effects. Furthermore, the sensitivity of resources may vary from area to area because the nature of the resource, as well as geological, meteorological, biological, and other factors, vary from place to place.

### 1.2.1. Visibility

Visitors to national parks and wildernesses list the ability to view unobscured scenic vistas as a significant part of a satisfying experience. Unfortunately, visibility impairment has been documented in all Class I areas with visibility monitoring. Most visibility impairment is in the form of regional haze. The greatest visibility impairment due to regional haze occurs in the eastern United States and in southern California, while the least impairment occurs in the Colorado Plateau and Nevada Great Basin areas, and in Alaska. Ammonium sulfate contributes at least 50% to visibility impairment at most Class I areas in the eastern United States. The contribution to visibility impairment from ammonium nitrate is highest in central and southern California and in the Midwest. The largest region of high rural organic carbon visibility impairment is in the southeastern United States; impairment in this range is also present in the Sierra Nevada region of California and in the northern Rockies of Montana. The highest contribution to visibility impairment from fine soil is found in the arid Southwest. The highest coarse particle contribution to impairment is also in the arid Southwest and southern California. (DeBell et al. 2006) Visibility impairment on Federal lands can also result from plume intrusion and has been documented in Mount Zirkel Wilderness, Moosehorn National Wildlife Refuge, and Grand Canyon National Park.

### 1.2.2. Vegetation

While several components of air pollution (e.g., sulfur dioxide, nitrogen dioxide, and peroxyacyl nitrates) can affect vegetation, ozone is generally acknowledged as the air pollutant causing the greatest amount of injury and damage to vegetation. The most common visible effects are stipple (dark colored lesions on leaves resulting from pigmentation of injured cells), fleck (collapse of a few cells in isolated areas of the upper layers of the leaf, resulting in tiny light-colored lesions), mottle (degeneration of the chlorophyll in certain areas of the leaf giving the leaf a blotchy appearance), necrosis (death of tissue), and in extreme cases, mortality. Aside from visible injury, ozone exposure can result in less obvious physiological impairment such as decreased growth or altered carbon allocation.

Ozone fumigation experiments have identified a number of plant species that are sensitive to ozone. For example, fumigations were conducted in Great Smoky Mountains National Park (Tennessee and North Carolina) from 1987 to 1992. On the basis of foliar injury, thirty species were rated as sensitive to ozone levels that occurred in the park. The species with foliar injury included black cherry (*Prunus serotina*) and American sycamore (*Platanus occidentalis*). Additional observations and physiological measurements indicated elevated ozone concentrations reduced leaf, root, and total dry weights, and increased the severity of leaf stipple and premature leaf abscission in these two species (Neufeld and Renfro 1993a,b). Field observations have documented foliar injury of these species in other eastern United States areas such as Brigantine Wilderness (New Jersey) and Cape Romain Wilderness (South Carolina).

Ponderosa pine (*Pinus ponderosa*) and Jeffrey pine (*Pinus jeffreyi*) are recognized as good candidates for ozone-injury surveys in the western United States, based on their documented sensitivity. For example, these species were examined for ozone injury in national parks and national forests in the California Sierra Nevada from 1991 to 1995. The sites surveyed included Lassen Volcanic, Yosemite, and Sequoia/Kings Canyon National Parks and the Tahoe, Eldorado, Stanislaus, Sierra, and Sequoia National Forests. Foliar injury attributable to ozone was found at all areas, and the extent of injury generally increased in a southward direction along the Sierra Nevada (Miller 1995).

### 1.2.3. Soils and Surface Waters

Acidity in rain, snow, cloud water, and dry deposition can affect soil fertility and nutrient cycling processes in watersheds and can result in acidification of lakes and streams with low buffering capacity. Deposition of sulfate to sensitive watersheds results in leaching of base cations, soil acidification, and surface-water acidification. In some soils, sulfate adsorption results in "delayed" acidification of surface waters. Deposition of excess nitrogen species (nitrate and ammonium) to both terrestrial and aquatic systems can result in acidifying streams, lakes, and soils. There is also evidence that nitrogen deposition can cause shifts in phytoplankton composition in lakes in which biological activity is limited by nitrogen availability, i.e., increased nitrogen deposition can cause phytoplankton species that use nitrogen more efficiently to eventually dominate the lake.

Water chemistry surveys and on-going monitoring show that many high elevation lakes on Federal lands in the Sierra Nevada, Cascades, and Rocky Mountains are sensitive to acid deposition. In general, these lakes are on bedrock that provides them with very little buffering capacity. Some of these lakes, for example, Loch Vale in Rocky Mountain National Park (Colorado) experience episodic acidification during Spring snow melt (Baron and Campbell 1997).

Through funding provided by the Southern Appalachian Mountains Initiative, Herlihy et al. (1996) compiled information on surface water sensitivity of streams in nine of the eleven Class I areas in the Southern Appalachians. The nine Class I areas were grouped according to geology, physiography, and stream chemistry, then the groupings were ranked in terms of effects. Class I areas in the West Virginia Plateau (Otter Creek and Dolly Sods Wildernesses) had the highest percentage of acidic stream length and lowest pH values. Class I areas in the Northern and Southern Blue Ridge (e.g., Shenandoah National Park in Virginia and Joyce Kilmer/Slickrock Wilderness in North Carolina) had a lower percentage of acidic stream length, however, streams with low buffering capacity were common. The Alabama Plateau Class I area (Sipsey Wilderness) had streams with the highest buffering capacity. (Note that the authors based their report on surveys conducted by others and did not account for potential differences in methods of data collection.)

A number of Federal areas contain estuarine and coastal areas that may experience eutrophication as a result of excess nitrogen deposition resulting from air pollution and other sources of nitrogen. For example, symptoms of eutrophication, including nutrient enrichment and algal blooms, have been observed in Everglades National Park and Chassahowitzka Wilderness (Florida).

## 1.3. Legal Responsibilities (Revised)

The specific legal responsibilities that Congress has given FLMs to protect natural, cultural, and scenic resources on the public lands from air pollution are identified in Appendix B. Statutes described in Appendix B include agency organic acts, the Wilderness Act, and the Clean Air Act (CAA).

The fundamental Congressional direction for managing public lands arises out of respective organic acts. Each of these laws is essentially a charter from Congress to the Executive Branch providing a purpose for parks, wildernesses, and refuges, respectively, and establishing broad management objectives for these areas. The Wilderness Act sets aside a subset of these public lands where natural processes are allowed to dominate. The agency stewards develop specific management objectives building on the organic acts using public involvement, regulations, best available science, and additional direction provided by Congress.

Among this additional Congressional direction is the Clean Air Act (CAA). It further characterizes some of the public lands as "Class I" areas and bestows on the land managers an affirmative responsibility to protect these areas from air pollution. The CAA directs that the FLMs identify and protect air quality related values, including visibility. This direction is consistent with the underlying charters provided by the organic acts and the Wilderness Act. The similarities of management objectives, and of the policies and procedures necessary for protecting Class I areas, are at the core of the FLAG process. Please note that although all wilderness is not Class I, and the FLMs have not proposed that non-Class I wilderness be classified as Class I, management actions (e.g., limiting human activities) that satisfy wilderness management objectives for Class II areas, are often substantially the same as those used in Class I area management.

In implementing laws, it is essential to understand the intent of Congress. In the case of the CAA, the FLM gleans additional insight from a passage in Senate Report No. 95-127, 95th Congress, 1st Session, 1977 which states:

> The Federal Land Manager holds a powerful tool. He is required to protect Federal lands from deterioration of an established value, even when Class I [increments] are not exceeded. . . . While the general scope of the Federal Government's activities in preventing significant deterioration has been carefully limited, the FLM should assume an aggressive role in protecting the air quality values of land areas under their jurisdiction. In cases of doubt the land manager should err on the side of protecting the air quality-related values for future generations.

Although the FLMs have an "affirmative responsibility" to protect AQRVs, they have no permitting authority under the CAA, and they have no authority under the CAA to establish air quality-related rules or standards. The FLM role within the regulatory context consists of considering whether emissions from a new source,  or emission increases from a modified source, may have an adverse impact on AQRVs and providing comments to permitting authorities (States or EPA). It is important to emphasize that the FLAG report only explains factors and information the FLMs expect to use when carrying out their consultative role. It is not a rule or standard.

The FLAG report describes the steps and process that the FLMs intend to go through in order to perform their statutory duties. Consequently, the scope of the FLAG report is to provide a more consistent approach for the three FLM agencies to evaluate air pollution effects on resources, and to provide guidance to permitting authorities and permit applicants regarding necessary AQRV analyses. Although FLAG strives to be consistent with regulatory programs and initiatives such as the Regional Haze Rule and New Source Review Reform, no direct ties exist between FLAG and these regulatory requirements.

## 1.4. Commonalities Among Federal Land Managers

If a new source is proposed near two or more areas managed by different FLMs, the FLMs generally try to coordinate in their interactions with the permitting authority and with the applicant. For example, two or more FLMs involved in pre-application meetings typically try to minimize the workload for the applicant by reaching agreement on the types of analyses the application should contain. Beyond coordinating during permit review, FLMs currently base requests and decisions on similar principles regarding resource protection and FLM responsibilities. Listed below are the common principles in five areas of air resource management. In addition, Appendix C provides the FLM's 'General Policy for Managing Air Quality Related Values in Class I Areas.'

### 1.4.1. Identifying AQRVs (Revised)

FLMs agree on the following definition of an AQRV:

> A resource, as identified by the FLM for one or more Federal areas that may be adversely affected by a change in air quality. The resource may include visibility or a specific scenic, cultural, physical, biological, ecological, or recreational resource identified by the FLM for a particular area.

This definition is compatible with the general definition of AQRV that appears in the *Federal Register* (45 FR 43003, June 25, 1980). That definition includes visibility, flora, fauna, odor, water, soils, geologic features, and cultural resources. FLMs have the responsibility to identify specific AQRVs of areas they manage. To this end, FLMs further refine AQRVs beyond the above definition to be more site-specific (i.e., area specific) by using on-site information. To the extent possible, the FLMs have identified specific AQRVs for many Class I areas. Site-specific AQRV lists are available on the respective Agency web sites, or by contacting the Agencies directly. The FLMs also recognize that, ideally, inventories should be developed for all Class I areas. The FLMs may identify additional AQRVs in the future as more is learned through science about the sensitivity of resources to air pollution. A public process involving the regulated community and other interested members of the public is necessary and will be accomplished through participation in the land management planning process or reply to an announcement in the *Federal Register*. Finally, FLMs agree on the need for continued inventory, research, and monitoring to improve their ability to determine which AQRVs are most sensitive to air pollution and the sensitivity of these AQRVs.

### 1.4.2. Determining the Levels of Pollution that Trigger Concern for the Well-Being of AQRVs (Revised)

FLMs acknowledge the importance of being able to agree among themselves on the levels of pollution that trigger concerns for AQRVs. FLMs recognize the need to assess cumulative impacts and the difficulties associated with this process. Difficulties arise when a large number of minor source impacts eventually lead to an unacceptable cumulative impact or when a new source applies for a PSD permit in an area that has a high background concentration of pollution from existing sources. The agencies will evaluate a proposed new source within the context of the total impacts that are occurring or that potentially could occur from permitted/existing sources on the AQRVs of the area and should consider the effects of both emission increases and decreases.

### 1.4.3. Visibility

FLMs use EPA-approved models [Appendix W of Part 51 (EPA's *Guideline on Air Quality Models*, revised November 2005), as required under the PSD regulations at 40 CFR 51.166(1) and 52.21(1)] and the recommendations of the Interagency Work Group on Air Quality Modeling (IWAQM) to evaluate visibility impacts. The models use thresholds of visibility degradation measured in light extinction to evaluate source impacts to haze (far-field/multi-source impacts), and EPA established criteria for coherent plume impacts (near-field impacts). Currently all FLMs use Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring data to determine current conditions for visibility in FLM areas.

### 1.4.4. Biological and Physical Effects

All FLMs rely on research, monitoring, models, and effects experts to identify and understand physical, biological, and chemical changes resulting from air pollution and relating them to changes in AQRVs. Further, they focus on sensitive AQRVs (defined as either species or processes) to assess this biological/physical/chemical change.

### 1.4.5. Determining Pollution Levels of Concern (Revised)

FLMs rely on the best scientific information available in the published literature and best available data to make informed decisions regarding levels of pollution likely to cause adverse impacts. FLMs re-evaluate, update, and assess this information as appropriate. They consider specific Agency and Class I area legislative mandates in their decisions and, in cases of doubt, "err on the side of protecting the AQRVs for future generations." (Senate Report No. 95-127, 95th Congress, 1st Session, 1977)

For air quality dispersion modeling analyses, FLMs follow Appendix W of Part 51 (EPA's *Guideline on Air Quality Models*, revised November 2005), as required under the PSD regulations at 40 CFR 51.166(1) and 52.21(1), and the recommendations of the Interagency Work Group on Air Quality Modeling (IWAQM). FLMs recommend protocols for modeling analyses to permit applicants on a case-by-case basis considering types and amount of emissions, location of source, and meteorology. When reviewing modeling and impact analysis results, all FLMs consider frequency, magnitude, duration, location of impacts, and other factors, in determining whether impacts are adverse.

### 1.4.6. FLM Databases (Revised)

#### *Air Resources Information System (ARIS) (Formerly Air Synthesis) (Revised)*

ARIS provides information on air quality related values in NPS and FWS Class I areas, as well as in many NPS Class II areas. ARIS identifies specific AQRVs, and provides information on air quality and its effects in parks and wildernesses.

#### *Natural Resource Information System – Air Module (NRIS-AIR) (Revised)*

Publicly available USDA Forest Service Class I and II area information and related resource data can be linked to or found at http://www.fs.fed.us/air. If desired information and data cannot be found, contact any air program manager or specialist at national or regional offices for assistance.

## 1.5. Regulatory Developments Since FLAG 2000 (New)

Several regulatory developments have occurred since the FLMs published the FLAG report in December 2000. Some of these regulatory developments may have a significant effect on air resource management in mandatory Class I areas, or how these effects are assessed. First, on April 15, 2003, the Environmental Protection Agency (EPA) promulgated revisions to Appendix W of 40 C.F.R. §51 (*Guideline on Air Quality Models*). EPA revised the Guideline to adopt the CALPUFF model as a preferred long-range transport model for inclusion in Appendix A of that document. Prior to that date, FLAG 2000 relied on CALPUFF as the suggested model of choice for long-range transport assessments in accordance with recommendations of the Interagency Work Group on Air Quality Models (IWAQM). EPA's adoption of CALPUFF substantiates the Agencies' model choice. In addition, EPA's action, combined with improved computer technology, has resulted in the availability of more meteorological data. These improvements have enhanced the ability of permitting authorities and applicants to perform the types of modeling analyses suggested in FLAG. However, the FLMs will continue to work with the EPA on recommendations for future long-range transport model development.

On May 12, 2005, the EPA published the Clean Air Interstate Rule (CAIR) to reduce interstate transport of fine particulate matter and ozone. The CAIR applied to 28 eastern states and the District of Columbia, and required those areas to significantly reduce emissions of sulfur dioxide ($SO_2$) and/or nitrogen oxides ($NO_x$) from utilities. Although EPA developed the CAIR to address violations of the National Ambient Air Quality Standards (NAAQS) for fine particulates ($PM_{2.5}$) and ozone, the associated $SO_2$ and $NO_x$ emission reductions would also benefit visibility and other AQRVs at many eastern Class I areas. The Agencies supported the CAIR, however, because it did not apply to western states, the majority of the Class I areas would not have directly benefited from the rule. Please note that at the time of this writing CAIR has been remanded to the EPA for revision to address various court challenges, and EPA has proposed a new transport rule as a replacement (EPA 2010a).

On July 6, 2005, the EPA published a final rule and associated guidelines that detail the Best Available Retrofit Technology (BART) requirements of the Regional Haze Rule. Among other things, the BART guidelines advise States to rely on the CALPUFF model for long-range visibility impairment assessments, provide thresholds for what constitutes causing or contributing to regional haze visibility impairment, and includes screening level values that exempt certain sources from further analysis. As discussed in more detail below, the Agencies believe the assumptions and methodology included in the BART guidelines also have merit with respect to evaluating haze-like visibility impairment for New Source Review under the PSD and other programs. Consequently, the Agencies are paralleling some of those BART guidelines in this FLAG revision.

Please note that FLAG 2000 acknowledges the EPA's July 1999 Regional Haze Rule, and discusses possible changes to FLAG that may be necessary as States implement the Regional Haze Rule. Although the EPA promulgated the Regional Haze Rule before the FLMs published FLAG 2000, there were several improvements and differences in the associated EPA guidance documents (e.g., those related to Natural Conditions and Tracking Progress) that were not finalized until December 2003. Therefore, these documents were not reflected in FLAG 2000, but have been considered in this revision. Currently, State Implementation Plans (SIPs) under the Regional Haze Rule are being developed, and submitted to the EPA for approval. If the new visibility SIPs adequately account for new source growth, the Agencies may need to make further revisions to the FLAG recommendations to reflect progress made through the SIP process that could minimize the focus the FLMs place on individual sources.

EPA has also developed other regulations, standards, and policies that will help reduce air pollution and resulting impacts at FLM areas (e.g., revised ozone, sulfur dioxide, nitrogen dioxide, and particulate matter standards; mobile source controls).

# 2. Federal Land Managers' Approach to AQRV Protection

FLM responsibilities for resource protection on Federal lands are clear and there should be no misunderstanding regarding the tools the FLM uses to fulfill these responsibilities. Opportunities to influence decisions regarding pollution sources external to the park or wilderness are limited. However, FLMs strive to minimize emissions from internal sources and their effects. Approaches for minimizing air pollution from external and internal sources are discussed in detail below.

## 2.1. AQRV Protection and Identification (Revised)

Congress assigned the FLMs an affirmative responsibility to protect AQRVs in Federal Class I areas. The FLMs interpret this assignment as a responsibility to:

- Identify AQRVs in each of the Class I areas.
- Establish inventorying and monitoring protocols for AQRVs.
- Prioritize AQRV inventorying and monitoring.
- Specify a process for evaluating air pollution effects on AQRVs, including the use of sensitive indicators.
- Specify adverse effects for each AQRV.

To the extent possible, AQRVs have been identified for each Class I area. As noted above, the FLMs may identify additional AQRVs in the future as more is learned about the sensitivity of resources to air pollution. The FLMs will provide a public process involving the regulated community and other interested members of the public in order to seek public input regarding AQRV-identification issues. This desired public involvement will be accomplished through participation in the land management planning process or reply to an announcement in the *Federal Register*.

While the sensitivity of an AQRV to air pollution may be known, long-term monitoring of the health or status of the AQRV may not have been accomplished. The expense of monitoring all AQRVs simultaneously is prohibitive. Consequently, FLMs seek opportunities through the permitting process and through partnerships to gather more information about condition of AQRVs.

Because AQRVs themselves are often difficult to measure, surrogates are used as indicators, or sensitive indicators, of the health or status of the AQRV. A working process for Class I area management and AQRV protection is outlined ahead in this document.

**Sipsey Wilderness, Alabama.**
Credit: Steve Boutcher

An adverse impact is determined for each AQRV. An adverse impact from air pollution results in a diminishment of the Class I area's national significance, that is, the reason the Class I area was created. Adverse impacts can also be an impairment of the structure or functioning of the ecosystem, as well as an impairment of the quality of the visitor experience. The FLMs make an adverse impact determination on a case-by-case basis, based on technical and other information, which is then conveyed to the permitting authority.[4] The permitting authority then considers this, along with other factors, in its determination regarding the permit application.

## 2.2. New Source Review (Revised)

Section 165 of the CAA spells out the roles and responsibilities for FLMs in New Source Review, including the Prevention of Significant Deterioration (PSD) permitting program. Other laws, such as the respective agency organic acts and the Wilderness Act, provide the fundamental underpinning of land management direction to land managers. The following discussion merges this complex labyrinth of legal responsibilities as it relates to air resource management.

### 2.2.1. Roles and Responsibilities of FLMs (Revised)

The federal officials directly responsible for the national parks, national wildlife refuges, and national forests (e.g., park superintendents, refuge managers, and forest supervisors, respectively) derive their responsibility from the respective agency organic acts. Furthermore, these officials, and the FLM for the respective agencies, have an affirmative responsibility under Section 165 of the CAA to protect and

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[4] As discussed elsewhere in this report, if a proposed source's impacts on AQRVs exceed established significance criteria, the FLMs will consider the magnitude, frequency, geographic extent, etc. of the impacts, and other relevant factors, in determining whether or not the impacts are adverse.

enhance the AQRVs of Class I areas from the adverse effects of air pollution. The FLM for the USFS is the Regional Forester or the Forest Supervisor depending on the specific location. The FLM for the NPS and FWS is the Department of the Interior's Assistant Secretary for Fish and Wildlife and Parks.

The FLMs have visibility protection responsibility under 40 CFR §51.307 (New source review), which spells out the requirements for State Implementation Plan (SIP) visibility protection programs, as well as 40 CFR §52.27 (Protection of visibility from sources in attainment areas) and 40 CFR §52.28 (Protection of visibility from sources in non-attainment areas). These three provisions, taken together along with the SIP-approved rules, establish the visibility protection program for new and modified sources throughout the country.

### *Notification*

Section 165 (42 USC 7475) of the CAA requires the EPA, or the State/local permitting authority, to notify the FLM if emissions from a proposed project may impact a Class I area. The permitting authority should forward PSD applications to the FLM for review and analysis as soon as possible after receipt, giving the FLM an opportunity to review the application concurrently with the permitting authority.

Generally, the permitting authority should notify the FLM of all new or modified major facilities proposing to locate within 100 km (62 miles) of a Class I area. In addition, the permitting authority should notify the FLM of "very large sources" with the potential to affect Class I areas proposing to locate at distances greater than 100 km. (Reference March 19, 1979, memorandum from EPA Assistant Administrator for Air, Noise, and Radiation to Regional Administrators, Regions I - X). Given the multitude of possible size/distance combinations, the FLMs can not precisely define in advance what constitutes a "very large source" located more than 100 km away that may impact a particular Class I area. However, as discussed elsewhere in this report, the Agencies have adopted a size (Q)/distance (D) criteria to screen out from AQRV review those sources with relatively small amounts of emissions located a large distance from a Class I area. Consequently, as a minimum, the permitting authority should notify the FLM of all sources that exceed this Q/D criteria. Nevertheless, the FLM and permitting authority should still work together to determine which other PSD applications the FLM is to be made aware of in excess of 100 km. In making this determination, the FLM and permitting authority should consider, on a case-by-case basis, such factors as:

- Current conditions of sensitive AQRVs;
- Magnitude of emissions;
- Distance from the Class I area;
- Potential for source growth in an area/region;
- Existing/prevailing meteorological conditions;
- Cumulative effects of several sources to AQRVs, as well as changes in their emissions.

Additionally, such dialogue facilitates coordination between permitting authorities and the FLMs. The significance of the impact to AQRVs is more important than the distance of the source. Not all PSD permit applications that the FLM is notified of will be analyzed in-depth by the FLM. FLM notification of a PSD permit application for a project located greater than 100 km does not mean that the permit application will be reviewed by the FLM in detail. Notification of PSD permit applications in excess of 100 km by the permitting authority allows the FLM to gauge the level of potential cumulative effects. As indicated above, the FLM decides which PSD permit applications to review on a case-by-case basis depending on the potential impacts to AQRVs.

### *Pre-Application Meetings*

To expedite the PSD permit review process, the FLM encourages pre-application meetings with permitting authorities and permit applicants to discuss air quality concerns for a specific Class I area in question. Given preliminary information, such as the source's location and the types and quantity of projected air emissions, the FLM can discuss specific AQRVs for an area and advise the applicant of the analyses needed to assess potential impacts on these resources.

### *Completeness Determination*

To further minimize delays, the FLMs encourage the permitting authority to use comments provided by the FLM concerning the completeness of the application, and to not deem the application complete until the applicant performs all necessary air quality impact analyses, including all relevant AQRV impact information. The permitting authority should then notify the FLM when they deem the application to be complete.

### *Visibility Protection Procedures*

Additional procedural requirements apply when a proposed source has the potential to impair visibility in a Class I area (40 CFR §52.27(d)(2007); 40 CFR §51.307(a)(2007)). Specifically, the permitting authority must, upon receiving a permit application for a source that may affect visibility in any Class I area, notify the FLM in writing. Such notification shall include a copy of all information relevant to the permit application, including the proposed source's anticipated impacts on visibility in a Class I area. The permitting authority shall notify the FLM within 30 days of receipt and at least 60 days prior to the close of the comment period.

If the FLM notifies the permitting authority that the proposed source may adversely impact visibility in a Class I area, or may adversely impact visibility in a previously identified integral (scenic) vista, then the permitting authority is to work with the FLM to address their concerns. If the permitting authority agrees with the FLM's finding that visibility in a Class I area may be adversely affected, the permit may not be issued. Even though the permitting authority may agree with the FLM's adverse impact finding regarding integral vistas, the permitting authority may still issue a permit if the emissions from the source are consistent with reasonable progress toward the national goal of preventing or remedying visibility impairment. In making this decision, the permitting authority may take into account the costs of compliance, the time needed for compliance, the energy and non-air quality environmental impacts of compliance, and the useful life of the source.

The FLM will make a preliminary determination regarding possible adverse visibility impacts upon receipt of all relevant information, including the draft permit and any associated staff analysis.

### 2.2.2. Elements of Permit Review

The FLM review of a PSD application for a proposed project that may impact a Class I area generally consists of three main analyses:

1. Air quality impact analysis to ensure that predicted pollutant levels in Class I areas do not exceed National Ambient Air Quality Standards (NAAQS) and PSD increments, and to provide sufficient information for the FLM to conduct an AQRV impact analysis. Ensuring that permit applicants meet these requirements is the direct responsibility of the permitting authority (see discussion below);
2. AQRV impact analysis to ensure that the Class I area resources (i.e., visibility, flora, fauna, etc.) are not adversely affected by the proposed emissions. The AQRV impact analysis includes interpreting the significance of the results from the applicant's air quality impact analysis and is the responsibility of the FLM (see discussion below); and
3. Best Available Control Technology (BACT) analysis to help ensure that the source installs the best control technology to minimize emission increases from the proposed project (See Appendix D for a summary of this analysis). The final BACT determination is a direct responsibility of the permitting authority.

#### *Air Quality Impact Analysis*

The permit applicant must perform an air quality impact analysis for each pollutant subject to PSD review (40 CFR §51.166). This analysis must show the contribution of the proposed emissions to increment consumption and to the existing ambient pollution levels in a Class I park or wilderness area. The applicant must perform a cumulative increment analysis for each pollutant and averaging time for which the proposed source will have a significant impact. Because proposed sources are not yet operating, the air quality analysis should rely on mathematical dispersion models to estimate the air quality impact of the proposed emissions. The FLMs provide the applicants with guidance on where to place model receptors within the Class I area. The applicant is responsible to provide sufficient information for the FLM to make a decision about the acceptability of potential AQRV impacts as a consequence of the new source.

The applicant must perform the air quality impact analysis using approved models and procedures as specified in Appendix W of Part 51 (EPA's *Guideline on Air Quality Models*, revised November 2005), as required under the PSD regulations at 40 CFR 51.166(1) and 52.21(1). The applicant should explicitly state all assumptions for the analysis, and furnish sufficient information on modeling input so that the FLM can validate and duplicate the model results. FLMs encourage the permit applicant to submit a modeling protocol for review before performing the Class I modeling analyses. This protocol should include the proposed air quality analysis methodology and model input (i.e., emissions, stack data, meteorological data, etc.), and the proposed location of the receptors in the FLM area.

#### *AQRV Impact Analysis*

According to the CAA's legislative history and current EPA regulations and guidance, the air quality impact analysis that provides sufficient information to enable the FLM to conduct the AQRV impact analysis is one part of a permit application just as are the BACT analysis and the air quality impact analysis relative to the increments and NAAQS. The applicant bears the entire cost of preparing the permit application including the complete air quality impact analysis.

It is important to highlight the distinction between the air quality impact analyses that the applicant performs and the AQRV impact analyses that FLMs perform. Whereas the permit applicant calculates changes in pollutant concentrations, deposition rates, or visibility extinction, the FLM assesses the extent to which these impacts affect sensitive visual, aquatic, or terrestrial resources. Given the FLM's statutory responsibilities and expertise, the FLM must have responsibility to consider whether the amount of pollution dispersed into the air or deposited on the ground (or in water) would have an adverse impact on any AQRV, and if so, to demonstrate that claim to the permitting authority. In making an adverse impact finding, FLMs consider such factors as magnitude, frequency, duration, location, geographic extent, and timing of impacts, as well as current and projected conditions of AQRVs based on cumulative impacts.

The FLM uses the results from the applicant's air quality impact analysis and other information to conduct the

AQRV impact analysis and make an informed decision about whether or not AQRVs will be adversely affected. If the FLM concludes that AQRVs will be adversely affected, the FLM will so demonstrate to the permitting authority. The following sections of this document give guidance to applicants on how to conduct an air quality impact analysis and how the FLM uses this information to make an AQRV impact decision.

### *Cumulative Impact Analysis*

The FLM will evaluate on a case-by-case basis both the permit applicant's contribution to the AQRV impacts, as well as the cumulative source impacts on AQRVs, taking into account expected emission reductions. A cumulative air quality analysis in which the proposed source and any recently permitted (but not yet operating) sources in the area are modeled is an important part of any AQRV impact analysis. This cumulative modeled impact is then added to measured ambient levels (to the extent that such monitoring data are available) so that the FLM can assess the total effect of the anticipated ambient concentrations on AQRVs. If no representative monitoring data are available, the total pollutant concentrations should be estimated by modeling emissions from all contributing sources in the area.

### *Information Provided by the FLM to the Applicant*

To assist the permit applicant in performing air quality impact analyses, the FLMs will provide all available information about AQRVs for a particular Class I area that may be adversely affected by emissions from the proposed source. FLMs will recommend available methods the applicant should use to analyze the potential effects (i.e., pollutant concentration, deposition rates, and visibility extinction) in the Class I area. In addition to identifying AQRVs, FLMs will, to the extent possible:

- identify inventories, surveys, monitoring data, scientific studies, or other published reports that are the basis for identification of AQRVs;
- identify specific receptors known to be most sensitive to air pollution and the pollutant or pollutants that individually or in combination can cause or contribute to an adverse effect on each receptor;
- identify the critical pollutant concentrations above which adverse effects are known or suspected to occur;
- recommend methods the applicant should use for predicting ambient pollutant concentrations and other related impacts (e.g., deposition, visibility) which may cause or contribute to an adverse effect on each receptor; and
- suggest screening level values or criteria that would be used to assess whether a proposed emissions increase would have a *de minimis* impact on AQRVs.

## 2.2.3. FLM Permit Review Process

The FLM's current permit review process for any application that may impact a FLM area is described below.

1. **Pre-application.** If possible, participate in any pre-application meeting to learn specifics of the proposed project (size, emissions, location, etc.) and to provide information regarding recommended Class I analyses.
2. **Modeling Protocol.** The FLMs encourage the permit applicant to submit a modeling protocol for review before performing the Class I modeling analyses. This protocol should include the proposed air quality analysis methodology and model input (i.e., emissions, stack data, meteorological data, etc.), and the proposed location of the receptors in the FLM area.
3. **Completeness Determination.** Upon receipt, the FLM will review the application and provide comments to the permitting authority regarding the completeness of the application and the need for additional information regarding the BACT, Air Quality Impacts, and AQRV Impacts analyses. The FLM will coordinate with the permitting authority and the permit applicant to ensure that all the necessary information to enable the FLM to make an impact determination is included.
4. **Public Comment Period.** After review of all relevant information, the FLM will provide pertinent comments to the permitting authority, before or during the official public comment period, and/or at scheduled public hearings.
5. **No Class I Increment Violated and No Adverse Impacts.** If no Class I increment is violated and no adverse impacts to AQRVs are expected, the FLM will inform the permitting authority of this determination and no further FLM action is necessary. The FLM may still provide BACT comments.
6. **No Class I Increment Violated but AQRV Impacts Uncertain.** If no Class I increment is violated but uncertainty exists regarding potential adverse impacts to AQRVs, the FLM may request that the permitting authority include a permit condition that requires the permittee to conduct relevant post-construction AQRV or air quality monitoring. The FLM may also request certain control technologies or methods to reduce impacts.
7. **Class I Increment Violated, but No Adverse AQRV Impacts.** If the Class I increment is violated, but no adverse AQRV impacts are anticipated, the applicant requests the FLM to "certify" no adverse impact under Section 165(d)(2)C)(iii) of the Clean Air Act [42 USC 7475(d)(2)(C)(iii)(1998)]. If the FLM concurs, (s)he makes a preliminary determination that no adverse impacts will occur.

- The FLM will inform the applicant, the State/local permitting authority, and EPA of the preliminary no adverse impact determination.
- The FLM will notify the public of its preliminary no adverse impact determination either through the permitting authority's notice procedures, or through separate notice in the *Federal Register*. Such notice should include a statement as to the availability of supporting documentation for inspection and copying, and an announcement of at least a 30 day public comment period on issues directly relevant to the determination in question.
- The FLM will review and prepare response to public comments.
- The FLM will make a final determination regarding no adverse impacts, with a clear and concise statement of reasons supporting that determination.
- The FLM will inform the permit applicant, the permitting authority, and EPA of its final determination and if the final determination is "no adverse impact," the FLM shall so "certify" in a letter to the affected parties.
- Simultaneous with above, the FLM will publish a final determination in the 'Notice' section of the *Federal Register*, including a clear and concise statement of reasons supporting that determination, statement as to availability of supporting documentation for inspection and copying, and statement as to immediate effective date (date signed) of final determination.
- The FLM will contact the permitting authority and request a revision to the State Implementation Plan (SIP) to eliminate the Class I increment violations.

8. **Adverse Impact Determination**. Regardless of increment status, the FLM may make a preliminary determination that the proposed project will cause, or contribute to, an adverse impact on AQRVs. Before officially declaring an adverse impact, the FLM will inform the proposed new source and the permitting authority that an adverse impact determination is imminent and suggest that the draft permit be modified. If the draft permit is modified to satisfy the concerns of the FLM, then an adverse determination is avoided.
    - The FLM will inform the applicant, the permitting authority, and EPA of a preliminary adverse impact determination.
    - The FLM will notify the public of the preliminary adverse impact determination either through the permitting authority's notice procedures, or through separate notice in the *Federal Register*. Such notice should include a statement as to the availability of supporting documentation for inspection and copying, and an announcement of at least a 30 day public comment period on issues directly relevant to the determination in question.
    - The FLM will review and prepare response to public comments.
    - The FLM will make a final determination regarding adverse impacts, with a clear and concise statement of reasons supporting that determination.
    - The FLM will inform the permit applicant, the permitting authority, and EPA of its final determination.
    - Simultaneous with above, the FLM will publish a final determination in the 'Notice' section of the *Federal Register*, including a clear and concise statement of reasons supporting that determination, statement as to availability of supporting documentation for inspection and copying, and statement as to immediate effective date (date signed) of final determination.
    - If the FLM makes a final determination that a source will have an adverse impact, the FLM will oppose the permit. However, the permit applicant may propose to mitigate any adverse impacts (via reducing emissions, obtaining emission offsets, etc.). If the applicant adequately mitigates the adverse impacts to the satisfaction of the FLM, the FLM will withdraw his objection to the permit. If the adverse impacts are not adequately mitigated and the permitting authority nevertheless issues the permit, the FLM may appeal the permit.

Note: If the permitting authority's SIP makes execution of the above listed steps impossible (e.g., inadequate time allotments for the FLM's determination or lack of timely FLM notice) the procedures shall be adjusted as appropriate. In addition, the above procedures (6 and 7) could also be modified to accommodate those situations when the FLM chooses to certify that existing impacts are adverse, absent a proposed new source. Such an action would alert potential permit applicants that adverse impacts exist and any new source would need to mitigate its potential impacts. Although each FLM may implement the above procedures somewhat differently, the FLAG goal is to reduce the differences in implementing the above steps.

Furthermore, FLMs intend to coordinate on air permit modeling requirements for new or modified sources that are geographically near more than one FLM area. For example, a proposed source in eastern Tennessee that lies equidistant from NPS-administered Great Smoky Mountains National Park and the FS-administered Joyce Kilmer/Slickrock Wilderness would receive coordinated guidance on modeling requirements from the FLMs. The FLMs may or may not have common AQRVs at different Class I areas, making coordination beneficial. The FLMs may also coordinate on potential permit conditions and mitigation strategies.

### 2.2.4. Criteria for Decision Making (Adverse Impact Considerations) (Revised)

As previously mentioned, the legislative history of the CAA provides direction to the FLM on how to comply with the affirmative responsibility to protect AQRVs in Class I areas, and in cases of doubt, the land manager should err on the side of protecting air quality-related values for future generations.

The FLMs define adverse impact on AQRVs as:

> An unacceptable effect, as identified by an FLM that results from current, or would result from predicted, deterioration of air quality in a Federal Class I or Class II area. A determination of unacceptable effect shall be made on a case-by-case basis for each area taking into account existing air quality conditions. It should be based on a demonstration that the current or predicted deterioration of air quality will cause or contribute to a diminishment of the area's national significance, impairment of the structure and functioning of the area's ecosystem, or impairment of the quality of the visitor experience in the area.

Also, the Federal visibility protection regulations (40 CFR §51.300, et seq., §52.27) define adverse impact on visibility as:

> [V]isibility impairment which interferes with the management, protection, preservation or enjoyment of the visitor's visual experience of the Federal class I area. This determination must be made on a case-by-case basis taking into account the geographic extent, intensity, duration, frequency, and time of visibility impairment, and how these factors correlate with: (1) times of visitor use of the Federal class I area, and (2) the frequency and timing of natural conditions that reduce visibility. (Id. §51.301(a))

FLMs typically address adverse impacts on a case-by-case basis in response to PSD permit applications. The factors the FLMs will consider in making an adverse impact determination are discussed in more detail below (see section 4.3). When an adverse impact is predicted, FLMs recommend that permits either be modified to protect AQRVs or be denied. FLMs can also address adverse conditions outside of the PSD process. They do so through a variety of mechanisms: certify visibility impairment; participate in regional assessments; informally collaborate with States and EPA; review lease permits, SIP revisions, National Environmental Policy Act (NEPA) analyses, Park/Refuge/Forest management plans, CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) reviews, and other documents.

In some States, FLMs use screening procedures or thresholds that indicate when the condition of an AQRV is acceptable or unacceptable. The pollutant concentration or loading rate that will adversely impact an AQRV can vary among Class I areas, and depends on current conditions. After a threshold is reached, an increase in pollutant concentrations is likely to be unacceptable. A concern threshold can be an adverse impact threshold or other quantifiable level in resource condition or pollutant exposure identified by the FLM.

### 2.2.5. Air Pollution Permit Conditions that Benefit Class I Areas

The FLM does not determine what permit conditions will be required or administer permit conditions; that is the responsibility of the permitting authority. However, the FLMs may request permit conditions or agree to withdraw objections to permit issuance if requested conditions are included. The FLMs view the inclusion of certain PSD permit conditions by the permitting authority as a means to help protect or enhance the condition of AQRVs when:

1. Air pollution source(s) may cause impacts that exceed protection thresholds for AQRVs;
2. Terrestrial resources, aquatic resources, and/or visibility are currently adversely impacted by air pollution and proposed emissions will exacerbate these adverse conditions;
3. FLM policies require improvement or restoration of AQRVs in parks and wildernesses; and
4. There is uncertainty on the extent and magnitude of air pollution effects on AQRVs.

Recommended permit conditions may include requiring emission offsets, AQRV and/or air quality monitoring, inventories, post-construction reassessment, LAER (or other improved control technologies), or other measures to protect, enhance, or restore resources and values of parks and wildernesses. Permit conditions may:

1. Result in net air quality benefits at a protected area or within a region;
2. Contribute to a reduction of air pollution within a region;
3. Promote ecosystem inventories and/or monitoring to evaluate physical and biological resource damage caused by air pollution emissions; and
4. Promote ecosystem restoration or improve the condition of resources that have been damaged by air pollution emissions.

The basis of an air permit condition should be identified in the public notice for the draft permit. To be effective, permit conditions must be federally enforceable and guaranteed. Air permit provisions may be temporary or permanent depending on the nature of the permit requirements.

Procedures to implement an air permit condition must be acceptable to the FLM (e.g., an agreement between parties [memorandum of understanding, interagency agreement] is an option to accomplish inventory, monitoring, or other requirements).

### 2.2.6. Reducing Pollution in Nonattainment Areas (Nonattainment Permit Process)

The PSD program does not apply with respect to a particular pollutant when the source locates in an area designated non-attainment for that pollutant. Instead, pollution sources are regulated by Non-attainment Area New Source Review (NNSR). NNSR includes air quality planning and regulation of stationary sources. Air quality planning addresses issues such as lowest achievable emission rate (LAER), offsets, reasonably available control technology (RACT), and mobile and stationary source control strategies. New major stationary sources and major modifications of sources in designated non-attainment areas must satisfy NNSR before construction begins. For visibility protection, SIPs must include either EPA-approved provisions to comply with 40 CFR §51.307 for the non-attainment pollutant, otherwise, the federally promulgated visibility provisions at 40 CFR §52.28 would apply to all sources located in non-attainment areas. Therefore, FLMs can provide suggestions to the permitting authority regarding these conditions during the permitting and planning processes.

SIPs provide a mechanism to address AQRV impacts when the source or the Class I area is located in a non-attainment area. FLMs may recommend that States adopt policies, rules, or regulations in their SIPs requiring a demonstration that offsets will result in a net air quality benefit within any Class I area likely to be impacted by emissions from the source to be permitted. FLMs may also request emissions reductions greater than 1:1, perhaps offset rates of 1.5 or 2.0 to 1, or higher, depending on the nature and magnitude of impacts to be offset. Such recommendations can be developed jointly in a meeting with the regulatory authority or in a letter from the FLM.

Mitigation measures recommended by FLMs may include stringent control technologies to minimize the increase in emissions and the impact on AQRVs. Monitoring can determine whether predicted resource conditions are observed. Offsets ensure that net emissions reductions from all sources will occur within a geographic area and their resulting air quality impacts at the Class I area will be mitigated.

## 2.3. Other Air Quality Review Considerations (Revised)

At all Class I areas where visibility has been monitored, visibility conditions have been found to be impaired by human-caused pollution. The impairment comes primarily from older sources, not new sources. From a regional perspective, new or modified sources (using new/cleaner technologies) contribute far less to impaired AQRV conditions than old sources. EPA has implemented a call for reducing $NO_x$ emissions from older sources in the eastern U.S. to meet existing ozone standards. In addition to complying with national ambient standards, States are now developing plans to implement EPA's Regional Haze Regulations. If these requirements are implemented, then progress toward remedying impaired AQRVs is likely. However, given the sensitivity of some AQRVs to low levels of pollution, programs focused on reaching national goals, such as the NAAQS or visibility, may not fully remedy impacts on AQRVs in all locations. It is for this reason that the FLM does pursue other strategies to protect AQRVs. The following sections discuss FLM issues that go beyond NSR.

### 2.3.1. Remedying Existing Adverse Impacts

Allowing the existence of adverse impacts would be inconsistent with the mandates of the FLM agencies. Consequently, FLMs may request or participate in regional assessments to protect AQRVs, and remedy any existing adverse impacts on AQRVs, as appropriate. Regional assessments often use a multi-faceted approach to remedy impairment. For example, categories addressed by the Grand Canyon Visibility Transport Commission (GCVTC) include air pollution prevention; clean air corridors; stationary sources; sources in and near Class I areas; mobile sources; road dust; fire; and future regional coordination.

Clean Air Act requirements for remedying existing visibility impairment provide a mechanism for addressing impacts from specific sources or groups of sources [42 USC 7491). Negotiations at the Centralia Power Plant in the state of Washington provide an example of how to build partnerships and work collaboratively to obtain retrofit controls or more stringent control technologies for sources that affect a FLM area. Through a collaborative decision making process, owners of the Centralia plant agreed to reduce sulfur dioxide emissions at the plant by 90%. In another case, the FWS identified plume impacts from a pulp and paper mill located seven miles upwind of the Moosehorn Wilderness Area. Using cameras provided by the IMPROVE monitoring network, plumes from the mill were documented entering the Moosehorn Wilderness Area. In collaboration with the State of Maine, additional controls for nitrogen oxides and updated particulate controls were incorporated into the mill's PSD permit to address the plume impacts.

FLMs may also coordinate with others to ensure that emission reductions in nonattainment areas will improve air quality in FLM areas. Recommendations on urban planning were developed with FLM involvement to address nonattainment areas in California. Data documenting ozone effects on vegetation were provided to the planning authority.

### 2.3.2. Requesting State Implementation Plan (SIP) Revisions to Address AQRV Adverse Impacts (Revised)

A SIP is the mechanism that states use to develop the pollution control programs that will be used to achieve and maintain the NAAQS, as well as prevent significant deterioration of air quality. It is important for FLMs to be involved in SIP development, as participation provides an opportunity to influence planning of pollution control programs that can benefit air quality in FLM areas. Once a SIP is fully approved by EPA, it is legally enforceable under both State and Federal law. FLMs assist in the development of SIPs by providing analysis and comment to address existing impacts of concern. This approach is particularly useful for addressing impacts on AQRVs other than visibility, since the Clean Air Act does not provide specific requirements for other AQRVs.

SIP revisions could be used to address multiple sources and regional pollution that adversely affect AQRVs in all Class I areas. For example, in South Coast and San Diego, California, SIP revisions included FLM recommendations to reduce the impact of minor sources on AQRVs. South Coast recommendations addressed visibility while the San Diego recommendations addressed all AQRVs. EPA's $NO_x$ SIP Call in the east is another example of obtaining emission reductions through the SIP revision process. The $NO_x$ SIP Call was directed at 20 eastern States and the District of Columbia to address $NO_x$ emissions from existing large sources. Significant reductions in ozone formation and nitrogen deposition have occurred as a result of these efforts.

### 2.3.3. Periodic Increment Consumption Review (Revised)

EPA has indicated its intention to establish a SIP revision requirement to address existing adverse impacts on AQRVs. The FLMs strongly support EPA exercising its authority in this way. In the interim, however, there are existing SIP revision requirements that are not being fully utilized. EPA's current regulations require States to conduct a periodic review of the adequacy of their PSD plan and program. [40 CFR §51.166(a)(4)] This would include an assessment of increment consumption in Class I and Class II areas. Few States have ever conducted a comprehensive, cumulative increment consumption analysis for one or more Class I areas. In addition, many PSD sources have not exceeded the significant impact levels for increment consumption; thus, few PSD permit applicants have had to perform a cumulative increment consumption analysis for Class I areas. Such a periodic increment consumption review would be beneficial given that the burden of proof for AQRV adverse impact determinations shifts from the FLM to the applicant when the increment has been consumed.

In its 1990 report, *Air Pollution: Protecting Parks and Wilderness From Nearby Pollution Sources,* the U.S. General Accounting Office (GAO) found that only 1 percent of the sources within 100 kilometers of five Class I areas it investigated were required to have permits under the PSD program, with 99 percent of the sources being minor or grandfathered sources. It also found that "non-PSD sources contribute from 53 to 90 percent of five of the six criteria pollutants emitted within a 100-kilometer radius of each of the five Class I areas." As part of its investigation, GAO noted that "a significant portion of total emissions of volatile organic compounds generally comes from small sources...and suggested that as part of the overall control strategy, States may want to consider lowering thresholds for regulating new sources to 25 tons of volatile organic compounds a year." According to the investigation, 55 percent of anthropogenic VOC emissions come from new sources or modifications totaling five tons per year or less. In a review of PSD permit applications near Mesa Verde National Park (a Class I area in Colorado), a cumulative modeling analysis of increment-consuming sources found that approximately 80 percent of the $NO_2$ Class I increment at the park had been consumed, but much of it by minor sources.

The FLMs have encouraged EPA to provide clearer direction on how often these periodic reviews should occur as the lack of a prescribed time-frame for conducting such analyses has clearly led to noncompliance with this requirement over the past twenty years by States.

## 2.4. Managing Emissions Generated in and Near FLM Areas (Revised)

Specific strategies need to be developed and implemented for reducing and preventing pollution from the many diverse sources and activities in communities surrounding FLM areas, including "gateway" communities (i.e., those adjacent to FLM areas). Accountability mechanisms are needed to ensure that appropriate actions are taken, reported and incorporated into SIPs, visibility protection plans, and Federal land management plans. Various forums (e.g., the Western Regional Air Partnership, and the Southern Appalachian Mountains Initiative) addressed some of the emissions sources of concern and developed regional strategies. In addition, EPA has formed other "regional planning organizations" for implementing its regional haze rule. FLMs participate in these forums, consistent with Federal law (e.g., Federal Advisory Committee Act), to the maximum extent possible and coordinate their activities within those forums to ensure that comprehensive strategies are developed and implemented to address all the key emissions sources near FLM areas.

A systematic assessment of emission sources in and near FLM areas would be extremely helpful for formulating strategies aimed at mitigating or eliminating adverse impacts on area resources, and the NPS has performed micro-emission inventories for several of its Class I areas. However, without this assessment for all areas it is not possible to accurately quantify the extent to which these emissions contribute to the overall problem. Nevertheless, FLMs can, and should, take steps to minimize emissions generated on FLM lands even without an accurate inventory of emissions sources.

### 2.4.1. Prescribed Fire

Prescribed fire is a land management tool used for multiple landscape objectives. Prescribed fire allows the FLM to mimic natural fire return intervals under controlled conditions where smoke management can minimize air quality impacts. The alternative is wildfires, which can be very difficult to control and may cause much more severe air quality impacts. A modeling assessment suggests that using prescribed fire to minimize wildfires can result in a net reduction in fine particle ($PM_{2.5}$) emissions in the long-term. In the Pacific Northwest wildfire emissions were found to be greater than prescribed fire emissions in the same airshed (Ottmar 1996).

Since the early 1900s, wildfire has been aggressively suppressed on most of the nation's public lands to protect public safety, property, and to prevent what was thought to be the destruction of our natural and cultural resources. Fire-exclusion practices have resulted in forests, shrub lands, and grasslands plagued with a variety of problems, including overcrowding, resulting from the encroachment of species normally suppressed by fire; vulnerability of trees to insects and disease; and inadequate reproduction of certain species. In addition, heavy accumulation of fuels (such as dead vegetation on the forest floor) can cause fires to be catastrophic, which threatens firefighter and public safety, impairs forest and ecosystem health, destroys property and natural and cultural resources, and degrades air quality. The intense or extended periods of smoke associated with wildfires can also cause serious health effects and significantly decrease visibility.

FLMs recognize prescribed fire as a valuable tool; they also recognize that emissions from prescribed fire can be a significant source of air pollution. Smoke particles are also in the size range (< 2.5 µm) that they play a significant role in visibility impairment. Particulate matter is the main pollutant of concern from smoke because it can cause serious health problems, especially for people with respiratory illness. The FLMs are committed to minimizing the impacts from smoke by following sound smoke management practices, and if practical, using non-burning alternatives (i.e., mechanical clearing, chipping, mulching) to achieve land management objectives. Each prescribed burn site will have unique characteristics, but in general, smoke impacts can be minimized by burning during weather conditions that provide optimal humidity levels and dispersion conditions for the type of materials being burned, in addition to limiting the amount of materials and acreage burned at one time.

EPA has worked in partnership with land management agencies in the U.S. Departments of Agriculture, Defense, and the Interior; State Foresters; State air regulators; Tribes; and others to obtain recommendations and develop a national policy that addresses how best to improve the quality of wildland ecosystems (including forests and grasslands) and reduce threats of catastrophic wildfires through the increased use of managed fire, while achieving national clean air goals (EPA 1998b). EPA's interim air quality policy on fire describes criteria for wildland managers (federal, state, tribal, and private), and state and tribal air pollution agencies, to use in planning for and implementing prescribed fires, and recommends a variety of smoke management techniques that land managers can use to help reduce smoke impacts from prescribed fires. The policy is available at EPA's web site: http://www.epa.gov/ttn/faca/fa08.html. In addition, on March 22, 2007, EPA promulgated its Exceptional Events Rule that clarifies how ambient air quality standard exceedances from wildland fire will be treated in determining attainment and nonattainment status. In that rule, EPA committed to revising its 1998 wildland fire policy (72 FR 13560, March 22, 2007).

### 2.4.2. Strategies to Minimize Emissions from Sources In and Near FLM Areas (Revised)

Aside from prescribed fire, other activities in and near FLM areas that generate air pollution include vehicle emissions, road building, operation of generators, oil and gas development, etc. Developing strategies for addressing natural resource impacts in or near an FLM area should not only take into consideration the type of activities generating the emissions and their amount, but also the existing condition of the resources of that area. More stringent measures should be recommended for sources in and near FLM areas that are already experiencing adverse effects from air pollution.

Examples of potential air pollution prevention practices that FLM agencies may encourage or develop and use are categorized under the following three strategies:

*Pollution Prevention Strategies*

- Review land management plans for affected FLM areas to assess whether they include strategies to limit and reduce air pollution emissions and incorporate protective measures into planning and decision documents.
- Place priority on pollution prevention.
- Encourage zero and near-zero emitting technologies.
- Promote energy conservation and the use of renewable energy sources.
- Promote use of clean fuels.

*Mobile Source Strategies*

- Promote the adoption of Low Emission Vehicle standards or the conversion of Federal fleets to alternative fuels.
- Improve control of evaporative emissions.
- Promote more stringent emission standards for the tour bus industry and other high-emitting vehicles used in federal areas (e.g., park shuttle vehicles).
- Considering restricting access of high emitting vehicles to sensitive areas.
- Retire high-emitting vehicles from Federal fleets as quickly as practicable and/or relocate high-emitting vehicles to less sensitive areas until they can be retired.
- Establish emission budgets from the transportation sector for selected FLM areas.
- Develop mass transit systems in some NPS units (e.g., light rail in Grand Canyon NP and a bus system in Zion NP).

*Minor Source Strategies (Revised)*

- Apply RACT, BACT, LAER, best and reasonably available control measures, etc., to existing federal sources, as appropriate.
- Recommend going beyond conformity requirements to include the protection of AQRVs in FLM areas, and ensure all actions FLMs can practicably control in and near FLM areas will not cause, or contribute to, an adverse impact on any AQRV.

Improved involvement with interested parties in gateway communities will likely be required to ensure growth in these communities occurs in a manner that mitigates the impact on natural resources. These communities may need to enhance their participation in the planning processes of FLMs. Similarly, FLMs should participate in planning activities for public lands located in the FLM area and communities adjacent to FLM areas to ensure air quality concerns are adequately addressed. Mechanisms should be identified and developed for community involvement in developing, implementing, and enforcing emission management strategies for sources near and in FLM areas.

Implementing strategies to achieve emission reductions in and near FLM areas will require efforts in at least three specific areas:

1. FLMs should ensure that sufficient emphasis is placed in agency planning documents requiring the minimization of air pollution emissions from new activities or practices.
2. FLMs should inventory air pollution emissions within FLM areas. After emissions have been quantified, FLMs, States, and adjacent communities will be able to assess the impact of these emissions through the use of appropriate models. Knowledge of Class I area emissions will also improve FLM ability to consult with States during the development and review of their SIPs (especially visibility SIPs). The NPS has developed an emissions inventory tool, the Climate Leadership in Parks (CLIP) Tool, that can be utilized by FLMs to inventory both greenhouse gases and all criteria air pollutants.
3. FLMs should cooperate with States and local communities in assessing the need for, and the development of, appropriate emission reduction strategies in and near FLM areas that address non-PSD sources. For Class I areas, the Regional Planning Organizations have completed analyses of emissions from nearby communities and activities that will serve as the basis for identifying strategies to reduce emissions. Without an acknowledgment from States and local communities that these sources may pose a threat to FLM areas and a systematic assessment of these potential impacts, current efforts to protect FLM area resources may be insufficient.

### 2.4.3. Conformity Requirements in Nonattainment Areas

Conformity criteria and procedures ensure that actions on lands administered by Federal agencies do not cause a violation of the NAAQS, increase the frequency of any standards violations, or delay attainment of a standard. Conformity to SIPs is only required for activities within nonattainment areas for non-transportation related sources if emissions are above de minimis levels and regionally significant. Any activity that represents 10 percent, or more, of the emission inventory for that pollutant in the non-attainment or maintenance area is regionally significant. Examples of actions that may require a conformity determination include road paving projects, ski area development, or mining. Activities such as prescribed fire, that are included in a conforming land management plan, are exempt from conformity requirements. Please note that conformity determinations must be made in accordance with applicable EPA regulations, are typically done before a project is approved, and are part of the NEPA process.

The FLM should define the process to be used in conformity determinations and perform the conformity analysis before a project is implemented. A conformity analysis typically includes emission calculations, public participation, mitigation measures/implementation schedules, and reporting methods. The Pacific Southwest Region of the USFS has published a *Conformity Handbook for FLMs* to assist in conformity compliance. In an approved Plan of Operation, FLMs can require monitoring. For example, in the case of Carlota Mine, located on National Forest land in Arizona, the USFS requested additional mitigation measures to protect AQRVs in the Superstition Wilderness.

Transportation projects in FLM areas classified as nonattainment are subject to a more complicated transportation conformity process. Consultation with State and local air quality and transportation agencies will be required to comply with applicable regulations.

# 3. Subgroup Reports: Technical Analyses and Recommendations

## 3.1. Subgroup Objectives and Tasks

Subgroups were formed to address the four key issues relevant to AQRV identification and evaluation issues: policy (and procedures), visibility, ozone, and deposition. Each of these subgroups reviewed the commonalities among the FLMs then addressed the tasks assigned to them by FLAG. One of their first tasks was to differentiate between Phase I tasks, those which could be resolved in the short term without significant additional resources, and Phase II issues, those that would require a longer period or greater effort.

Subgroups were asked to reach common ground among the FLMs on the issues. The intent was to develop, to the extent possible, consistent policies, processes, and terminology that could be used when identifying AQRVs and evaluating impacts on AQRVs. This involves recommending consistent approaches for identifying air pollution effects on AQRVs, for determining adverse impacts, and for attributing adverse impacts to specific pollution sources. In addition, the FLMs consider that AQRV protection from visibility, ozone, and deposition impacts are equally important. However, we also recognize that given the current state of the science, attributing adverse impacts to specific sources are easier to document for visibility than for deposition and ozone, and easier for deposition than ozone.

The individual subgroup reports document the common policies, procedures, and definitions identified or developed during Phase I activities. The Visibility, Ozone, and Deposition subgroup reports are included below. The FLAG Policy Subgroup Report was used as the basis for much of the rest of this *FLAG Phase I Report*, including much of section 1 ‘Background’ and section 2 ‘Federal Land Managers’ Approach to AQRV Protection’.

## 3.2. Initial Screening Criteria (New)

Experience with the FLAG 2000 recommendations in dealing with many new source review applications led the Agencies to believe that an initial screen that would exempt a source from AQRV impact review based on its annual emissions and distance from a Class I area may be appropriate in most situations. As part of its Regional Haze Regulation, the EPA has introduced a screening criteria in its BART guidelines based on a source’s annual emission strength and distance from a Class I area. The EPA stated that it would be reasonable to conclude that the following sources would not be considered to cause or contribute to visibility impairment:

**Acadia National Park, Maine.**
Credit: National Park Service

- those located more than 50 km from any Class I area that emit less than 500 tons per year of $NO_x$ or $SO_2$ (or combined $NO_x$ and $SO_2$), and
- those located more than 100 km from any Class I area that emit less than 1,000 tons per year of $NO_x$ or $SO_2$ (or combined $NO_x$ and $SO_2$).

In both cases, the annual emissions over distance factor equates to 10.

The Agencies have concluded that a similar approach has merit with respect to new source impacts at Class I areas, for air pollution sources with relatively steady emissions throughout each year. However, the Agencies are modifying the size criteria to also include Particulate Matter less than 10 microns in size ($PM_{10}$) and sulfuric acid mist ($H_2SO_4$) emissions because those pollutants also impair visibility and contribute to other resource impacts. In addition, rather than the two-step BART test, the Agencies are using a fixed Q/D factor of 10 as a screening criteria for sources locating/located greater than 50 km from a Class I area. Furthermore, the Agencies are expanding the screening criteria to include all AQRVs, not just visibility. Therefore, the Agencies will consider a source locating greater than 50 km from a Class I area to have negligible impacts with respect to Class I AQRVs if its total $SO_2$, $NO_x$, $PM_{10}$, and $H_2SO_4$ annual emissions (in tons per year, based on 24-hour maximum allowable emissions), divided by the distance (in km) from the Class I area (Q/D) is 10 or less. The Agencies would not request any further Class I AQRV impact analyses from such sources.

In cases where a source's operations which generate visibility-affecting emissions are limited to time periods shorter than a year, the short-term potential to impact visibility may not be adequately expressed by the Q/D concept. For example, a source that is operated either seasonally or intermittently, and has zero emissions for substantial portions of a year, would have a total annual emission rate that under-represents its potential emission strength over a shorter time frame, such as a day or week. Because visibility is an air quality related value that is sensitive to immediate and short-term conditions, in order to apply the Q/D≤10 screening tool, these types of sources need to first adjust the tons-per-year emissions to reflect what the emissions would be if the source operated year-round. For instance, if operations are restricted to 3,000 hours per year, then the annual steady-state-equivalent emission rate (Q) is found by multiplying the permitted total tons per year for $SO_2$, $NO_x$, $PM_{10}$ , and $H_2SO_4$ by the ratio of hours: 8,760 hours per year/3,000 hours operation.[5] Then, using this annual equivalent Q in the Q/D test, the Agencies will consider a source locating greater than 50 km and showing that its ratio of annual equivalent Q (tons per year) divided by distance from the Class I area (km) of 10 or less, as having negligible impacts with respect to Class I visibility impacts, and would not request any further Class I visibility impact analyses from such sources.

## 3.3. Visibility

### 3.3.1. Introduction (Revised)

This chapter describes methods for analyzing the impacts on visibility from new or modified air pollution sources. This includes sources that fall under the purview of the Prevention of Significant Deterioration (PSD) regulations and sources that are being analyzed for Environmental Assessments and/or Environmental Impact Statements under the National Environmental Policy Act (NEPA). The basis for some of the decisions outlined in this chapter is Section 169A of the Clean Air Act. The opening statement of this section states: "Congress hereby declares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from man made air pollution." Under the regulations promulgated for visibility protection (40 CFR §51.301 (x)) visibility impairment is defined as "…any humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions." The remainder of this chapter describes methods that allow for new source growth to be analyzed against the constraint of preventing visibility impairment as defined in 40 CFR §51.301 (x), that is, new source growth should not allow any humanly perceptible change in visibility as compared against natural conditions.

#### *Visibility Impairment*

Before proceeding with the discussion, it is useful to identify the ways that visibility impairment can manifest itself. First, the pollutant loading of a section of the atmosphere can become visible, by the contrast or color difference between a layer or plume and a viewed background, such as a landscape feature or the sky. The second way that visibility is impaired is a general alteration in the appearance of landscape features or the sky, changing the color or the contrast between landscape features or causing features of a view to disappear. The first phenomenon is commonly referred to as plume impairment, whereas the second phenomenon is sometimes referred to as uniform haze impairment. As plumes are transported within a stable atmospheric layer, they may become a layered haze. As plumes and other more diffuse emission sources are transported and become well mixed in the atmosphere, they may develop into a uniform haze.

#### *Visibility Parameters (Revised)*

The analysis methods for new source growth, described in this chapter, deal with the visibility effects of discrete plumes and the aggregation of discrete plumes into a uniform haze. The difference in these phenomena, as treated in this chapter, is whether the visibility effect is primarily seen as a section of the atmosphere which exhibits a change in contrast or color as compared with a viewed background, or whether the effect is due to an alteration of the appearance of the background features themselves. For the first situation, the contrast (C) and color difference index ($\Delta E$) of the plume and the viewing background are calculated. For the second situation, the change in atmospheric light extinction ($\Delta b_{ext}$), relative to natural conditions, is calculated. The light extinction is inversely proportional to "visual range." An approximation for which situation applies is the distance from the point of emission. (Distance serves as an indicator of where steady state conditions may apply.) The visibility impairment from sources within 50 kilometers of a view is usually calculated using contrast and color difference, whereas visibility impairment from sources greater than 50 kilometers from a view, or the aggregation of a number of plumes, regardless of distance, is usually calculated using the change in light extinction. The distance approximation is useful for distinguishing these two phenomena; the terms "near field" and "distant/multi-source" are sometimes used in the remainder of this document to make this distinction.

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[5] Or, an intermittent hourly emission limit could be annualized by multiplying by 8,760 hours per year/2,000 lb/ton (= 4.38).

### 3.3.2. Recommendations for Evaluating Visibility Impacts (Revised)

There are two fundamentally different approaches one could adopt to determine visibility impairment. One is a technically rigorous, complex, and situation-specific method, while the other is a more generalized approach. The more rigorous approach requires determination of particle concentrations and size distributions, calculation of particle growth dynamics, and application of elaborate physics (e.g., Mie Theory) to determine the optical characteristics of the aerosol distribution. Sophisticated radiative transfer models are then applied, using aerosol optical characteristics, lighting and scene characteristics, and spatial distribution of the pollutants to calculate the path and wavelength of image-forming and non-image-forming light that reaches a specific observer from all points in the scene being viewed.

While such a detailed analysis may be useful for assessing specific cases, it is usually impractical for situations in which visibility could be experienced in a nearly infinite variety of circumstances. Practical limitations frequently dictate that it is more reasonable to use a generalized approach to determine the change in extinction by using bulk-averaged aerosol-specific extinction efficiencies rather than trying to reproduce the complex optical phenomena that may occur in the atmosphere.

Consequently, as a first-level analysis, FLAG recommends the generalized approach for determining the effects on visibility from a proposed new source's emissions. The procedure is to estimate the atmospheric concentrations of visibility impairing pollutants, apply representative visibility parameters, calculate the change from specified reference levels, and compare this change with prescribed threshold values. The more detailed analysis described above may be appropriate as a refined analysis in the event the source fails the first-level analysis.

FLAG is using EPA's estimates of natural visibility conditions under its Regional Haze Rule as reference levels for Class I visibility analyses. Comparison with natural conditions will help ensure that those conditions will not be impaired in keeping with Section 169A of the CAA. Because of the different requirements of the two modeling approaches discussed below, natural conditions should be expressed using two different metrics:

- Standard visual range (visual range adjusted to a Rayleigh condition of 10 $Mm^{-1}$), for near field modeling. Present EPA guideline visibility models traditionally accept visibility conditions expressed in these terms.
- Extinction, for distant/multi-source modeling. Visibility conditions should be expressed in terms of the averaged extinction efficiencies of the individual atmospheric constituents that comprise the total extinction. The relative humidity effects of the hygroscopic particles should be accounted for when the change in extinction is calculated.

Information needed to calculate the above indices for all 156 Class I areas for which visibility is an important attribute is provided in Tables 5 through 10 at the end of this chapter. If estimates are needed for Class II areas, the FLM can provide them.

### 3.3.3. Air Quality Models and Visibility Assessment Procedures (Revised)

The modeling discussion will be divided into two parts to address the very different requirements for 1) near field modeling where plumes or layers are compared against a viewing background, and 2) distant/multi-source modeling for plumes and aggregations of plumes that affect the general appearance of a scene. Note that both of the above analyses might apply depending on the source's proximity to all portions of the Class I area or multiple Class I areas.

FLAG 2000 provided information in the form of recommendations, specific processes, and interpretations of results for assessing visibility impacts of sources affecting Class I areas (although some of this information is generally applicable to Class II areas, as well). The information separately addressed assessments for sources proposing to locate relatively near (within 50 km) and at farther distances (greater than 50 km) from these areas. It also recommended impairment thresholds and identified the conditions for which cumulative analyses could be warranted. This revision (FLAG 2010) updates the Distant/Multi-source analysis discussed in FLAG 2000, and clarifies the recommendations regarding the near-field (within 50 km)/steady-state analysis.

#### *Near Field Analysis Technique for Analyzing Plumes or Layers Viewed Against a Background (Revised)*

#### The Model (Near Field – Steady State Conditions Applicable) (Revised)

EPA has recommended a methodology to assess impacts due to coherent plumes. A guideline for when these steady state conditions apply is the distance from the source to the view of concern. This technique is usually applied for sources locating within 50 km of a Class I area. Applicants should first model their potential plume impacts using the screening model, VISCREEN (EPA 1992a), or, if the next level of analysis is called for, PLUVUE II (EPA 1992b and 1996a). Both of these models use steady-state, gaussian-based plume dispersion techniques to calculate one-hour concentrations within an elevated plume. These two models calculate the change in the color difference index ($\Delta E$) and contrast between the plume and the viewing background. Values of $\Delta E$ and plume contrast are based on the concentrations of fine primary particulates (including sulfates), nitrogen dioxide ($NO_2$), and the geometry of the observer, target, plume, and the position of the sun. PLUVUE II also allows consideration of the effects of secondarily formed sulfates. Plume contrast results from an increase or decrease in light transmitted from the viewing background through the plume to the observer. The specifics of the emission scenarios and plume/observer geometries for modeling should be selected in consultation with the appropriate Agency representatives. At the present time there is no recommended procedure for conducting analyses of multiple sources with these modeling tools, so multiple coherent plumes should be treated individually, or combined into a representative single source if appropriate. Alternatively, the techniques outlined in the Distant/Multi-Source section below may be used on a case-by-case basis.

### The Recommended Procedures (Near Field – Steady State Conditions) (Revised)

Until better modeling tools are available, FLAG recommends using the present EPA techniques for plume visual impact screening analyses (EPA 1992c). However, unlike those procedures, which suggest the use of current average annual visibility conditions, FLAG recommends that for Class I areas the visual range corresponding to natural conditions be used to generate the hourly estimates of ΔE and plume contrast. FLAG recommends this change in order for the analysis technique to be consistent with the national visibility goal. For plume analyses, FLAG recommends using the monthly average natural visual range conditions provided for each area in Table 10.

If a screening analysis of a new or modified source can demonstrate that its emissions will not cause a plume with any hourly estimates of ΔE greater than or equal to 2.0, or the absolute value of the contrast values (|C|) greater than or equal to 0.05, the FLM is likely not to object to the issuance of the PSD permit based on near field visibility impacts and no further near field visibility analyses will be requested. More refined analyses (i.e., PLUVUE II) would be undertaken if the above conditions are not met and would be compared against lower levels of concern. For PLUVUE II analyses, the FLM would likely not object if ΔE < 1.0 and |C| < 0.02.

All analysis for Class I visibility impacts should include all visibility impairing emissions. This means that even if a facility is only considered a significant emitter of one pollutant, all pollutants that may contribute to impairment should be modeled together. Furthermore, since visibility is an instantaneous value, short-term (24-hour) maximum allowable emissions should be used.

- Level-1 Near Field Screening. Conducting a complete refined plume blight analysis can become rather complex, so three levels of evaluation are available to an applicant. The first, Level-1 screening, is the simplest and most conservative method. As described in the EPA's Workbook for Estimating Visibility Impairment (EPA-450/4-80-031):

  > Level-1 Screening: Level-1 screening is designed to provide a conservative estimate of plume visual impacts (i.e., impacts that would be larger than those calculated with more realistic input and modeling assumptions). This conservatism is achieved by the use within the screening model VISCREEN of worst-case meteorological conditions: extremely stable (F) atmospheric condition, coupled with a very low wind speed (1 m/s) persisting for 12 hours, with a wind that would transport the plume directly adjacent to the observer (as shown schematically in Figure 7).

  Since little project specific information is used for a Level-1 screening analysis, documentation requirements are minimal. Basic information of emissions, meteorological parameters, and model results should be provided. Applicants are encouraged to supply electronic copies of all files necessary to reproduce the results. If an application shows estimated impact values within the thresholds, it is unlikely that additional evaluation will be necessary.

- Level-2 Near Field Screening. If Level-2 screening is necessary, more project specific information is now incorporated. Actual meteorology from the area and emission characteristics of the facility are used. Again, as described in the EPA's Workbook for Estimating Visibility Impairment:

  > Level-2 Screening: As shown in Figure 1, Level-2 plume visual impact screening is done if the Level-1 results exceed the screening criteria. The objective of Level-2 screening is identical to that of Level-1—the estimation of worst-day plume visual impacts—but in Level-2 screening more realistic (less conservative) input, representative of the given source and the Class I area, is provided. This situation-specific input may include particle size distributions for plume and background that are different from those used in the default Level-1 analysis. Median background visual range based on on-site measurements rather than the map shown in Figure 9 might be used. However, the most important potential difference in input between Level-1 and Level-2 analysis centers on meteorology and plume transport and dispersion patterns. While the Level-1 analysis assumes F stability, a 1 m/s wind speed, and a wind direction that would carry plume material very close to the observer, in the Level-2 analysis, meteorological data and topography representative of the source area and Class I area may suggest that worst-case plume dispersion conditions are different.

It is important to note that the Agencies have maintained the recommendation that all applicants compare estimated modeled impacts from a facility against natural conditions. This is true for all analysis levels. The use of five years of site-representative meteorology and facility-specific emission characteristics is what makes this analysis different.

As a result of the increased project-specific information, documentation also should include summaries and/or tables describing the additional data sets and evaluation steps taken to conduct the analysis.

Once again, meeting screening thresholds means that it is likely that the Agencies' Class I air quality modeling procedures will have been satisfied.

- Level-3 Near Field Refined Analysis. A Level-3 analysis is the final assessment. An applicant can conduct a full refined analysis demonstrating estimates of frequency, magnitude, and spatial extent of a proposed project's visibility impacts. The EPA's Workbook for Estimating Visibility Impairment says:

> Level-3 Analysis: In Level-3 analysis, the objective is broadened from conservative analysis of worst-case conditions to a realistic analysis of all conditions that would be expected to occur in a typical year in the region that includes both the emission source and the observer. Level-3 analysis is no longer considered screening because it is a comprehensive analysis of the magnitude and frequency of occurrence of plume visual impacts as observed at a sensitive Class I area vista.
>
> It is important to determine the frequency of occurrence of visual impact because the adversity or significance of impact is dependent on how frequently an impact of a given magnitude occurs. For example, if a plume is perceptible from a Class I area a third of the time, the impact would be considered much more significant than if it were perceptible only one day per year. The assessment of frequency of occurrence of impact should be an integral part of Level-3 visual impact analysis.

As mentioned above, the threshold values for this analysis step changed. For this step, EPA's PLUVUE II model is currently recommended. One main difference with PLUVUE II is its inability to evaluate more than one hour of impact per run. Because it is customary to evaluate five years of site-specific meteorology, it can become an extensive process. Applicants may want to develop and utilize tools to group hourly meteorological and post processing scenarios. The analysis identifies specific locations for plume/observer relationships. These observation points should be established within each potentially impacted Class I area. With each observer, potential impacts are calculated for all possible views. As with the meteorology, PLUVUE II is only able to assess one observer location per model run. Specific information on setup methods can be found in EPA's Workbook for Estimating Visibility Impairment and PLUVUE II manual.

Substantial documentation is needed for this more refined analysis. The discussion should summarize data sources, processing methods, and modeling utilities used, and information regarding all assumptions or consolidation criteria. In short, sufficient information and electronic files should be provided to the Agencies that will allow reviewers to reproduce the results. Due to the complexity of this refined analysis, the Agencies suggest that consultation occur between the applicant and the Agencies before working on the impact analysis begins. Furthermore, selection of model parameters and input data should be documented in a written protocol and agreed upon by the affected Agencies in advance of any modeling being conducted.

If the estimated plume parameters exceed the aforementioned values, the FLM would rely on a case-by-case effects-based test (NPS 1993), taking into account magnitude, frequency, duration, and other factors, to decide whether to make an adverse impact determination.

### Distant/Multi-Source Techniques for Analyzing Whether a Plume or an Aggregation of Plumes Alters the General Appearance of a Scene (Revised)

This analysis is generally more complex than the near field, coherent plume modeling analyses and the guidance from EPA is less definitive, though it is evolving. The modeling system should include the capability to assess single and multiple sources in a temporally and spatially varying meteorological domain, accommodate modeling domains measuring hundreds of kilometers, include rough and complex terrain, provide pollutant concentration estimates for averaging times from one-hour to annual, and address inert and secondarily formed pollutants and dry and wet deposition. In the early 1990s the FLMs and the EPA recognized the need for a consistent, technically credible technique to estimate contributions to air quality of multiple new sources locating more than 50 km from Class I areas. Towards that end, on April 15, 2003, the EPA promulgated revisions to Appendix W of 40 C.F.R. §51 (*Guideline on Air Quality Models*). The EPA revised the Guideline to adopt the CALPUFF model as the preferred long-range transport model for inclusion in Appendix A of that document. This technique is usually applied when sources are located more than 50 kilometers from portions of a Class I area, when an aggregation of plumes may impact an area, or when the assumptions inherent in steady state visibility models do not apply.

The first-level analysis procedures discussed in this revision differ from FLAG 2000 in several discrete areas, but generally remain the same. The primary differences are in the areas of the reference natural conditions that are used in the comparisons for thresholds of concern and using the average monthly relative humidity adjustment factors rather than the hour-by-hour factors identified in FLAG 2000. CALPUFF is still the preferred first-level air quality model for calculating pollutant concentrations, however, using "CALPUFF Lite" with single station meteorology is no longer recommended. We wish to emphasize that the first-level procedures defined herein are to be taken as a whole; any deviations from these procedures or ostensible refinements compromise the integrity of the analysis, and may warrant an hourly analysis for all hours in the analysis. Furthermore, the metric used for the first-level analysis (relative change in light extinction) is not necessarily the appropriate metric for a refined analysis. The procedures and metrics for refined analyses will need to be agreed upon by the affected Agencies.

The initial step in conducting the first-level analysis is to run CALPUFF using a minimum of three years of mesoscale meteorological model output, and preferably five years, consistent with current EPA guidance. Selection of model parameters and input data should be documented in a written protocol and agreed upon by the affected Agencies in advance of any modeling being conducted. Please note emissions input considerations and model receptor grid data are discussed below. The indices for comparison with the Agencies' levels of concern are calculated in CALPOST. The remainder of this discussion is focused on CALPOST.

After CALPUFF is run, CALPOST is used to evaluate whether the proposed source or modification will be below the Agencies' threshold for concern (i.e., 5% change in light extinction). The CALPOST parameter MVISBK is set to eight (8), sub-mode five (M8_MODE = 5), and the background hygroscopic and non-hygroscopic aerosol levels are derived from the annual average natural conditions provided in Table 6. The monthly relative humidity adjustment factors for the Class I area are input to the RHFAC array (Tables 7-9) in CALPOST. The 98th percentile test applies to the number of days that any model receptor in the Class I area exceeds the threshold. The visibility threshold for concern is not exceeded if the 98th percentile change in light extinction is less than 5% for each year modeled, when compared to the annual average natural condition value for that Class I area.

If this analysis indicates that the 98th percentile values for change in light extinction are equal to or greater than 5% for any year, then the Agencies will further scrutinize the applicant's proposal. The Agencies will consider the full range of factors discussed below (in the "Expansion of Discussion of Process for Adverse Impact Determination" chapter) and any refined analyses provided by the applicant before making a recommendation to the FLM regarding potential adverse impacts. As noted above, these refined analyses should account for the relevant physicochemical processes that produce visibility impairing pollutants and accurately treat the relevant radiative transfer properties affecting visibility. This will likely entail using different meteorological and air quality models capable of producing hourly concentrations, or less, and using a three dimensional radiative transfer model (see refined analysis discussion below).

For consistency with implementation of BART or the regional haze rule to specific Class I areas, the FLM or permitting authority may recommend use of the 20% best natural background values provided in Table 5 in lieu of annual averages on a case-by-case basis.

### Background Information on Thresholds

In its BART guidelines, EPA indicated that for regional haze, a source whose 98th percentile value of the haze index is greater than 0.5 deciview (dv) (approximately a 5% change in light extinction) is considered to contribute to regional haze visibility impairment. Similarly, a source that exceeds 1.0 dv (approximately a 10% change in light extinction) causes visibility impairment. The 0.5 dv and 1.0 dv thresholds are similar to what the Agencies used in FLAG 2000. Therefore, for consistency between visibility protection programs and to address similar concerns, the Agencies will also use the 98th percentile value as a threshold in the first-level visibility analyses for new source impacts.

In its 2005 BART guidelines, the EPA also concluded that by using the 98th percentile of CALPUFF modeled impacts the sources that contribute 0.5 deciview to regional haze visibility impairment in a Class I area would effectively be captured, while minimizing the likelihood that the highest modeled visibility impacts might be caused by conservative assumptions in the model. Similarly, using the monthly average relative humidity adjustment factors, rather than the hour-by-hour factors, reduces some of the higher (e.g., weather –related) values seen in FLAG 2000.

Using the 98th percentile of modeled visibility values to compare to the 5% change in extinction threshold would exclude roughly seven days per year from consideration for each Class I area. However, consistent with the BART guidelines, the 98th percentile test applies to the number of days that any model receptor in the Class I area exceeds the threshold. Also, this test is limited to haze-like, first-level analyses. Therefore, all applicable sources locating within 50 km of a Class I area would still need to assess coherent plume impacts in accordance with the procedure described above. Furthermore, applicable sources would need to assess sulfur and nitrogen deposition impacts at the Class I area.

#### *Natural Conditions*

FLAG 2000 discussed assessing the change in visibility due to a proposed new source relative to annual average natural conditions. Therefore, it is important to define natural conditions for each Class I area. At the time of FLAG 2000, the Agencies acknowledged that the EPA was working on defining natural conditions in support of their visibility regulations. In the absence of more specific data, the FLMs at that time adopted the appropriate aerosol concentrations developed by the National Acid Precipitation Assessment Program (NAPAP) as estimates of natural conditions for each Class I area. The EPA has since published natural condition estimates for each Class I area. The natural condition values provided in FLAG 2000 and those developed by the EPA are based on similar underlying assumptions; consequently, the estimates are similar. Regardless, the EPA estimates should be used by applicants in future visibility impact assessments. Please note that Tables 5 and 6 contain estimates for the 20% best natural visibility and annual average natural visibility conditions for each Class I area, respectively.

### *Relative Humidity Adjustment Factor*

FLAG 2000 discussed the importance of the relative humidity adjustment factor (f(RH)) when calculating the sulfate and nitrate components of the visibility extinction coefficient. These aerosols are hygroscopic and the addition of water enhances their scattering efficiencies. FLAG 2000 recommended using hour-by-hour f(RH) for the analysis. The EPA, in its 2005 BART guidelines, concluded that by using a monthly average f(RH) the likelihood that the highest modeled visibility impacts were caused by short-term and geographically different meteorological phenomena (e.g., weather events) would be minimized. The Agencies agree with the EPA that using the monthly f(RH) effectively neutralizes short-term weather events and are adopting a similar approach for Class I visibility impact analyses for new sources. Therefore, new sources performing Class I visibility analyses should use monthly average f(RH) values developed by EPA for large hygroscopic particles (Table 7), small hygroscopic particles (Table 8), and sea salt (Table 9), rather than the hourly values discussed in FLAG 2000.

### *Emissions Input*

There are two other aspects of the visibility impact analysis that the Agencies would like to clarify at this time: (1) emissions input, and (2) the model receptor grid. Regarding the emission inputs, because applicants are assessing a 24-hour average regional haze visibility impact, it is important that they model a corresponding maximum allowable 24-hour mass emission rate, as opposed to monthly or annual average emissions. Using a 30 day average emission rate as input to the visibility modeling analyses does not restrict the facility from emitting pollution at a higher rate for shorter time periods (e.g., 24-hour average). A 30 day average emission rate smooths out days with high emissions, and therefore, would underestimate the predicted 24-hour visibility impacts. Because the emission rates and the corresponding averaging times influence the outcome of the analyses, it is critical that appropriate emissions are matched to the averaging time being assessed, and that these emission rates ultimately are included as enforceable permit conditions. This approach is consistent with the *Guideline on Air Quality Models* (Appendix W of 40 C.F.R. §51) and the EPA BART guidelines. Furthermore, if an applicant chooses to conduct any refined analyses, where visibility impairment is assessed at no more than an hourly basis, maximum hourly emissions should be analyzed.

Please note that all visibility impairing pollutants should be modeled from all modified or affected emission unit(s), regardless of which pollutants actually triggered NSR. Particulate Matter (PM) should also be speciated into filterable PM (coarse, fine, elemental carbon) and Condensable PM (organic carbon and sulfates) based on the best available information. Particulate speciation data for several source types can be found on the NPS Air Resources Division's web site at:

- http://www.nature.nps.gov/air/permits/ect/index.cfm

Applicants should calculate the 24-hour average net emission increase for each pollutant from modified facilities as the maximum allowable 24-hour average minus the actual hourly rate averaged over the past two years (annual emissions over past two years/hours of operation over last two years).[6]

### *Model Receptor Grid*

Since FLAG 2000 was published, the NPS Air Resources Division has developed a database of modeling receptors for all of the Class I areas in the contiguous United States. A file conversion program to convert the data from latitude/longitude to other common mapping coordinates (currently Lambert Conformal and Universal Transverse Mercator (UTM)) has also been developed. Alaska and Hawaii are not yet complete, but will be included in the data sets when they are available.

Permit applicants can download the Class I Receptor Data files, as well as the Conversion program, from the link below. For modeling consistency, the Agencies ask that permit applicants use the uniform receptor grids provided. Also available are the Class I boundary shape files that were used to create the receptor data files.

- http://www.nature.nps.gov/air/Maps/Receptors/index.cfm

Receptor grids for FLM Class II areas should be dense enough to determine Class II increment consumption and

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[6] Note that this is different from the emission change calculation used for short-term increment, which is calculated as the maximum allowable 24-hour average minus the highest occurrence over the past two years.

to perform any required "secondary impacts" (i.e., soils, vegetation and visibility) analyses.

*Refined Analysis*

It is important to reiterate that the FLAG distant/multi-source visibility analysis is only a first-level screening technique, primarily designed to identify those sources that are unlikely to significantly affect visibility and warrant no further analysis, and those that may adversely impact visibility and warrant further scrutiny. Visibility is experienced instantaneously, not on a 24-hour average basis. The 24-hour average visibility calculation in FLAG is acceptable because of a number of simplifying assumptions in the prescribed technique. Accepting certain EPA BART guideline procedures as an update to the FLAG techniques does not alter the first-level nature of the procedure. Modifying those simplifying assumptions negates the acceptability of using a 24-hour average. Consequently, any applicant whose visibility analysis deviates from the recommended FLAG screening procedures warrants performing an hour-by-hour analysis.

Deviations from the first-level screening procedure should lead to refinements in the modeling and visibility analyses, not arbitrary adjustments to the prescribed first-level technique. This is especially important in dealing with weather-related events. The Agencies believe that by paralleling the BART guideline procedures they have adequately taken into account the effects of meteorological extremes, and model uncertainty. Therefore, given the Agencies' desire to balance the positive and negative biases of the FLAG screening methodology, any modifications to the screening technique invalidate the Level 1 model results. Consequently, the Agencies do not expect permit applicants that exceed the visibility effects thresholds to scrutinize the data and attempt to disregard specific impact days due to weather. Under those circumstances, the permit applicant can accept the modeling results at face value, and then the FLM will decide whether or not those impacts are adverse. Alternatively, the applicant could conduct an hour-by-hour analysis (as opposed to using a 24-hour average) by performing a refined analysis using a more sophisticated approach that requires determining particle concentrations and size distributions, calculation of particle growth dynamics, and application of Mie Theory to determine the optical characteristics of the aerosol distribution. Sophisticated radiative transfer models can then be applied, using aerosol optical characteristics, lighting and scene characteristics, and spatial distribution of the pollutants to calculate the path and wavelength of image-forming and non-image-forming light that reaches a specific observer from all points in the scene being viewed. The concept of this more refined approach is discussed in FLAG 2000, and one possible approach is included in "*Proposed FLAG Level II and III Visibility Assessment*" (Schichtel et al. 2006). However, if this situation arises, permit applicants are encouraged to consult with the Agencies and discuss the specifics of this refined analysis.

### 3.3.4. Summary (Revised)

FLAG provides recommendations, specific procedures, and interpretation of results for assessing visibility impacts of new or modified sources on Class I area resources. Although FLMs only have a formal role in the permitting process for applications that affect Class I areas, this information can be used for Class II areas as well. FLAG addresses assessments for sources proposed for locations near (generally within 50 km) and at large distances (greater than 50 km) from these areas. The key components of the recommendations are highlighted below.

In general, FLAG recommends that an applicant:

- Apply the Q/D test (see section 3.2, 'Initial Screening Criteria') for proposed sources greater than 50 km from a Class I area to determine whether or not any further visibility analysis is necessary.
- Consult with the appropriate regulatory agency and with the FLM for the affected Class I area(s) or other affected area for confirmation of preferred visibility analysis procedures.
- Obtain FLM recommendation for the specified reference levels (estimate of natural conditions) and, if applicable, FLM recommended plume/observer geometries and model receptor locations.
- Apply the applicable EPA Guideline, steady-state models for regions within the Class I area that are affected by plumes or layers that are viewed against a background (generally within 50 km of the source).
    - Calculate hourly estimates of changes in visibility, as characterized by the change in the color difference index ($\Delta E$) and plume contrast (C), with respect to natural conditions, and compare these estimates with the thresholds given in section 3.3.3.
- For regions of the Class I area where visibility impairment from the source would cause a general alteration of the appearance of the scene (generally 50 km or more away from the source or from the interaction of the emissions from multiple sources), apply a non-steady-state air quality model with chemical transformation capabilities (refer to EPA guidance documents), which yields ambient concentrations of visibility-impairing pollutants. At each Class I receptor:
    - Calculate the change in extinction due to the source being analyzed, compare these changes with the reference conditions, and then compare these results with the thresholds given in section 3.3.3.
    - Utilize estimates of annual average natural visibility conditions for each Class I area as presented in Table 6, unless otherwise recommended by the

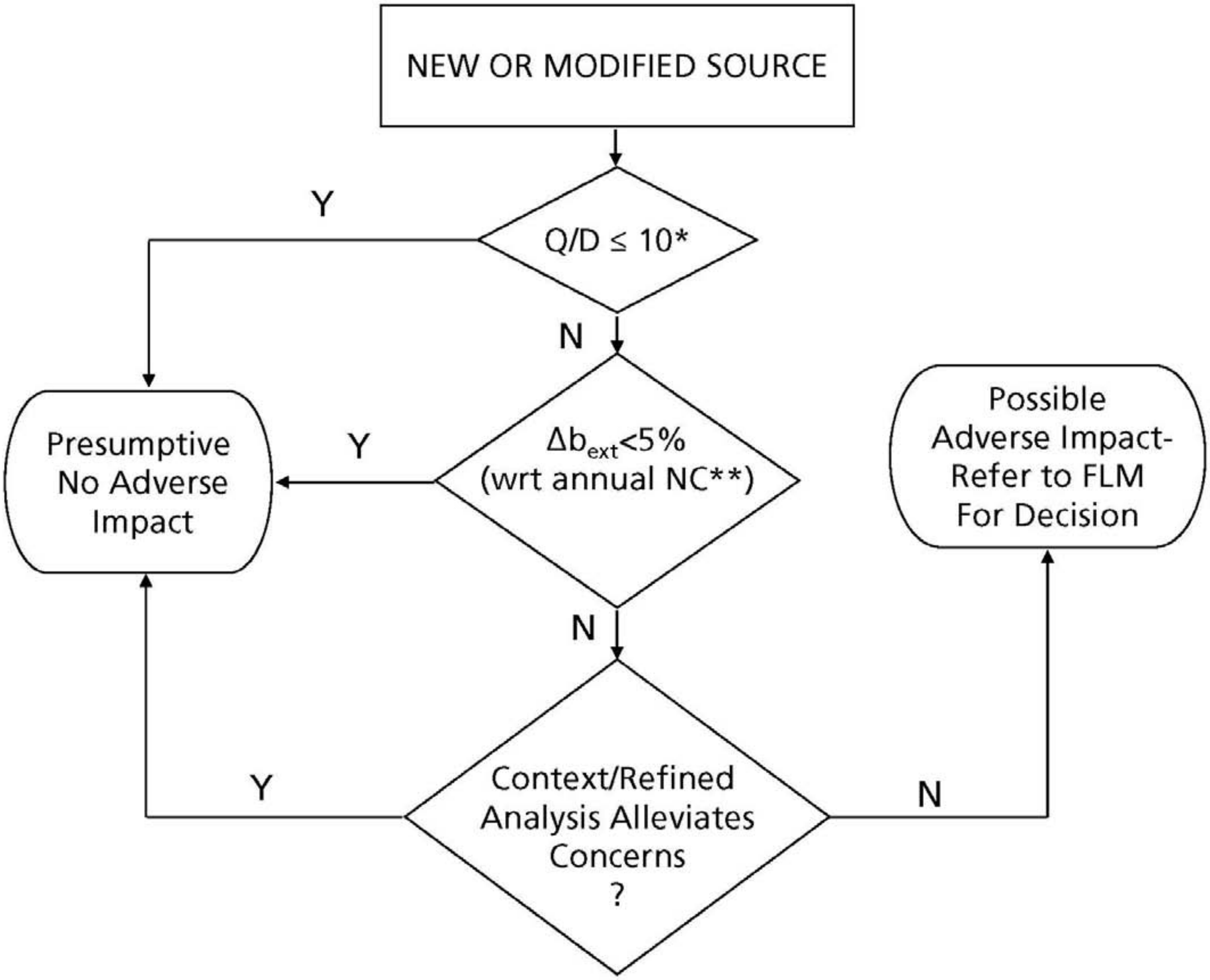

**Figure 4. Procedure for Visibility Assessment for Distant/Multi-Source Applications (Revised)**
*Q/D test only applies to sources located greater that 50 km from a Class I area.
**Difference Change in the 98th percentile with respect to (wrt) the annual average Natural Condition (NC). Applicant should use the 20th percentile best natural condition background if recommended by the FLM or permitting authority.

FLM or permitting authority. Alternative estimates of visibility conditions are provided in Table 5 for consistency with State agencies that elected to use 20% best visibility for regional haze or BART implementations.

- If first-level modeling results are above levels of concern, continue to consult with the Agencies to discuss other considerations (e.g., possible impact mitigation, more refined analyses).

This review process for distant/multi-source applications is portrayed schematically in Figure 4.

### 3.3.5. Natural Visibility Conditions and Analysis Methods (New)

Both distant/multi-source applications and near-field analyses require an estimate of natural visibility conditions. The effects of visibility impairing emissions from a source are compared to the natural visibility conditions to determine the potential for unacceptable visibility impacts. The methods and data for calculating natural visibility conditions in FLAG are presented in this section. The calculation of visibility metrics under the distant/multi-source application is also described. For the distant/multi-source application, aerosol species components are provided for input to the CALPUFF modeling system, which is the suggested model for most of these applications. For near-field analyses, visual ranges under natural conditions are provided for input to the VISCREEN and PLUVUE-II models.

### *Natural visibility conditions*

**Distant/Multi-source:** Natural visibility conditions are affected by the light scattering of air molecules (Rayleigh scattering) and by naturally occurring aerosols. The majority of aerosols, both natural and anthropogenic, that affect light extinction can be categorized as sulfates ($(NH_4)_2SO_4$), nitrates ($NH_4NO_3$), organic mass (OM), elemental carbon (EC), soil, sea salt, and coarse mass (CM). The light scattering efficiency of aerosols is affected by the size of the aerosol relative to the wavelength of light. Sulfates, nitrates, and sea salt are all hygroscopic, which affects their size and their light scattering efficiency as they acquire or shed water molecules. The relationship between the aerosol components and light extinction is shown through the equations in Figure 5. The hygroscopic effects are accounted for through the relative humidity adjustment factors (f(RH)) terms in the equations in Figure 5. The aerosol concentrations and monthly relative humidity adjustment factors for calculating natural visibility conditions are found in Tables 5 through 10.

The aerosol concentrations for the 20% best natural conditions are found in Table 5 and the annual average natural concentrations are found in Table 6.

**Near-field:** The near-field visibility analysis is generally performed using either VISCREEN or PLUVUE-II. For calculating the effect of a plume on visibility, a background visibility, expressed as a visual range, must be input to these models. Appropriate average natural conditions, by month and Class I area are listed in Table 10. The values in Table 10 were determined by calculating the month by month light extinction values and calculating the visual range (VR) ($VR=3912/b_{ext}$).

### *Example Calculation of Natural Conditions and Change in Light Extinction*

The annual average concentration and the relative humidity adjustment factors ($f_{\{L,S,SS\}}(RH)$) for the Alpine Lakes Wilderness for January will be used for illustration of the calculations.

1. Look up the Alpine Lakes Wilderness annual average concentration values in Table 6 for sulfate ($(NH_4)_2SO_4$), nitrate ($NH_4NO_3$), organic mass (OM), Elemental Carbon (EC), soil, coarse mass (CM), sea salt, and Rayleigh scattering.

**Table 2. Section of Table 6 Used for Step 1 Calculations of the Alpine Lakes Wilderness Example**

| Class I Area | $(NH_4)_2SO_4$ µg/m³ | $NH_4NO_3$ µg/m³ | OM µg/m³ | EC µg/m³ | Soil µg/m³ | CM µg/m³ | Sea Salt µg/m³ | Rayleigh $Mm^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| Acadia NP | 0.23 | 0.10 | 1.67 | 0.02 | 0.24 | 2.14 | 0.14 | 12 |
| Agua Tibia Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.14 | 11 |
| Alpine Lakes Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.23 | 1.30 | 0.06 | 11 |
| … | … | … | … | … | … | … | … | … |

2. Look up the f(RH) factors for large sulfate/nitrate (table 7), small sulfate/nitrate (table 8), and sea salt (table 9); January in this example.
   a. $f_L(RH) = 3.86$
   b. $f_S(RH) = 5.87$
   c. $f_{SS}(RH) = 5.35$
3. Calculate the large and small sulfate, nitrate, and organic mass, as defined in Figure 5.

**Table 3. Step 3 Calculation Results for the Alpine Lakes Wilderness Example**

| | Total | Large | Small |
|---|---|---|---|
| Sulfate | 0.12 | 0.00072 | 0.11928 |
| Nitrate | 0.10 | 0.0005 | 0.0995 |
| Organic Mass | 0.60 | 0.018 | 0.582 |

4. Apply to $b_{ext}$ equation in Figure 5:

$$
\begin{aligned}
b_{ext} = & \\
& 2.2 \times 5.87 \times 0.11928 + && \{\text{Sulfate}\} \\
& 4.8 \times 3.86 \times 0.00072 \\
& + 2.4 \times 5.87 \times 0.0995 + && \{\text{Nitrate}\} \\
& 5.1 \times 3.86 \times 0.0005 \\
& + 2.8 \times 0.582 + 6.1 \times && \{\text{Organic Mass}\} \\
& 0.018 \\
& + 10 \times 0.02 && \{\text{Elemental Carbon}\} \\
& + 1 \times 0.23 && \{\text{Soil}\} \\
& + 0.6 \times 1.30 && \{\text{Coarse Mass}\} \\
& + 1.7 \times 5.35 \times 0.06\} && \{\text{Sea Salt} \\
& + 11 && \{\text{Rayleigh}\} \\
& + 0.33 \times 0 && \{NO_2\} \\
b_{ext} & = 17.46\ Mm^{-1}
\end{aligned}
$$

To calculate the change in light extinction from the impacts from an air pollution source, the species concentrations from the source are added to the total species concentrations in steps 3 and 4 above and the new total light extinction is calculated. Therefore, if a source contributed 0.05 µg/m$^3$ of sulfate ($(NH_4)_2SO_4$) and 0.01 µg/m$^3$ of nitrate ($NH_4NO_3$) at a receptor, the total, large and small sulfate and nitrate values would be:

**Table 4. Step 4 Calculation Results for the Alpine Lakes Wilderness Example**

| | Total | Large | Small |
|---|---|---|---|
| Sulfate | 0.17 (0.12+0.05) | 0.001445 | 0.168555 |
| Nitrate | 0.11 (0.10+0.01) | 0.000605 | 0.109395 |

The other concentrations and the relative humidity adjustment factors would remain as in step 4 of the natural condition example. After recalculating the light extinction accounting for the effect of the source ($b_{ext(source+nat\ cond)}$), the new light extinction would be 18.25 Mm$^{-1}$.

The change in light extinction ($\Delta b_{ext}$) would simply be:

$$\Delta b_{ext} = (b_{ext(source+nat\ cond)} - b_{ext(nat\ cond)}) / b_{ext(nat\ cond)} \quad \text{or:}$$

$$\Delta b_{ext} = (18.25 - 17.46) / 17.46$$

$$\Delta b_{ext} = 0.045\ (4.5\%)$$

The example provided here is to illustrate the process. Usually the concentrations and relative humidity adjustment factors would be extracted from the appropriate tables and input to one of the air quality model post processing programs.

$$
\begin{aligned}
b_{ext} = \; & 2.2 \times f_S(RH) \times [\text{Small Sulfate}] + 4.8 \times f_L(RH) \times [\text{Large Sulfate}] \\
& + 2.4 \times f_S(RH) \times [\text{Small Nitrate}] + 5.1 \times f_L(RH) \times [\text{Large Nitrate}] \\
& + 2.8 \times [\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}] \\
& + 10 \times [\text{Elemental Carbon}] \\
& + 1 \times [\text{Fine Soil}] \\
& + 0.6 \times [\text{Coarse Mass}] \\
& + 1.7 \times f_{SS}(RH) \times [\text{Sea Salt}] \\
& + \text{Rayleigh Scattering (Site Specific)} \\
& + 0.33 \times [NO_2\ (\text{ppb})] \;\; \{\text{or as: } 0.1755 \times [NO_2\ (\mu g/m^3)]\}
\end{aligned}
$$

Where:

[ ] indicates concentrations in $\mu g/m^3$

$f_S(RH)$ = Relative humidity adjustment factor for small sulfate and nitrate

$f_L(RH)$ = Relative humidity adjustment factor for large sulfate and nitrate

$f_{SS}(RH)$ = Relative humidity adjustment factor for sea salt

For Total Sulfate $< 20\ \mu g/m^3$:

$$[\text{Large Sulfate}] = ([\text{Total Sulfate}] / 20\ \mu g/m^3) \times [\text{Total Sulfate}]$$

For Total Sulfate $\geq 20\ \mu g/m^3$:

$$[\text{Large Sulfate}] = [\text{Total Sulfate}]$$

And:

$$[\text{Small Sulfate}] = [\text{Total Sulfate}] - [\text{Large Sulfate}]$$

To calculate large and small nitrate and organic mass, substitute ({Large, Small, Total} {Nitrate, Organic Mass}) for Sulfate.

**Figure 5. IMPROVE Equation for Calculating Light Extinction**
http://vista.cira.colostate.edu/improve/Publications/GrayLit/019_RevisedIMPROVEeq/RevisedIMPROVEAlgorithm3.doc

## Table 5. 20% Best Natural Conditions – Concentrations and Rayleigh Scattering By Class I Area

| Class I Area | $(NH_4)_2SO_4$ µg/m3 | $NH_4NO_3$ µg/m3 | OM µg/m$^3$ | EC µg/m$^3$ | Soil µg/m$^3$ | CM µg/m$^3$ | Sea Salt µg/m$^3$ | Rayleigh Mm$^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Acadia NP | 0.09 | 0.03 | 0.68 | 0.01 | 0.10 | 0.94 | 0.03 | 12 | B20% |
| Agua Tibia Wilderness | 0.03 | 0.04 | 0.26 | 0.01 | 0.26 | 1.20 | 0.04 | 11 | B20% |
| Alpine Lakes Wilderness | 0.04 | 0.03 | 0.15 | 0.01 | 0.05 | 0.30 | 0.02 | 11 | B20% |
| Anaconda Pintler Wilderness | 0.04 | 0.03 | 0.12 | 0.01 | 0.07 | 0.31 | 0.00 | 10 | B20% |
| Ansel Adams Wilderness | 0.02 | 0.01 | 0.12 | 0.01 | 0.07 | 0.44 | 0.01 | 9 | B20% |
| Arches NP | 0.07 | 0.06 | 0.23 | 0.01 | 0.14 | 0.89 | 0.01 | 9 | B20% |
| Badlands NP | 0.05 | 0.05 | 0.23 | 0.01 | 0.22 | 0.99 | 0.00 | 11 | B20% |
| Bandelier NM | 0.07 | 0.06 | 0.31 | 0.01 | 0.16 | 0.91 | 0.00 | 9 | B20% |
| Bering Sea Wilderness | | | | | | | | | B20% |
| Big Bend NP | 0.05 | 0.04 | 0.24 | 0.01 | 0.11 | 0.80 | 0.00 | 10 | B20% |
| Black Canyon of the Gunnison NP | 0.06 | 0.04 | 0.24 | 0.01 | 0.13 | 0.88 | 0.00 | 9 | B20% |
| Bob Marshall Wilderness | 0.05 | 0.04 | 0.19 | 0.01 | 0.08 | 0.37 | 0.00 | 10 | B20% |
| Bosque del Apache Wilderness | 0.08 | 0.06 | 0.30 | 0.01 | 0.15 | 0.97 | 0.02 | 10 | B20% |
| Boundary Waters Canoe Area Wilderness | 0.11 | 0.02 | 0.50 | 0.01 | 0.13 | 0.86 | 0.01 | 11 | B20% |
| Breton Wilderness | 0.14 | 0.05 | 0.73 | 0.01 | 0.27 | 2.26 | 0.07 | 11 | B20% |
| Bridger Wilderness | 0.05 | 0.04 | 0.14 | 0.01 | 0.07 | 0.33 | 0.00 | 9 | B20% |
| Brigantine Wilderness | 0.12 | 0.04 | 0.86 | 0.01 | 0.24 | 1.73 | 0.04 | 12 | B20% |
| Bryce Canyon NP | 0.04 | 0.05 | 0.18 | 0.01 | 0.10 | 0.60 | 0.00 | 9 | B20% |
| Cabinet Mountains Wilderness | 0.05 | 0.05 | 0.13 | 0.01 | 0.09 | 0.42 | 0.01 | 10 | B20% |
| Caney Creek Wilderness | 0.07 | 0.06 | 0.68 | 0.01 | 0.14 | 1.51 | 0.02 | 11 | B20% |
| Canyonlands NP | 0.07 | 0.06 | 0.23 | 0.01 | 0.14 | 0.89 | 0.01 | 9 | B20% |
| Cape Romain Wilderness | 0.14 | 0.06 | 0.88 | 0.01 | 0.24 | 1.99 | 0.04 | 12 | B20% |
| Capitol Reef NP | 0.06 | 0.07 | 0.26 | 0.01 | 0.15 | 0.79 | 0.01 | 9 | B20% |
| Caribou Wilderness | 0.03 | 0.02 | 0.12 | 0.01 | 0.08 | 0.24 | 0.01 | 10 | B20% |
| Carlsbad Caverns NP | 0.06 | 0.05 | 0.26 | 0.01 | 0.12 | 0.82 | 0.00 | 9 | B20% |
| Chassahowitzka Wilderness | 0.14 | 0.08 | 1.02 | 0.01 | 0.28 | 2.46 | 0.02 | 11 | B20% |
| Chiricahua NM | 0.06 | 0.05 | 0.27 | 0.01 | 0.13 | 0.81 | 0.00 | 10 | B20% |
| Chiricahua Wilderness | 0.06 | 0.05 | 0.27 | 0.01 | 0.13 | 0.81 | 0.00 | 10 | B20% |
| Cohutta Wilderness | 0.09 | 0.08 | 0.69 | 0.01 | 0.15 | 1.06 | 0.01 | 11 | B20% |
| Crater Lake NP | 0.02 | 0.02 | 0.08 | 0.01 | 0.07 | 0.23 | 0.01 | 9 | B20% |
| Craters of the Moon NM | 0.06 | 0.05 | 0.19 | 0.01 | 0.12 | 0.69 | 0.01 | 10 | B20% |
| Cucamonga Wilderness | 0.03 | 0.03 | 0.15 | 0.01 | 0.14 | 0.67 | 0.01 | 9 | B20% |
| Denali NP & Pres | 0.04 | 0.02 | 0.08 | 0.01 | 0.05 | 0.31 | 0.01 | 11 | B20% |
| Desolation Wilderness | 0.04 | 0.03 | 0.15 | 0.01 | 0.09 | 0.51 | 0.01 | 9 | B20% |
| Diamond Peak Wilderness | 0.02 | 0.02 | 0.08 | 0.01 | 0.07 | 0.23 | 0.01 | 9 | B20% |
| Dolly Sods Wilderness | 0.10 | 0.05 | 0.80 | 0.01 | 0.17 | 0.96 | 0.01 | 10 | B20% |
| Dome Land Wilderness | 0.03 | 0.02 | 0.18 | 0.01 | 0.08 | 0.43 | 0.01 | 10 | B20% |
| Eagle Cap Wilderness | 0.05 | 0.02 | 0.17 | 0.01 | 0.10 | 0.50 | 0.01 | 10 | B20% |
| Eagles Nest Wilderness | 0.04 | 0.03 | 0.14 | 0.01 | 0.08 | 0.36 | 0.00 | 8 | B20% |
| Emigrant Wilderness | 0.03 | 0.02 | 0.10 | 0.00 | 0.08 | 0.50 | 0.01 | 10 | B20% |
| Everglades NP | 0.16 | 0.07 | 0.77 | 0.01 | 0.16 | 1.86 | 0.12 | 11 | B20% |
| Fitzpatrick Wilderness | 0.05 | 0.04 | 0.14 | 0.01 | 0.07 | 0.33 | 0.00 | 9 | B20% |
| Flat Tops Wilderness | 0.04 | 0.03 | 0.14 | 0.01 | 0.08 | 0.36 | 0.00 | 8 | B20% |
| Galiuro Wilderness | 0.06 | 0.05 | 0.27 | 0.01 | 0.13 | 0.81 | 0.00 | 10 | B20% |

**Table 5. 20% Best Natural Conditions – Concentrations and Rayleigh Scattering By Class I Area**

| Class I Area | $(NH_4)_2SO_4$ µg/m3 | $NH_4NO_3$ µg/m3 | OM $\mu g/m^3$ | EC $\mu g/m^3$ | Soil $\mu g/m^3$ | CM $\mu g/m^3$ | Sea Salt $\mu g/m^3$ | Rayleigh $Mm^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Gates of the Mountains Wilderness | 0.04 | 0.04 | 0.13 | 0.01 | 0.07 | 0.49 | 0.00 | 9 | B20% |
| Gearhart Mountain Wilderness | 0.02 | 0.02 | 0.08 | 0.01 | 0.07 | 0.23 | 0.01 | 9 | B20% |
| Gila Wilderness | 0.06 | 0.04 | 0.22 | 0.01 | 0.09 | 0.45 | 0.00 | 9 | B20% |
| Glacier NP | 0.05 | 0.03 | 0.17 | 0.01 | 0.11 | 0.57 | 0.00 | 11 | B20% |
| Glacier Peak Wilderness | 0.02 | 0.03 | 0.09 | 0.00 | 0.04 | 0.28 | 0.01 | 11 | B20% |
| Goat Rocks Wilderness | 0.02 | 0.01 | 0.06 | 0.00 | 0.04 | 0.21 | 0.01 | 10 | B20% |
| Grand Canyon NP | 0.04 | 0.03 | 0.12 | 0.01 | 0.10 | 0.59 | 0.00 | 9 | B20% |
| Grand Teton NP | 0.06 | 0.05 | 0.17 | 0.01 | 0.08 | 0.33 | 0.00 | 9 | B20% |
| Great Gulf Wilderness | 0.09 | 0.04 | 0.56 | 0.01 | 0.10 | 1.05 | 0.02 | 11 | B20% |
| Great Sand Dunes NP & Pres | 0.06 | 0.05 | 0.29 | 0.01 | 0.15 | 0.90 | 0.00 | 9 | B20% |
| Great Smoky Mountains NP | 0.09 | 0.06 | 0.78 | 0.01 | 0.16 | 1.47 | 0.01 | 11 | B20% |
| Guadalupe Mountains NP | 0.06 | 0.05 | 0.26 | 0.01 | 0.12 | 0.82 | 0.00 | 9 | B20% |
| Haleakala NP | 0.05 | 0.04 | 0.24 | 0.01 | 0.11 | 1.59 | 0.13 | 10 | B20% |
| Hawaii Volcanoes NP | 0.03 | 0.04 | 0.27 | 0.01 | 0.06 | 0.64 | 0.11 | 10 | B20% |
| Hells Canyon Wilderness | 0.06 | 0.02 | 0.19 | 0.01 | 0.14 | 0.81 | 0.01 | 11 | B20% |
| Hercules-Glades Wilderness | 0.09 | 0.06 | 0.78 | 0.01 | 0.16 | 1.86 | 0.02 | 11 | B20% |
| Hoover Wilderness | 0.03 | 0.02 | 0.08 | 0.01 | 0.06 | 0.55 | 0.00 | 9 | B20% |
| Isle Royale NP | 0.10 | 0.02 | 0.34 | 0.01 | 0.09 | 0.79 | 0.01 | 12 | B20% |
| James River Face Wilderness | 0.11 | 0.06 | 0.71 | 0.01 | 0.20 | 1.39 | 0.01 | 11 | B20% |
| Jarbidge Wilderness | 0.05 | 0.03 | 0.14 | 0.01 | 0.05 | 0.33 | 0.00 | 10 | B20% |
| John Muir Wilderness | 0.02 | 0.01 | 0.12 | 0.01 | 0.07 | 0.44 | 0.01 | 9 | B20% |
| Joshua Tree NP | 0.04 | 0.02 | 0.20 | 0.01 | 0.17 | 0.94 | 0.02 | 10 | B20% |
| Joyce Kilmer-Slickrock Wilderness | 0.09 | 0.06 | 0.78 | 0.01 | 0.16 | 1.47 | 0.01 | 11 | B20% |
| Kaiser Wilderness | 0.02 | 0.01 | 0.12 | 0.01 | 0.07 | 0.44 | 0.01 | 9 | B20% |
| Kalmiopsis Wilderness | 0.03 | 0.02 | 0.31 | 0.01 | 0.05 | 0.99 | 0.04 | 12 | B20% |
| Kings Canyon | 0.03 | 0.03 | 0.18 | 0.01 | 0.08 | 0.73 | 0.02 | 11 | B20% |
| La Garita Wilderness | 0.06 | 0.04 | 0.24 | 0.01 | 0.13 | 0.88 | 0.00 | 9 | B20% |
| Lassen Volcanic NP | 0.03 | 0.02 | 0.12 | 0.01 | 0.08 | 0.24 | 0.01 | 10 | B20% |
| Lava Beds NM | 0.03 | 0.03 | 0.14 | 0.01 | 0.06 | 0.46 | 0.00 | 10 | B20% |
| Linville Gorge Wilderness | 0.08 | 0.06 | 0.67 | 0.01 | 0.14 | 1.04 | 0.01 | 11 | B20% |
| Lostwood Wilderness | 0.06 | 0.04 | 0.23 | 0.01 | 0.22 | 1.05 | 0.01 | 11 | B20% |
| Lye Brook Wilderness | 0.05 | 0.03 | 0.36 | 0.01 | 0.09 | 0.63 | 0.01 | 11 | B20% |
| Mammoth Cave NP | 0.11 | 0.08 | 0.86 | 0.01 | 0.24 | 1.54 | 0.01 | 11 | B20% |
| Marble Mountain Wilderness | 0.03 | 0.02 | 0.12 | 0.01 | 0.06 | 0.36 | 0.01 | 10 | B20% |
| Maroon Bells-Snowmass Wilderness | 0.04 | 0.03 | 0.14 | 0.01 | 0.08 | 0.36 | 0.00 | 8 | B20% |
| Mazatzal Wilderness | 0.06 | 0.05 | 0.30 | 0.01 | 0.14 | 0.80 | 0.00 | 10 | B20% |
| Medicine Lake Wilderness | 0.06 | 0.05 | 0.24 | 0.01 | 0.20 | 1.13 | 0.00 | 11 | B20% |
| Mesa Verde NP | 0.06 | 0.05 | 0.24 | 0.01 | 0.17 | 0.67 | 0.00 | 9 | B20% |
| Mingo Wilderness | 0.12 | 0.04 | 0.88 | 0.01 | 0.21 | 1.49 | 0.01 | 12 | B20% |
| Mission Mountains Wilderness | 0.05 | 0.04 | 0.19 | 0.01 | 0.08 | 0.37 | 0.00 | 10 | B20% |
| Mokelumne Wilderness | 0.04 | 0.03 | 0.15 | 0.01 | 0.09 | 0.51 | 0.01 | 9 | B20% |
| Moosehorn Wilderness | 0.11 | 0.04 | 0.76 | 0.01 | 0.12 | 1.25 | 0.02 | 12 | B20% |
| Mount Adams Wilderness | 0.02 | 0.01 | 0.06 | 0.00 | 0.04 | 0.21 | 0.01 | 10 | B20% |
| Mount Baldy Wilderness | 0.05 | 0.04 | 0.19 | 0.01 | 0.11 | 0.53 | 0.00 | 9 | B20% |
| Mount Hood Wilderness | 0.02 | 0.02 | 0.06 | 0.00 | 0.05 | 0.15 | 0.01 | 10 | B20% |

**Table 5. 20% Best Natural Conditions – Concentrations and Rayleigh Scattering By Class I Area**

| Class I Area | $(NH_4)_2SO_4$ µg/m3 | $NH_4NO_3$ µg/m3 | OM µg/$m^3$ | EC µg/$m^3$ | Soil µg/$m^3$ | CM µg/$m^3$ | Sea Salt µg/$m^3$ | Rayleigh $Mm^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Mount Jefferson Wilderness | 0.02 | 0.02 | 0.08 | 0.00 | 0.03 | 0.31 | 0.01 | 11 | B20% |
| Mount Rainier NP | 0.03 | 0.02 | 0.18 | 0.01 | 0.06 | 0.83 | 0.02 | 11 | B20% |
| Mount Washington Wilderness | 0.02 | 0.02 | 0.08 | 0.00 | 0.03 | 0.31 | 0.01 | 11 | B20% |
| Mount Zirkel Wilderness | 0.06 | 0.04 | 0.16 | 0.01 | 0.09 | 0.60 | 0.00 | 8 | B20% |
| Mountain Lakes Wilderness | 0.02 | 0.02 | 0.08 | 0.01 | 0.07 | 0.23 | 0.01 | 9 | B20% |
| North Absaroka Wilderness | 0.05 | 0.04 | 0.16 | 0.00 | 0.11 | 0.82 | 0.00 | 9 | B20% |
| North Cascades NP | 0.02 | 0.03 | 0.09 | 0.00 | 0.04 | 0.28 | 0.01 | 11 | B20% |
| Okefenokee Wilderness | 0.13 | 0.07 | 0.92 | 0.01 | 0.22 | 1.69 | 0.03 | 11 | B20% |
| Olympic NP | 0.04 | 0.03 | 0.23 | 0.01 | 0.03 | 0.50 | 0.04 | 11 | B20% |
| Otter Creek Wilderness | 0.10 | 0.05 | 0.80 | 0.01 | 0.17 | 0.96 | 0.01 | 10 | B20% |
| Pasayten Wilderness | 0.04 | 0.03 | 0.07 | 0.00 | 0.07 | 0.24 | 0.01 | 10 | B20% |
| Pecos Wilderness | 0.04 | 0.03 | 0.16 | 0.01 | 0.08 | 0.67 | 0.00 | 8 | B20% |
| Petrified Forest NP | 0.06 | 0.06 | 0.28 | 0.01 | 0.15 | 0.75 | 0.00 | 9 | B20% |
| Pine Mountain Wilderness | 0.06 | 0.05 | 0.30 | 0.01 | 0.14 | 0.80 | 0.00 | 10 | B20% |
| Pinnacles NM | 0.06 | 0.04 | 0.31 | 0.01 | 0.16 | 1.50 | 0.06 | 11 | B20% |
| Point Reyes NS | 0.12 | 0.04 | 0.33 | 0.01 | 0.13 | 1.08 | 0.25 | 12 | B20% |
| Presidential Range-Dry River Wilderness | 0.09 | 0.04 | 0.56 | 0.01 | 0.10 | 1.05 | 0.02 | 11 | B20% |
| Rawah Wilderness | 0.06 | 0.04 | 0.16 | 0.01 | 0.09 | 0.60 | 0.00 | 8 | B20% |
| Red Rock Lakes Wilderness | 0.06 | 0.05 | 0.17 | 0.01 | 0.08 | 0.33 | 0.00 | 9 | B20% |
| Redwood NP | 0.05 | 0.03 | 0.28 | 0.01 | 0.06 | 1.02 | 0.10 | 11 | B20% |
| Rocky Mountain NP | 0.04 | 0.02 | 0.15 | 0.01 | 0.09 | 0.68 | 0.00 | 9 | B20% |
| Roosevelt Campobello International Park | 0.11 | 0.04 | 0.76 | 0.01 | 0.12 | 1.25 | 0.02 | 12 | B20% |
| Saguaro NP | 0.07 | 0.05 | 0.32 | 0.01 | 0.22 | 1.15 | 0.03 | 10 | B20% |
| Saint Marks Wilderness | 0.14 | 0.06 | 0.81 | 0.01 | 0.24 | 2.17 | 0.04 | 11 | B20% |
| Salt Creek Wilderness | 0.05 | 0.06 | 0.31 | 0.01 | 0.17 | 1.00 | 0.02 | 10 | B20% |
| San Gabriel Wilderness | 0.03 | 0.03 | 0.15 | 0.01 | 0.14 | 0.67 | 0.01 | 9 | B20% |
| San Gorgonio Wilderness | 0.03 | 0.02 | 0.15 | 0.01 | 0.10 | 0.62 | 0.02 | 10 | B20% |
| San Jacinto Wilderness | 0.03 | 0.02 | 0.15 | 0.01 | 0.10 | 0.62 | 0.02 | 10 | B20% |
| San Pedro Parks Wilderness | 0.05 | 0.04 | 0.14 | 0.01 | 0.09 | 0.34 | 0.01 | 8 | B20% |
| San Rafael Wilderness | 0.03 | 0.04 | 0.22 | 0.01 | 0.11 | 0.79 | 0.02 | 10 | B20% |
| Sawtooth Wilderness | 0.05 | 0.04 | 0.23 | 0.01 | 0.10 | 0.37 | 0.00 | 10 | B20% |
| Scapegoat Wilderness | 0.05 | 0.04 | 0.19 | 0.01 | 0.08 | 0.37 | 0.00 | 10 | B20% |
| Selway-Bitterroot Wilderness | 0.04 | 0.03 | 0.12 | 0.01 | 0.07 | 0.31 | 0.00 | 10 | B20% |
| Seney Wilderness | 0.08 | 0.01 | 0.38 | 0.01 | 0.09 | 0.80 | 0.01 | 12 | B20% |
| Sequoia NP | 0.03 | 0.03 | 0.18 | 0.01 | 0.08 | 0.73 | 0.02 | 11 | B20% |
| Shenandoah NP | 0.08 | 0.07 | 0.56 | 0.01 | 0.14 | 1.20 | 0.01 | 10 | B20% |
| Shining Rock Wilderness | 0.05 | 0.05 | 0.51 | 0.01 | 0.13 | 0.56 | 0.01 | 10 | B20% |
| Sierra Ancha Wilderness | 0.06 | 0.05 | 0.33 | 0.02 | 0.14 | 0.73 | 0.01 | 10 | B20% |
| Simeonof Wilderness | 0.06 | 0.05 | 0.25 | 0.02 | 0.04 | 1.18 | 0.25 | 12 | B20% |
| Sipsey Wilderness | 0.11 | 0.10 | 0.81 | 0.01 | 0.25 | 1.66 | 0.01 | 11 | B20% |
| South Warner Wilderness | 0.03 | 0.03 | 0.14 | 0.01 | 0.06 | 0.46 | 0.00 | 10 | B20% |
| Strawberry Mountain Wilderness | 0.05 | 0.02 | 0.17 | 0.01 | 0.10 | 0.50 | 0.01 | 10 | B20% |
| Superstition Wilderness | 0.07 | 0.05 | 0.31 | 0.01 | 0.16 | 0.84 | 0.00 | 10 | B20% |

## Table 5. 20% Best Natural Conditions – Concentrations and Rayleigh Scattering By Class I Area

| Class I Area | $(NH_4)_2SO_4$ µg/m3 | $NH_4NO_3$ µg/m3 | OM µg/m$^3$ | EC µg/m$^3$ | Soil µg/m$^3$ | CM µg/m$^3$ | Sea Salt µg/m$^3$ | Rayleigh Mm$^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Swanquarter Wilderness | 0.12 | 0.06 | 0.65 | 0.01 | 0.23 | 2.38 | 0.05 | 12 | B20% |
| Sycamore Canyon Wilderness | 0.06 | 0.05 | 0.28 | 0.01 | 0.12 | 0.62 | 0.00 | 9 | B20% |
| Teton Wilderness | 0.06 | 0.05 | 0.17 | 0.01 | 0.08 | 0.33 | 0.00 | 9 | B20% |
| Theodore Roosevelt NP | 0.07 | 0.04 | 0.26 | 0.01 | 0.21 | 1.20 | 0.01 | 11 | B20% |
| Thousand Lakes Wilderness | 0.03 | 0.02 | 0.12 | 0.01 | 0.08 | 0.24 | 0.01 | 10 | B20% |
| Three Sisters Wilderness | 0.02 | 0.02 | 0.08 | 0.00 | 0.03 | 0.31 | 0.01 | 11 | B20% |
| Tuxedni Wilderness | 0.03 | 0.04 | 0.09 | 0.01 | 0.03 | 0.52 | 0.05 | 12 | B20% |
| UL Bend Wilderness | 0.05 | 0.03 | 0.18 | 0.01 | 0.15 | 0.93 | 0.01 | 11 | B20% |
| Upper Buffalo Wilderness | 0.08 | 0.06 | 0.68 | 0.01 | 0.16 | 1.33 | 0.01 | 11 | B20% |
| Ventana Wilderness | 0.06 | 0.04 | 0.31 | 0.01 | 0.16 | 1.50 | 0.06 | 11 | B20% |
| Virgin Islands NP | 0.18 | 0.07 | 0.21 | 0.01 | 0.12 | 1.53 | 0.26 | 11 | B20% |
| Voyageurs NP | 0.12 | 0.02 | 0.56 | 0.01 | 0.10 | 0.86 | 0.01 | 12 | B20% |
| Washakie Wilderness | 0.05 | 0.04 | 0.16 | 0.00 | 0.11 | 0.82 | 0.00 | 9 | B20% |
| Weminuche Wilderness | 0.06 | 0.04 | 0.24 | 0.01 | 0.13 | 0.88 | 0.00 | 9 | B20% |
| West Elk Wilderness | 0.04 | 0.03 | 0.14 | 0.01 | 0.08 | 0.36 | 0.00 | 8 | B20% |
| Wheeler Peak Wilderness | 0.04 | 0.03 | 0.16 | 0.01 | 0.08 | 0.67 | 0.00 | 8 | B20% |
| White Mountain Wilderness | 0.05 | 0.03 | 0.24 | 0.01 | 0.08 | 0.67 | 0.01 | 9 | B20% |
| Wichita Mountains Wilderness | 0.03 | 0.04 | 0.28 | 0.01 | 0.15 | 1.52 | 0.01 | 11 | B20% |
| Wind Cave NP | 0.05 | 0.04 | 0.20 | 0.01 | 0.19 | 1.05 | 0.00 | 10 | B20% |
| Wolf Island Wilderness | 0.13 | 0.07 | 0.92 | 0.01 | 0.22 | 1.69 | 0.03 | 11 | B20% |
| Yellowstone NP | 0.06 | 0.05 | 0.17 | 0.01 | 0.08 | 0.33 | 0.00 | 9 | B20% |
| Yolla Bolly-Middle Eel Wilderness | 0.03 | 0.02 | 0.12 | 0.01 | 0.06 | 0.36 | 0.01 | 10 | B20% |
| Yosemite NP | 0.03 | 0.02 | 0.10 | 0.00 | 0.08 | 0.50 | 0.01 | 10 | B20% |
| Zion NP | 0.05 | 0.06 | 0.28 | 0.01 | 0.10 | 0.60 | 0.01 | 10 | B20% |

**Table 6. Annual Average Natural Conditions - Concentrations and Rayleigh Scattering By Class I Area**

| Class I Area | $(NH_4)_2SO_4$ µg/m3 | $NH_4NO_3$ µg/m3 | OM µg/$m^3$ | EC µg/$m^3$ | Soil µg/$m^3$ | CM µg/$m^3$ | Sea Salt µg/$m^3$ | Rayleigh $Mm^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Acadia NP | 0.23 | 0.10 | 1.67 | 0.02 | 0.25 | 2.14 | 0.14 | 12 | Annual |
| Agua Tibia Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.14 | 11 | Annual |
| Alpine Lakes Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.23 | 1.30 | 0.06 | 11 | Annual |
| Anaconda Pintler Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.39 | 1.79 | 0.02 | 10 | Annual |
| Ansel Adams Wilderness | 0.12 | 0.10 | 0.58 | 0.02 | 0.46 | 2.88 | 0.03 | 9 | Annual |
| Arches NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.92 | 0.01 | 9 | Annual |
| Badlands NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.01 | 11 | Annual |
| Bandelier NM | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.86 | 0.02 | 9 | Annual |
| Bering Sea Wilderness | | | | | | | | | Annual |
| Big Bend NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.03 | 10 | Annual |
| Black Canyon of the Gunnison NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.49 | 2.59 | 0.01 | 9 | Annual |
| Bob Marshall Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 2.34 | 0.01 | 10 | Annual |
| Bosque del Apache Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.04 | 10 | Annual |
| Boundary Waters Canoe Area Wilderness | 0.23 | 0.10 | 1.71 | 0.02 | 0.31 | 2.53 | 0.02 | 11 | Annual |
| Breton Wilderness | 0.23 | 0.10 | 1.78 | 0.02 | 0.48 | 3.01 | 0.19 | 11 | Annual |
| Bridger Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 1.88 | 0.01 | 9 | Annual |
| Brigantine Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.47 | 3.00 | 0.22 | 12 | Annual |
| Bryce Canyon NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.87 | 0.01 | 9 | Annual |
| Cabinet Mountains Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.41 | 2.31 | 0.02 | 10 | Annual |
| Caney Creek Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 3.00 | 0.03 | 11 | Annual |
| Canyonlands NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.92 | 0.01 | 9 | Annual |
| Cape Romain Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.45 | 3.00 | 0.20 | 12 | Annual |
| Capitol Reef NP | 0.11 | 0.10 | 0.58 | 0.02 | 0.50 | 2.78 | 0.00 | 9 | Annual |
| Caribou Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 1.82 | 0.01 | 10 | Annual |
| Carlsbad Caverns NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 9 | Annual |
| Chassahowitzka Wilderness | 0.23 | 0.10 | 1.81 | 0.02 | 0.50 | 3.00 | 0.08 | 11 | Annual |
| Chiricahua NM | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |
| Chiricahua Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |
| Cohutta Wilderness | 0.23 | 0.10 | 1.71 | 0.02 | 0.50 | 2.45 | 0.02 | 11 | Annual |
| Crater Lake NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.39 | 1.67 | 0.02 | 9 | Annual |
| Craters of the Moon NM | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.92 | 0.01 | 10 | Annual |
| Cucamonga Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.04 | 9 | Annual |
| Denali NP & Pres | 0.12 | 0.05 | 0.60 | 0.02 | 0.14 | 1.12 | 0.04 | 11 | Annual |
| Desolation Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.43 | 1.92 | 0.01 | 9 | Annual |
| Diamond Peak Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.39 | 1.67 | 0.02 | 9 | Annual |
| Dolly Sods Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.43 | 2.19 | 0.02 | 10 | Annual |
| Dome Land Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.03 | 10 | Annual |
| Eagle Cap Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.99 | 0.04 | 10 | Annual |
| Eagles Nest Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.48 | 2.12 | 0.00 | 8 | Annual |
| Emigrant Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 3.00 | 0.02 | 10 | Annual |
| Everglades NP | 0.23 | 0.10 | 1.79 | 0.02 | 0.50 | 3.00 | 0.31 | 11 | Annual |
| Fitzpatrick Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 1.88 | 0.01 | 9 | Annual |
| Flat Tops Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.48 | 2.12 | 0.00 | 8 | Annual |
| Galiuro Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |

**Table 6. Annual Average Natural Conditions - Concentrations and Rayleigh Scattering By Class I Area**

| Class I Area | $(NH_4)_2SO_4$ μg/m3 | $NH_4NO_3$ μg/m3 | OM μg/$m^3$ | EC μg/$m^3$ | Soil μg/$m^3$ | CM μg/$m^3$ | Sea Salt μg/$m^3$ | Rayleigh $Mm^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Gates of the Mountains Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.35 | 1.55 | 0.01 | 9 | Annual |
| Gearhart Mountain Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.39 | 1.67 | 0.02 | 9 | Annual |
| Gila Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.54 | 0.01 | 9 | Annual |
| Glacier NP | 0.11 | 0.10 | 0.59 | 0.02 | 0.50 | 3.00 | 0.01 | 11 | Annual |
| Glacier Peak Wilderness | 0.11 | 0.10 | 0.60 | 0.02 | 0.19 | 1.32 | 0.02 | 11 | Annual |
| Goat Rocks Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.23 | 1.23 | 0.03 | 10 | Annual |
| Grand Canyon NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.88 | 0.02 | 9 | Annual |
| Grand Teton NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.41 | 1.92 | 0.01 | 9 | Annual |
| Great Gulf Wilderness | 0.23 | 0.10 | 1.70 | 0.02 | 0.25 | 2.65 | 0.03 | 11 | Annual |
| Great Sand Dunes NP & Pres | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.99 | 0.01 | 9 | Annual |
| Great Smoky Mountains NP | 0.23 | 0.10 | 1.80 | 0.02 | 0.48 | 2.92 | 0.02 | 11 | Annual |
| Guadalupe Mountains NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 9 | Annual |
| Haleakala NP | 0.12 | 0.10 | 0.57 | 0.02 | 0.23 | 2.93 | 0.25 | 10 | Annual |
| Hawaii Volcanoes NP | 0.12 | 0.10 | 0.45 | 0.02 | 0.16 | 1.42 | 0.29 | 10 | Annual |
| Hells Canyon Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.48 | 2.97 | 0.01 | 11 | Annual |
| Hercules-Glades Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 3.00 | 0.02 | 11 | Annual |
| Hoover Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.97 | 0.01 | 9 | Annual |
| Isle Royale NP | 0.23 | 0.10 | 1.55 | 0.02 | 0.24 | 2.89 | 0.03 | 12 | Annual |
| James River Face Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.48 | 3.00 | 0.02 | 11 | Annual |
| Jarbidge Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |
| John Muir Wilderness | 0.12 | 0.10 | 0.58 | 0.02 | 0.46 | 2.88 | 0.03 | 9 | Annual |
| Joshua Tree NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.03 | 10 | Annual |
| Joyce Kilmer-Slickrock Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.48 | 2.92 | 0.02 | 11 | Annual |
| Kaiser Wilderness | 0.12 | 0.10 | 0.58 | 0.02 | 0.46 | 2.88 | 0.03 | 9 | Annual |
| Kalmiopsis Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.20 | 2.24 | 0.23 | 12 | Annual |
| Kings Canyon | 0.11 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.04 | 11 | Annual |
| La Garita Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.49 | 2.59 | 0.01 | 9 | Annual |
| Lassen Volcanic NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 1.82 | 0.01 | 10 | Annual |
| Lava Beds NM | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 2.36 | 0.01 | 10 | Annual |
| Linville Gorge Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.45 | 2.60 | 0.02 | 11 | Annual |
| Lostwood Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.03 | 11 | Annual |
| Lye Brook Wilderness | 0.23 | 0.10 | 1.59 | 0.02 | 0.28 | 1.79 | 0.02 | 11 | Annual |
| Mammoth Cave NP | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 2.73 | 0.02 | 11 | Annual |
| Marble Mountain Wilderness | 0.12 | 0.10 | 0.52 | 0.02 | 0.42 | 2.08 | 0.04 | 10 | Annual |
| Maroon Bells-Snowmass Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.48 | 2.12 | 0.00 | 8 | Annual |
| Mazatzal Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |
| Medicine Lake Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.48 | 3.00 | 0.01 | 11 | Annual |
| Mesa Verde NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.88 | 0.00 | 9 | Annual |
| Mingo Wilderness | 0.23 | 0.10 | 1.83 | 0.02 | 0.51 | 3.05 | 0.04 | 12 | Annual |
| Mission Mountains Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 2.34 | 0.01 | 10 | Annual |
| Mokelumne Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.43 | 1.92 | 0.01 | 9 | Annual |
| Moosehorn Wilderness | 0.23 | 0.10 | 1.79 | 0.02 | 0.23 | 2.56 | 0.11 | 12 | Annual |
| Mount Adams Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.23 | 1.23 | 0.03 | 10 | Annual |

**Table 6. Annual Average Natural Conditions - Concentrations and Rayleigh Scattering By Class I Area**

| Class I Area | $(NH_4)_2SO_4$ µg/m3 | $NH_4NO_3$ µg/m3 | OM µg/m$^3$ | EC µg/m$^3$ | Soil µg/m$^3$ | CM µg/m$^3$ | Sea Salt µg/m$^3$ | Rayleigh Mm$^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Mount Baldy Wilderness | 0.12 | 0.10 | 0.57 | 0.02 | 0.50 | 2.82 | 0.01 | 9 | Annual |
| Mount Hood Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.29 | 1.58 | 0.05 | 10 | Annual |
| Mount Jefferson Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.26 | 1.98 | 0.05 | 11 | Annual |
| Mount Rainier NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.24 | 2.27 | 0.07 | 11 | Annual |
| Mount Washington Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.26 | 1.98 | 0.05 | 11 | Annual |
| Mount Zirkel Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.45 | 2.69 | 0.00 | 8 | Annual |
| Mountain Lakes Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.39 | 1.67 | 0.02 | 9 | Annual |
| North Absaroka Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.43 | 2.84 | 0.01 | 9 | Annual |
| North Cascades NP | 0.11 | 0.10 | 0.60 | 0.02 | 0.19 | 1.32 | 0.02 | 11 | Annual |
| Okefenokee Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 3.00 | 0.08 | 11 | Annual |
| Olympic NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.15 | 1.88 | 0.14 | 11 | Annual |
| Otter Creek Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.43 | 2.19 | 0.02 | 10 | Annual |
| Pasayten Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.33 | 1.50 | 0.01 | 10 | Annual |
| Pecos Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.29 | 0.03 | 8 | Annual |
| Petrified Forest NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.01 | 9 | Annual |
| Pine Mountain Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |
| Pinnacles NM | 0.12 | 0.10 | 0.60 | 0.02 | 0.35 | 3.00 | 0.19 | 11 | Annual |
| Point Reyes NS | 0.12 | 0.10 | 0.60 | 0.02 | 0.24 | 3.00 | 2.11 | 12 | Annual |
| Presidential Range-Dry River Wilderness | 0.23 | 0.10 | 1.70 | 0.02 | 0.25 | 2.65 | 0.03 | 11 | Annual |
| Rawah Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.45 | 2.69 | 0.00 | 8 | Annual |
| Red Rock Lakes Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.41 | 1.92 | 0.01 | 9 | Annual |
| Redwood NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.16 | 3.00 | 0.96 | 11 | Annual |
| Rocky Mountain NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.90 | 0.00 | 9 | Annual |
| Roosevelt Campobello International Park | 0.23 | 0.10 | 1.79 | 0.02 | 0.23 | 2.56 | 0.11 | 12 | Annual |
| Saguaro NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.06 | 10 | Annual |
| Saint Marks Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 3.00 | 0.10 | 11 | Annual |
| Salt Creek Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.04 | 10 | Annual |
| San Gabriel Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.04 | 9 | Annual |
| San Gorgonio Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.05 | 10 | Annual |
| San Jacinto Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.05 | 10 | Annual |
| San Pedro Parks Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.19 | 0.01 | 8 | Annual |
| San Rafael Wilderness | 0.11 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.11 | 10 | Annual |
| Sawtooth Wilderness | 0.12 | 0.08 | 0.60 | 0.02 | 0.41 | 1.64 | 0.01 | 10 | Annual |
| Scapegoat Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 2.34 | 0.01 | 10 | Annual |
| Selway-Bitterroot Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.39 | 1.79 | 0.02 | 10 | Annual |
| Seney Wilderness | 0.23 | 0.10 | 1.74 | 0.02 | 0.26 | 1.95 | 0.02 | 12 | Annual |
| Sequoia NP | 0.11 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.04 | 11 | Annual |
| Shenandoah NP | 0.23 | 0.10 | 1.80 | 0.02 | 0.41 | 2.88 | 0.02 | 10 | Annual |
| Shining Rock Wilderness | 0.23 | 0.10 | 1.76 | 0.02 | 0.50 | 1.76 | 0.02 | 10 | Annual |
| Sierra Ancha Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |
| Simeonof Wilderness | 0.12 | 0.10 | 0.46 | 0.02 | 0.13 | 3.00 | 1.26 | 12 | Annual |
| Sipsey Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 3.00 | 0.04 | 11 | Annual |
| South Warner Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 2.36 | 0.01 | 10 | Annual |

**Table 6. Annual Average Natural Conditions - Concentrations and Rayleigh Scattering By Class I Area**

| Class I Area | $(NH_4)_2SO_4$ µg/m3 | $NH_4NO_3$ µg/m3 | OM µg/m$^3$ | EC µg/m$^3$ | Soil µg/m$^3$ | CM µg/m$^3$ | Sea Salt µg/m$^3$ | Rayleigh Mm$^{-1}$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| Strawberry Mountain Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.99 | 0.04 | 10 | Annual |
| Superstition Wilderness | 0.11 | 0.10 | 0.59 | 0.02 | 0.50 | 3.00 | 0.02 | 10 | Annual |
| Swanquarter Wilderness | 0.23 | 0.10 | 1.63 | 0.02 | 0.41 | 3.00 | 0.14 | 12 | Annual |
| Sycamore Canyon Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.03 | 9 | Annual |
| Teton Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.41 | 1.92 | 0.01 | 9 | Annual |
| Theodore Roosevelt NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.01 | 11 | Annual |
| Thousand Lakes Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 1.82 | 0.01 | 10 | Annual |
| Three Sisters Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.26 | 1.98 | 0.05 | 11 | Annual |
| Tuxedni Wilderness | 0.12 | 0.09 | 0.60 | 0.02 | 0.10 | 2.06 | 0.38 | 12 | Annual |
| UL Bend Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.45 | 3.00 | 0.00 | 11 | Annual |
| Upper Buffalo Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 3.00 | 0.03 | 11 | Annual |
| Ventana Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.35 | 3.00 | 0.19 | 11 | Annual |
| Virgin Islands NP | 0.23 | 0.10 | 0.35 | 0.02 | 0.50 | 3.00 | 0.84 | 11 | Annual |
| Voyageurs NP | 0.23 | 0.10 | 1.75 | 0.02 | 0.26 | 2.73 | 0.04 | 12 | Annual |
| Washakie Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.43 | 2.84 | 0.01 | 9 | Annual |
| Weminuche Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.49 | 2.59 | 0.01 | 9 | Annual |
| West Elk Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.48 | 2.12 | 0.00 | 8 | Annual |
| Wheeler Peak Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 2.29 | 0.03 | 8 | Annual |
| White Mountain Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.03 | 9 | Annual |
| Wichita Mountains Wilderness | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.03 | 11 | Annual |
| Wind Cave NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.49 | 2.98 | 0.01 | 10 | Annual |
| Wolf Island Wilderness | 0.23 | 0.10 | 1.80 | 0.02 | 0.50 | 3.00 | 0.08 | 11 | Annual |
| Yellowstone NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.41 | 1.92 | 0.01 | 9 | Annual |
| Yolla Bolly-Middle Eel Wilderness | 0.12 | 0.10 | 0.52 | 0.02 | 0.42 | 2.08 | 0.04 | 10 | Annual |
| Yosemite NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.44 | 3.00 | 0.02 | 10 | Annual |
| Zion NP | 0.12 | 0.10 | 0.60 | 0.02 | 0.50 | 3.00 | 0.01 | 10 | Annual |

**Table 7. Monthly $f_L(RH)$ – Large $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acadia NP | 2.74 | 2.46 | 2.45 | 2.66 | 2.67 | 2.73 | 2.99 | 3.03 | 3.16 | 2.91 | 2.89 | 2.96 |
| Agua Tibia Wilderness | 2.10 | 2.08 | 2.11 | 1.98 | 1.98 | 1.93 | 1.93 | 2.01 | 2.02 | 1.99 | 1.87 | 1.95 |
| Alpine Lakes Wilderness | 3.86 | 3.58 | 3.04 | 2.92 | 2.99 | 2.58 | 2.62 | 2.67 | 2.97 | 3.60 | 4.00 | 3.99 |
| Anaconda Pintler Wilderness | 2.75 | 2.46 | 2.24 | 2.08 | 2.06 | 2.01 | 1.76 | 1.72 | 1.88 | 2.22 | 2.66 | 2.74 |
| Ansel Adams Wilderness | 2.56 | 2.34 | 2.20 | 1.88 | 1.79 | 1.59 | 1.52 | 1.52 | 1.59 | 1.70 | 2.01 | 2.34 |
| Arches NP | 2.28 | 2.12 | 1.73 | 1.57 | 1.50 | 1.28 | 1.34 | 1.47 | 1.51 | 1.56 | 1.90 | 2.13 |
| Badlands NP | 2.31 | 2.31 | 2.31 | 2.21 | 2.34 | 2.25 | 2.08 | 2.05 | 2.02 | 2.05 | 2.38 | 2.33 |
| Bandelier NM | 2.10 | 1.90 | 1.72 | 1.51 | 1.53 | 1.38 | 1.63 | 1.87 | 1.80 | 1.59 | 1.87 | 2.04 |
| Bering Sea Wilderness | 3.02 | 3.17 | 3.20 | 3.19 | 3.23 | 3.34 | 3.78 | 4.16 | 3.64 | 3.19 | 3.12 | 3.13 |
| Big Bend NP | 1.72 | 1.61 | 1.44 | 1.38 | 1.47 | 1.48 | 1.58 | 1.74 | 1.83 | 1.63 | 1.63 | 1.70 |
| Black Canyon of the Gunnison NP | 2.15 | 2.05 | 1.83 | 1.75 | 1.74 | 1.51 | 1.59 | 1.78 | 1.80 | 1.68 | 1.96 | 2.06 |
| Bob Marshall Wilderness | 2.82 | 2.54 | 2.35 | 2.22 | 2.21 | 2.19 | 1.98 | 1.92 | 2.15 | 2.43 | 2.78 | 2.81 |
| Bosque del Apache Wilderness | 2.03 | 1.82 | 1.55 | 1.37 | 1.36 | 1.27 | 1.61 | 1.79 | 1.73 | 1.54 | 1.73 | 2.00 |
| Boundary Waters Canoe Area Wilderness | 2.50 | 2.25 | 2.28 | 2.09 | 2.20 | 2.43 | 2.57 | 2.71 | 2.78 | 2.38 | 2.64 | 2.64 |
| Breton Wilderness | 2.91 | 2.76 | 2.74 | 2.72 | 2.83 | 2.94 | 3.10 | 3.07 | 2.97 | 2.82 | 2.83 | 2.90 |
| Bridger Wilderness | 2.22 | 2.10 | 2.04 | 1.95 | 1.95 | 1.67 | 1.46 | 1.44 | 1.68 | 1.83 | 2.19 | 2.16 |
| Brigantine Wilderness | 2.49 | 2.32 | 2.38 | 2.28 | 2.50 | 2.56 | 2.69 | 2.81 | 2.82 | 2.71 | 2.45 | 2.50 |
| Bryce Canyon NP | 2.31 | 2.16 | 1.82 | 1.56 | 1.47 | 1.26 | 1.30 | 1.46 | 1.46 | 1.55 | 1.87 | 2.15 |
| Cabinet Mountains Wilderness | 3.07 | 2.73 | 2.45 | 2.26 | 2.24 | 2.21 | 1.98 | 1.92 | 2.19 | 2.53 | 3.03 | 3.11 |
| Caney Creek Wilderness | 2.77 | 2.53 | 2.37 | 2.43 | 2.68 | 2.71 | 2.59 | 2.60 | 2.71 | 2.69 | 2.67 | 2.79 |
| Canyonlands NP | 2.32 | 2.16 | 1.78 | 1.58 | 1.51 | 1.28 | 1.36 | 1.53 | 1.55 | 1.58 | 1.93 | 2.17 |
| Cape Romain Wilderness | 2.66 | 2.47 | 2.42 | 2.32 | 2.56 | 2.80 | 2.82 | 3.04 | 3.03 | 2.86 | 2.65 | 2.70 |
| Capitol Reef NP | 2.36 | 2.22 | 1.84 | 1.63 | 1.54 | 1.31 | 1.36 | 1.52 | 1.55 | 1.61 | 1.95 | 2.22 |
| Caribou Wilderness | 2.96 | 2.58 | 2.35 | 2.10 | 2.01 | 1.85 | 1.79 | 1.82 | 1.88 | 2.03 | 2.50 | 2.82 |
| Carlsbad Caverns NP | 2.07 | 1.81 | 1.50 | 1.42 | 1.51 | 1.48 | 1.72 | 1.90 | 2.03 | 1.64 | 1.76 | 2.00 |
| Chassahowitzka Wilderness | 3.03 | 2.82 | 2.74 | 2.65 | 2.63 | 3.00 | 3.02 | 3.15 | 3.14 | 3.03 | 2.97 | 3.09 |
| Chiricahua NM | 1.87 | 1.79 | 1.52 | 1.24 | 1.22 | 1.13 | 1.64 | 1.87 | 1.66 | 1.45 | 1.55 | 1.89 |
| Chiricahua Wilderness | 1.84 | 1.76 | 1.49 | 1.22 | 1.20 | 1.12 | 1.64 | 1.86 | 1.64 | 1.43 | 1.53 | 1.87 |
| Cohutta Wilderness | 2.84 | 2.61 | 2.49 | 2.36 | 2.72 | 2.97 | 3.00 | 3.07 | 3.08 | 2.89 | 2.72 | 2.85 |
| Crater Lake NP | 3.71 | 3.25 | 3.07 | 2.91 | 2.70 | 2.50 | 2.31 | 2.33 | 2.49 | 2.99 | 3.67 | 3.74 |
| Craters of the Moon NM | 2.58 | 2.34 | 2.03 | 1.84 | 1.83 | 1.65 | 1.40 | 1.39 | 1.52 | 1.80 | 2.35 | 2.54 |
| Cucamonga Wilderness | 2.21 | 2.14 | 2.13 | 1.96 | 1.95 | 1.90 | 1.91 | 1.96 | 1.98 | 1.96 | 1.90 | 2.02 |
| Denali NP & Pres | 2.48 | 2.44 | 2.15 | 1.96 | 1.98 | 2.13 | 2.47 | 2.90 | 2.95 | 2.84 | 2.69 | 2.68 |
| Desolation Wilderness | 2.73 | 2.42 | 2.18 | 1.84 | 1.74 | 1.56 | 1.47 | 1.49 | 1.58 | 1.73 | 2.12 | 2.54 |
| Diamond Peak Wilderness | 3.82 | 3.38 | 3.18 | 3.04 | 2.79 | 2.60 | 2.33 | 2.35 | 2.58 | 3.18 | 3.80 | 3.86 |
| Dolly Sods Wilderness | 2.53 | 2.39 | 2.38 | 2.20 | 2.63 | 2.65 | 2.74 | 2.90 | 2.94 | 2.65 | 2.45 | 2.61 |
| Dome Land Wilderness | 2.26 | 2.07 | 2.00 | 1.79 | 1.73 | 1.63 | 1.61 | 1.64 | 1.68 | 1.71 | 1.81 | 2.01 |
| Eagle Cap Wilderness | 3.44 | 3.02 | 2.54 | 2.31 | 2.28 | 2.01 | 1.78 | 1.75 | 1.97 | 2.61 | 3.34 | 3.56 |
| Eagles Nest Wilderness | 2.02 | 2.01 | 1.87 | 1.87 | 1.92 | 1.69 | 1.68 | 1.83 | 1.86 | 1.73 | 1.96 | 1.97 |
| Emigrant Wilderness | 2.67 | 2.42 | 2.26 | 1.92 | 1.81 | 1.59 | 1.49 | 1.50 | 1.58 | 1.72 | 2.08 | 2.45 |
| Everglades NP | 2.43 | 2.31 | 2.26 | 2.16 | 2.15 | 2.38 | 2.32 | 2.49 | 2.55 | 2.42 | 2.34 | 2.39 |
| Fitzpatrick Wilderness | 2.22 | 2.10 | 2.04 | 1.95 | 1.94 | 1.68 | 1.47 | 1.44 | 1.68 | 1.83 | 2.18 | 2.16 |
| Flat Tops Wilderness | 2.09 | 2.04 | 1.87 | 1.84 | 1.86 | 1.62 | 1.59 | 1.70 | 1.79 | 1.72 | 1.97 | 2.03 |
| Galiuro Wilderness | 1.80 | 1.67 | 1.47 | 1.21 | 1.18 | 1.10 | 1.43 | 1.66 | 1.53 | 1.42 | 1.57 | 1.87 |
| Gates of the Mountains Wilderness | 2.46 | 2.25 | 2.15 | 2.05 | 2.02 | 2.00 | 1.81 | 1.77 | 1.91 | 2.15 | 2.37 | 2.41 |

Table 7. Monthly $f_L(RH)$ – Large $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gearhart Mountain Wilderness | 3.30 | 2.89 | 2.62 | 2.45 | 2.29 | 2.13 | 1.88 | 1.90 | 2.03 | 2.47 | 3.09 | 3.27 |
| Gila Wilderness | 1.93 | 1.78 | 1.52 | 1.31 | 1.28 | 1.23 | 1.72 | 1.76 | 1.68 | 1.50 | 1.67 | 1.96 |
| Glacier NP | 3.21 | 2.84 | 2.69 | 2.55 | 2.58 | 2.56 | 2.24 | 2.22 | 2.57 | 2.81 | 3.08 | 3.13 |
| Glacier Peak Wilderness | 3.69 | 3.39 | 2.97 | 2.85 | 2.79 | 2.54 | 2.49 | 2.59 | 2.91 | 3.45 | 3.83 | 3.84 |
| Goat Rocks Wilderness | 3.83 | 3.44 | 3.10 | 2.97 | 2.82 | 2.60 | 2.48 | 2.55 | 2.88 | 3.49 | 3.91 | 3.98 |
| Grand Canyon NP | 2.13 | 2.01 | 1.74 | 1.46 | 1.36 | 1.19 | 1.29 | 1.49 | 1.47 | 1.50 | 1.75 | 1.98 |
| Grand Teton NP | 2.27 | 2.14 | 2.01 | 1.91 | 1.90 | 1.68 | 1.48 | 1.44 | 1.64 | 1.84 | 2.16 | 2.24 |
| Great Gulf Wilderness | 2.51 | 2.32 | 2.36 | 2.41 | 2.45 | 2.55 | 2.72 | 2.87 | 2.98 | 2.80 | 2.67 | 2.60 |
| Great Sand Dunes NP & Pres | 2.11 | 2.04 | 1.85 | 1.77 | 1.80 | 1.62 | 1.70 | 1.97 | 1.92 | 1.72 | 2.04 | 2.09 |
| Great Smoky Mountains NP | 2.85 | 2.57 | 2.51 | 2.35 | 2.72 | 2.98 | 2.98 | 3.08 | 3.10 | 2.87 | 2.71 | 2.85 |
| Guadalupe Mountains NP | 2.14 | 1.82 | 1.49 | 1.38 | 1.48 | 1.47 | 1.78 | 1.98 | 2.10 | 1.60 | 1.78 | 2.08 |
| Haleakala NP | 2.34 | 2.27 | 2.25 | 2.20 | 2.13 | 2.09 | 2.16 | 2.14 | 2.10 | 2.19 | 2.33 | 2.30 |
| Hawaii Volcanoes NP | 2.56 | 2.45 | 2.47 | 2.47 | 2.47 | 2.45 | 2.53 | 2.59 | 2.55 | 2.57 | 2.78 | 2.55 |
| Hells Canyon Wilderness | 3.05 | 2.65 | 2.22 | 1.97 | 1.91 | 1.81 | 1.55 | 1.52 | 1.68 | 2.15 | 2.90 | 3.15 |
| Hercules-Glades Wilderness | 2.70 | 2.48 | 2.30 | 2.30 | 2.57 | 2.59 | 2.56 | 2.60 | 2.69 | 2.54 | 2.57 | 2.72 |
| Hoover Wilderness | 2.63 | 2.38 | 2.21 | 1.88 | 1.77 | 1.56 | 1.46 | 1.47 | 1.55 | 1.69 | 2.05 | 2.42 |
| Isle Royale NP | 2.53 | 2.21 | 2.26 | 2.07 | 1.99 | 2.32 | 2.65 | 2.69 | 2.82 | 2.28 | 2.76 | 2.74 |
| James River Face Wilderness | 2.44 | 2.30 | 2.29 | 2.12 | 2.47 | 2.58 | 2.65 | 2.78 | 2.82 | 2.57 | 2.36 | 2.51 |
| Jarbidge Wilderness | 2.51 | 2.28 | 1.90 | 1.92 | 1.97 | 1.82 | 1.51 | 1.37 | 1.34 | 1.56 | 2.14 | 2.42 |
| John Muir Wilderness | 2.51 | 2.29 | 2.20 | 1.95 | 1.86 | 1.65 | 1.60 | 1.61 | 1.69 | 1.78 | 2.03 | 2.28 |
| Joshua Tree NP | 2.06 | 1.99 | 1.97 | 1.82 | 1.81 | 1.74 | 1.68 | 1.82 | 1.83 | 1.81 | 1.75 | 1.87 |
| Joyce Kilmer-Slickrock Wilderness | 2.86 | 2.58 | 2.51 | 2.36 | 2.71 | 2.97 | 2.98 | 3.06 | 3.08 | 2.87 | 2.72 | 2.85 |
| Kaiser Wilderness | 2.58 | 2.35 | 2.22 | 1.90 | 1.80 | 1.62 | 1.56 | 1.57 | 1.64 | 1.75 | 2.03 | 2.36 |
| Kalmiopsis Wilderness | 3.57 | 3.17 | 3.03 | 2.88 | 2.75 | 2.60 | 2.52 | 2.53 | 2.60 | 2.92 | 3.51 | 3.55 |
| Kings Canyon | 2.47 | 2.26 | 2.18 | 1.94 | 1.85 | 1.65 | 1.59 | 1.60 | 1.68 | 1.77 | 2.01 | 2.24 |
| La Garita Wilderness | 2.14 | 2.03 | 1.81 | 1.70 | 1.69 | 1.49 | 1.63 | 1.87 | 1.83 | 1.67 | 1.98 | 2.08 |
| Lassen Volcanic NP | 2.99 | 2.61 | 2.38 | 2.13 | 2.03 | 1.86 | 1.81 | 1.84 | 1.90 | 2.06 | 2.54 | 2.86 |
| Lava Beds NM | 3.31 | 2.88 | 2.64 | 2.44 | 2.29 | 2.13 | 1.98 | 1.99 | 2.10 | 2.43 | 3.03 | 3.26 |
| Linville Gorge Wilderness | 2.71 | 2.54 | 2.48 | 2.31 | 2.70 | 2.96 | 3.00 | 3.20 | 3.19 | 2.84 | 2.62 | 2.74 |
| Lostwood Wilderness | 2.51 | 2.45 | 2.54 | 2.06 | 2.03 | 2.21 | 2.23 | 2.05 | 2.02 | 2.13 | 2.69 | 2.67 |
| Lye Brook Wilderness | 2.46 | 2.30 | 2.34 | 2.31 | 2.42 | 2.47 | 2.60 | 2.76 | 2.84 | 2.70 | 2.54 | 2.51 |
| Mammoth Cave NP | 2.79 | 2.57 | 2.47 | 2.56 | 3.29 | 3.76 | 3.67 | 2.92 | 2.95 | 2.71 | 2.61 | 2.82 |
| Marble Mountain Wilderness | 3.48 | 3.08 | 2.95 | 2.78 | 2.67 | 2.53 | 2.50 | 2.52 | 2.55 | 2.78 | 3.32 | 3.42 |
| Maroon Bells-Snowmass Wilderness | 2.02 | 1.99 | 1.84 | 1.84 | 1.83 | 1.59 | 1.69 | 1.90 | 1.89 | 1.71 | 1.94 | 1.96 |
| Mazatzal Wilderness | 1.91 | 1.80 | 1.59 | 1.32 | 1.25 | 1.13 | 1.38 | 1.61 | 1.51 | 1.45 | 1.63 | 1.89 |
| Medicine Lake Wilderness | 2.53 | 2.46 | 2.46 | 2.02 | 2.00 | 2.13 | 2.12 | 1.95 | 1.98 | 2.10 | 2.63 | 2.65 |
| Mesa Verde NP | 2.45 | 2.25 | 1.98 | 1.57 | 1.61 | 1.31 | 1.62 | 1.87 | 1.75 | 1.66 | 2.01 | 2.30 |
| Mingo Wilderness | 2.73 | 2.52 | 2.34 | 2.28 | 2.53 | 2.60 | 2.64 | 2.67 | 2.71 | 2.56 | 2.56 | 2.73 |
| Mission Mountains Wilderness | 2.93 | 2.62 | 2.37 | 2.20 | 2.21 | 2.19 | 1.98 | 1.92 | 2.15 | 2.46 | 2.91 | 2.96 |
| Mokelumne Wilderness | 2.72 | 2.42 | 2.20 | 1.86 | 1.75 | 1.57 | 1.48 | 1.50 | 1.58 | 1.73 | 2.11 | 2.52 |
| Moosehorn Wilderness | 2.65 | 2.39 | 2.38 | 2.52 | 2.49 | 2.57 | 2.83 | 2.95 | 3.07 | 2.83 | 2.77 | 2.78 |
| Mount Adams Wilderness | 3.78 | 3.40 | 3.10 | 2.98 | 2.78 | 2.60 | 2.43 | 2.52 | 2.84 | 3.45 | 3.87 | 3.92 |
| Mount Baldy Wilderness | 2.00 | 1.86 | 1.62 | 1.34 | 1.29 | 1.18 | 1.50 | 1.73 | 1.60 | 1.51 | 1.73 | 2.01 |
| Mount Hood Wilderness | 3.71 | 3.33 | 3.08 | 2.96 | 2.74 | 2.55 | 2.34 | 2.42 | 2.72 | 3.35 | 3.81 | 3.84 |
| Mount Jefferson Wilderness | 3.89 | 3.48 | 3.27 | 3.16 | 2.89 | 2.66 | 2.35 | 2.35 | 2.63 | 3.34 | 3.92 | 3.95 |

**Table 7. Monthly $f_L(RH)$ – Large $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mount Rainier NP | 3.93 | 3.54 | 3.23 | 3.12 | 2.96 | 2.75 | 2.61 | 2.69 | 3.04 | 3.66 | 4.04 | 4.07 |
| Mount Washington Wilderness | 4.09 | 3.63 | 3.49 | 3.41 | 3.06 | 2.80 | 2.37 | 2.34 | 2.62 | 3.41 | 4.07 | 4.10 |
| Mount Zirkel Wilderness | 2.00 | 1.99 | 1.89 | 1.92 | 1.98 | 1.72 | 1.63 | 1.70 | 1.81 | 1.75 | 1.97 | 1.95 |
| Mountain Lakes Wilderness | 3.51 | 3.03 | 2.80 | 2.62 | 2.44 | 2.25 | 2.08 | 2.09 | 2.23 | 2.65 | 3.37 | 3.52 |
| North Absaroka Wilderness | 2.16 | 2.05 | 2.01 | 1.95 | 1.94 | 1.77 | 1.58 | 1.50 | 1.67 | 1.87 | 2.12 | 2.14 |
| North Cascades NP | 3.60 | 3.32 | 2.99 | 2.88 | 2.74 | 2.59 | 2.49 | 2.63 | 2.97 | 3.43 | 3.77 | 3.76 |
| Okefenokee Wilderness | 2.94 | 2.73 | 2.73 | 2.65 | 2.74 | 3.11 | 3.00 | 3.17 | 3.16 | 3.05 | 2.96 | 3.03 |
| Olympic NP | 3.80 | 3.50 | 3.30 | 3.21 | 2.76 | 2.89 | 2.61 | 2.94 | 3.23 | 3.73 | 3.99 | 3.95 |
| Otter Creek Wilderness | 2.55 | 2.41 | 2.40 | 2.23 | 2.64 | 2.69 | 2.80 | 2.96 | 3.00 | 2.69 | 2.48 | 2.63 |
| Pasayten Wilderness | 3.65 | 3.34 | 2.97 | 2.84 | 2.72 | 2.53 | 2.45 | 2.56 | 2.88 | 3.39 | 3.78 | 3.81 |
| Pecos Wilderness | 2.09 | 1.93 | 1.73 | 1.57 | 1.58 | 1.44 | 1.65 | 1.90 | 1.84 | 1.63 | 1.90 | 2.05 |
| Petrified Forest NP | 2.11 | 1.95 | 1.64 | 1.40 | 1.32 | 1.18 | 1.46 | 1.72 | 1.58 | 1.53 | 1.81 | 2.09 |
| Pine Mountain Wilderness | 1.96 | 1.86 | 1.64 | 1.35 | 1.28 | 1.15 | 1.38 | 1.62 | 1.53 | 1.48 | 1.66 | 1.93 |
| Pinnacles NM | 2.84 | 2.86 | 2.87 | 2.27 | 2.15 | 1.99 | 1.91 | 1.97 | 1.98 | 2.10 | 2.16 | 2.46 |
| Point Reyes NS | 2.96 | 2.73 | 2.61 | 2.28 | 2.20 | 2.04 | 2.12 | 2.16 | 2.18 | 2.23 | 2.47 | 2.75 |
| Presidential Range-Dry River Wilderness | 2.52 | 2.32 | 2.37 | 2.42 | 2.49 | 2.61 | 2.78 | 2.93 | 3.03 | 2.83 | 2.68 | 2.59 |
| Rawah Wilderness | 1.91 | 1.96 | 1.89 | 1.96 | 2.04 | 1.79 | 1.71 | 1.78 | 1.86 | 1.75 | 1.94 | 1.90 |
| Red Rock Lakes Wilderness | 2.39 | 2.20 | 2.06 | 1.95 | 1.92 | 1.80 | 1.60 | 1.54 | 1.69 | 1.93 | 2.30 | 2.37 |
| Redwood NP | 3.31 | 3.10 | 3.16 | 3.04 | 3.11 | 3.08 | 3.26 | 3.28 | 3.11 | 2.99 | 3.20 | 3.12 |
| Rocky Mountain NP | 1.77 | 1.85 | 1.84 | 1.95 | 2.04 | 1.80 | 1.73 | 1.77 | 1.84 | 1.70 | 1.84 | 1.76 |
| Roosevelt Campobello International Park | 2.66 | 2.39 | 2.38 | 2.53 | 2.49 | 2.57 | 2.82 | 2.93 | 3.05 | 2.83 | 2.78 | 2.79 |
| Saguaro NP | 1.69 | 1.56 | 1.40 | 1.13 | 1.12 | 1.05 | 1.37 | 1.62 | 1.47 | 1.38 | 1.50 | 1.83 |
| Saint Marks Wilderness | 2.98 | 2.78 | 2.73 | 2.69 | 2.74 | 3.04 | 3.17 | 3.21 | 3.10 | 2.96 | 2.94 | 3.06 |
| Salt Creek Wilderness | 2.01 | 1.79 | 1.51 | 1.45 | 1.55 | 1.48 | 1.64 | 1.80 | 1.91 | 1.64 | 1.72 | 1.91 |
| San Gabriel Wilderness | 2.25 | 2.17 | 2.14 | 1.96 | 1.95 | 1.90 | 1.91 | 1.95 | 1.98 | 1.97 | 1.91 | 2.04 |
| San Gorgonio Wilderness | 2.21 | 2.23 | 2.13 | 1.90 | 1.90 | 1.69 | 1.62 | 1.71 | 1.72 | 1.70 | 1.73 | 1.92 |
| San Jacinto Wilderness | 2.12 | 2.09 | 2.06 | 1.90 | 1.90 | 1.81 | 1.71 | 1.88 | 1.89 | 1.87 | 1.80 | 1.92 |
| San Pedro Parks Wilderness | 2.14 | 1.97 | 1.73 | 1.55 | 1.53 | 1.38 | 1.59 | 1.83 | 1.77 | 1.61 | 1.91 | 2.08 |
| San Rafael Wilderness | 2.50 | 2.37 | 2.34 | 2.12 | 2.10 | 2.05 | 2.10 | 2.15 | 2.20 | 2.15 | 2.07 | 2.25 |
| Sawtooth Wilderness | 2.79 | 2.44 | 2.05 | 1.83 | 1.80 | 1.66 | 1.37 | 1.35 | 1.43 | 1.77 | 2.47 | 2.75 |
| Scapegoat Wilderness | 2.74 | 2.47 | 2.30 | 2.18 | 2.16 | 2.14 | 1.93 | 1.87 | 2.07 | 2.35 | 2.70 | 2.72 |
| Selway-Bitterroot Wilderness | 2.90 | 2.57 | 2.26 | 2.05 | 2.03 | 1.95 | 1.67 | 1.63 | 1.81 | 2.19 | 2.76 | 2.91 |
| Seney Wilderness | 2.75 | 2.42 | 2.49 | 2.35 | 2.30 | 2.55 | 2.75 | 3.01 | 3.03 | 2.78 | 2.88 | 2.85 |
| Sequoia NP | 2.40 | 2.22 | 2.21 | 2.05 | 1.95 | 1.67 | 1.60 | 1.59 | 1.69 | 1.78 | 2.04 | 2.17 |
| Shenandoah NP | 2.44 | 2.28 | 2.29 | 2.12 | 2.45 | 2.56 | 2.65 | 2.79 | 2.81 | 2.53 | 2.34 | 2.55 |
| Shining Rock Wilderness | 2.78 | 2.56 | 2.48 | 2.33 | 2.72 | 2.98 | 3.02 | 3.17 | 3.18 | 2.91 | 2.68 | 2.79 |
| Sierra Ancha Wilderness | 1.92 | 1.81 | 1.59 | 1.32 | 1.25 | 1.13 | 1.42 | 1.65 | 1.54 | 1.47 | 1.66 | 1.93 |
| Simeonof Wilderness | 3.39 | 3.40 | 3.15 | 3.26 | 3.40 | 3.69 | 4.00 | 4.14 | 3.61 | 3.09 | 3.21 | 3.44 |
| Sipsey Wilderness | 2.79 | 2.58 | 2.42 | 2.36 | 2.64 | 2.86 | 2.94 | 2.92 | 2.93 | 2.78 | 2.64 | 2.80 |
| South Warner Wilderness | 3.06 | 2.67 | 2.39 | 2.16 | 2.05 | 1.90 | 1.68 | 1.69 | 1.79 | 2.11 | 2.67 | 2.97 |
| Strawberry Mountain Wilderness | 3.55 | 3.10 | 2.69 | 2.47 | 2.37 | 2.10 | 1.82 | 1.81 | 2.05 | 2.73 | 3.45 | 3.65 |
| Superstition Wilderness | 1.84 | 1.72 | 1.53 | 1.26 | 1.20 | 1.11 | 1.36 | 1.56 | 1.46 | 1.40 | 1.58 | 1.85 |
| Swanquarter Wilderness | 2.48 | 2.35 | 2.31 | 2.18 | 2.38 | 2.55 | 2.67 | 2.72 | 2.64 | 2.55 | 2.40 | 2.49 |
| Sycamore Canyon Wilderness | 2.01 | 1.93 | 1.70 | 1.40 | 1.33 | 1.17 | 1.38 | 1.67 | 1.58 | 1.52 | 1.70 | 1.97 |
| Teton Wilderness | 2.22 | 2.09 | 2.01 | 1.92 | 1.91 | 1.72 | 1.52 | 1.47 | 1.65 | 1.86 | 2.15 | 2.19 |

**Table 7. Monthly $f_L(RH)$ – Large $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Theodore Roosevelt NP | 2.47 | 2.42 | 2.45 | 2.12 | 2.14 | 2.21 | 2.14 | 1.99 | 1.99 | 2.10 | 2.58 | 2.57 |
| Thousand Lakes Wilderness | 3.04 | 2.63 | 2.42 | 2.17 | 2.06 | 1.88 | 1.82 | 1.85 | 1.91 | 2.08 | 2.61 | 2.91 |
| Three Sisters Wilderness | 4.03 | 3.59 | 3.43 | 3.34 | 3.02 | 2.78 | 2.40 | 2.38 | 2.65 | 3.39 | 4.02 | 4.04 |
| Tuxedni Wilderness | 2.97 | 2.83 | 2.47 | 2.40 | 2.38 | 2.50 | 2.96 | 3.19 | 3.18 | 2.91 | 2.91 | 3.03 |
| UL Bend Wilderness | 2.33 | 2.20 | 2.19 | 2.03 | 1.96 | 1.95 | 1.80 | 1.66 | 1.76 | 2.00 | 2.31 | 2.32 |
| Upper Buffalo Wilderness | 2.71 | 2.48 | 2.31 | 2.33 | 2.61 | 2.64 | 2.57 | 2.59 | 2.71 | 2.58 | 2.59 | 2.72 |
| Ventana Wilderness | 2.80 | 2.67 | 2.63 | 2.20 | 2.10 | 1.96 | 1.97 | 2.01 | 2.05 | 2.11 | 2.21 | 2.51 |
| Virgin Islands NP | 2.04 | 2.00 | 1.94 | 2.03 | 2.06 | 2.04 | 2.05 | 2.14 | 2.14 | 2.18 | 2.20 | 2.12 |
| Voyageurs NP | 2.46 | 2.22 | 2.22 | 2.07 | 2.09 | 2.46 | 2.46 | 2.59 | 2.70 | 2.35 | 2.58 | 2.55 |
| Washakie Wilderness | 2.16 | 2.05 | 2.01 | 1.94 | 1.93 | 1.74 | 1.54 | 1.48 | 1.66 | 1.86 | 2.12 | 2.14 |
| Weminuche Wilderness | 2.19 | 2.05 | 1.81 | 1.65 | 1.64 | 1.44 | 1.60 | 1.85 | 1.79 | 1.65 | 1.97 | 2.11 |
| West Elk Wilderness | 2.11 | 2.04 | 1.84 | 1.77 | 1.77 | 1.54 | 1.63 | 1.83 | 1.83 | 1.69 | 1.96 | 2.04 |
| Wheeler Peak Wilderness | 2.14 | 2.00 | 1.78 | 1.65 | 1.67 | 1.52 | 1.66 | 1.94 | 1.89 | 1.68 | 1.98 | 2.10 |
| White Mountain Wilderness | 2.00 | 1.79 | 1.51 | 1.40 | 1.44 | 1.37 | 1.64 | 1.82 | 1.85 | 1.59 | 1.72 | 1.95 |
| Wichita Mountains Wilderness | 2.39 | 2.25 | 2.10 | 2.11 | 2.39 | 2.24 | 2.02 | 2.13 | 2.35 | 2.22 | 2.28 | 2.41 |
| Wind Cave NP | 2.23 | 2.22 | 2.22 | 2.18 | 2.32 | 2.18 | 2.00 | 1.97 | 1.95 | 2.00 | 2.30 | 2.24 |
| Wolf Island Wilderness | 2.86 | 2.67 | 2.61 | 2.54 | 2.63 | 2.96 | 2.94 | 3.13 | 3.12 | 2.99 | 2.88 | 2.95 |
| Yellowstone NP | 2.24 | 2.11 | 2.03 | 1.95 | 1.94 | 1.78 | 1.59 | 1.53 | 1.69 | 1.91 | 2.19 | 2.22 |
| Yolla Bolly-Middle Eel Wilderness | 3.12 | 2.76 | 2.60 | 2.37 | 2.29 | 2.13 | 2.14 | 2.18 | 2.21 | 2.33 | 2.75 | 2.98 |
| Yosemite NP | 2.61 | 2.45 | 2.34 | 1.99 | 1.88 | 1.61 | 1.48 | 1.46 | 1.54 | 1.69 | 2.06 | 2.38 |
| Zion NP | 2.32 | 2.18 | 1.83 | 1.56 | 1.45 | 1.26 | 1.24 | 1.38 | 1.40 | 1.51 | 1.84 | 2.14 |

**Table 8. Monthly $f_S(RH)$ – Small $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acadia NP | 3.80 | 3.28 | 3.30 | 3.71 | 3.72 | 3.81 | 4.28 | 4.34 | 4.58 | 4.10 | 4.06 | 4.19 |
| Agua Tibia Wilderness | 2.68 | 2.61 | 2.63 | 2.42 | 2.40 | 2.33 | 2.33 | 2.45 | 2.49 | 2.46 | 2.29 | 2.42 |
| Alpine Lakes Wilderness | 5.87 | 5.35 | 4.34 | 4.13 | 4.30 | 3.50 | 3.61 | 3.69 | 4.27 | 5.43 | 6.15 | 6.08 |
| Anaconda Pintler Wilderness | 3.72 | 3.23 | 2.87 | 2.62 | 2.60 | 2.52 | 2.14 | 2.07 | 2.33 | 2.87 | 3.60 | 3.71 |
| Ansel Adams Wilderness | 3.51 | 3.11 | 2.87 | 2.34 | 2.18 | 1.86 | 1.75 | 1.76 | 1.88 | 2.05 | 2.55 | 3.12 |
| Arches NP | 2.96 | 2.70 | 2.09 | 1.84 | 1.75 | 1.40 | 1.49 | 1.69 | 1.76 | 1.83 | 2.33 | 2.69 |
| Badlands NP | 2.94 | 2.96 | 3.01 | 2.87 | 3.10 | 2.91 | 2.64 | 2.59 | 2.56 | 2.58 | 3.11 | 2.98 |
| Bandelier NM | 2.66 | 2.36 | 2.10 | 1.77 | 1.80 | 1.55 | 1.93 | 2.30 | 2.21 | 1.87 | 2.32 | 2.60 |
| Bering Sea Wilderness | 4.16 | 4.48 | 4.52 | 4.50 | 4.64 | 4.86 | 5.71 | 6.43 | 5.40 | 4.52 | 4.36 | 4.37 |
| Big Bend NP | 2.11 | 1.92 | 1.65 | 1.56 | 1.67 | 1.67 | 1.83 | 2.07 | 2.22 | 1.92 | 1.92 | 2.04 |
| Black Canyon of the Gunnison NP | 2.71 | 2.56 | 2.23 | 2.12 | 2.12 | 1.75 | 1.87 | 2.17 | 2.21 | 2.00 | 2.42 | 2.57 |
| Bob Marshall Wilderness | 3.84 | 3.35 | 3.06 | 2.86 | 2.86 | 2.84 | 2.49 | 2.39 | 2.77 | 3.22 | 3.81 | 3.83 |
| Bosque del Apache Wilderness | 2.56 | 2.23 | 1.83 | 1.54 | 1.54 | 1.39 | 1.90 | 2.16 | 2.09 | 1.79 | 2.09 | 2.53 |
| Boundary Waters Canoe Area Wilderness | 3.23 | 2.81 | 2.93 | 2.63 | 2.89 | 3.22 | 3.44 | 3.71 | 3.83 | 3.08 | 3.49 | 3.49 |
| Breton Wilderness | 4.08 | 3.82 | 3.79 | 3.74 | 3.94 | 4.12 | 4.41 | 4.37 | 4.18 | 3.92 | 3.93 | 4.06 |
| Bridger Wilderness | 2.78 | 2.60 | 2.55 | 2.43 | 2.45 | 1.99 | 1.65 | 1.63 | 2.03 | 2.25 | 2.78 | 2.68 |
| Brigantine Wilderness | 3.34 | 3.07 | 3.17 | 2.99 | 3.37 | 3.45 | 3.68 | 3.90 | 3.91 | 3.73 | 3.27 | 3.36 |
| Bryce Canyon NP | 3.02 | 2.77 | 2.23 | 1.84 | 1.70 | 1.38 | 1.42 | 1.67 | 1.67 | 1.81 | 2.30 | 2.75 |
| Cabinet Mountains Wilderness | 4.30 | 3.69 | 3.23 | 2.91 | 2.91 | 2.87 | 2.50 | 2.40 | 2.84 | 3.40 | 4.26 | 4.37 |
| Caney Creek Wilderness | 3.85 | 3.44 | 3.14 | 3.24 | 3.66 | 3.71 | 3.49 | 3.51 | 3.73 | 3.72 | 3.68 | 3.88 |
| Canyonlands NP | 3.03 | 2.77 | 2.17 | 1.86 | 1.76 | 1.40 | 1.52 | 1.78 | 1.81 | 1.87 | 2.38 | 2.77 |
| Cape Romain Wilderness | 3.66 | 3.33 | 3.24 | 3.07 | 3.46 | 3.88 | 3.91 | 4.31 | 4.30 | 4.00 | 3.62 | 3.73 |
| Capitol Reef NP | 3.10 | 2.86 | 2.27 | 1.94 | 1.81 | 1.45 | 1.52 | 1.77 | 1.81 | 1.91 | 2.43 | 2.86 |
| Caribou Wilderness | 4.17 | 3.50 | 3.11 | 2.68 | 2.54 | 2.28 | 2.21 | 2.26 | 2.36 | 2.60 | 3.39 | 3.93 |
| Carlsbad Caverns NP | 2.70 | 2.25 | 1.75 | 1.63 | 1.77 | 1.70 | 2.06 | 2.34 | 2.59 | 1.95 | 2.16 | 2.57 |
| Chassahowitzka Wilderness | 4.31 | 3.92 | 3.79 | 3.62 | 3.57 | 4.22 | 4.26 | 4.50 | 4.49 | 4.29 | 4.18 | 4.43 |
| Chiricahua NM | 2.29 | 2.19 | 1.75 | 1.34 | 1.31 | 1.18 | 1.94 | 2.28 | 1.95 | 1.64 | 1.79 | 2.34 |
| Chiricahua Wilderness | 2.25 | 2.14 | 1.71 | 1.30 | 1.28 | 1.17 | 1.95 | 2.26 | 1.93 | 1.61 | 1.75 | 2.31 |
| Cohutta Wilderness | 3.99 | 3.59 | 3.38 | 3.16 | 3.76 | 4.19 | 4.24 | 4.37 | 4.41 | 4.09 | 3.77 | 4.00 |
| Crater Lake NP | 5.58 | 4.73 | 4.37 | 4.09 | 3.70 | 3.37 | 3.05 | 3.08 | 3.38 | 4.26 | 5.52 | 5.64 |
| Craters of the Moon NM | 3.40 | 3.00 | 2.52 | 2.22 | 2.23 | 1.94 | 1.56 | 1.55 | 1.76 | 2.17 | 3.04 | 3.32 |
| Cucamonga Wilderness | 2.87 | 2.73 | 2.68 | 2.40 | 2.37 | 2.29 | 2.31 | 2.38 | 2.43 | 2.42 | 2.34 | 2.54 |
| Denali NP & Pres | 3.21 | 3.19 | 2.71 | 2.39 | 2.46 | 2.69 | 3.27 | 4.05 | 4.17 | 3.90 | 3.59 | 3.58 |
| Desolation Wilderness | 3.77 | 3.22 | 2.82 | 2.26 | 2.09 | 1.80 | 1.67 | 1.71 | 1.84 | 2.08 | 2.72 | 3.44 |
| Diamond Peak Wilderness | 5.79 | 4.97 | 4.61 | 4.35 | 3.90 | 3.55 | 3.08 | 3.12 | 3.55 | 4.63 | 5.75 | 5.88 |
| Dolly Sods Wilderness | 3.39 | 3.16 | 3.17 | 2.87 | 3.63 | 3.62 | 3.78 | 4.06 | 4.15 | 3.63 | 3.27 | 3.53 |
| Dome Land Wilderness | 2.97 | 2.64 | 2.51 | 2.17 | 2.08 | 1.91 | 1.89 | 1.93 | 2.01 | 2.06 | 2.23 | 2.56 |
| Eagle Cap Wilderness | 5.05 | 4.28 | 3.45 | 3.05 | 3.02 | 2.56 | 2.20 | 2.15 | 2.53 | 3.62 | 4.89 | 5.26 |
| Eagles Nest Wilderness | 2.48 | 2.48 | 2.29 | 2.32 | 2.42 | 2.03 | 2.02 | 2.24 | 2.31 | 2.09 | 2.42 | 2.42 |
| Emigrant Wilderness | 3.69 | 3.25 | 2.98 | 2.39 | 2.21 | 1.86 | 1.71 | 1.73 | 1.85 | 2.07 | 2.68 | 3.32 |
| Everglades NP | 3.14 | 2.93 | 2.83 | 2.67 | 2.63 | 3.03 | 2.91 | 3.22 | 3.33 | 3.12 | 2.95 | 3.08 |
| Fitzpatrick Wilderness | 2.78 | 2.60 | 2.54 | 2.43 | 2.44 | 1.99 | 1.66 | 1.63 | 2.02 | 2.25 | 2.77 | 2.68 |
| Flat Tops Wilderness | 2.61 | 2.53 | 2.28 | 2.26 | 2.31 | 1.91 | 1.86 | 2.04 | 2.19 | 2.06 | 2.42 | 2.51 |
| Galiuro Wilderness | 2.17 | 1.99 | 1.68 | 1.30 | 1.26 | 1.14 | 1.62 | 1.96 | 1.75 | 1.60 | 1.82 | 2.31 |
| Gates of the Mountains Wilderness | 3.20 | 2.85 | 2.71 | 2.57 | 2.53 | 2.50 | 2.21 | 2.14 | 2.37 | 2.74 | 3.09 | 3.12 |

**Table 8. Monthly $f_S$(RH) – Small $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gearhart Mountain Wilderness | 4.80 | 4.05 | 3.60 | 3.30 | 3.04 | 2.76 | 2.37 | 2.39 | 2.62 | 3.36 | 4.45 | 4.76 |
| Gila Wilderness | 2.40 | 2.16 | 1.77 | 1.45 | 1.41 | 1.33 | 2.11 | 2.12 | 2.00 | 1.73 | 1.99 | 2.45 |
| Glacier NP | 4.53 | 3.87 | 3.63 | 3.39 | 3.51 | 3.48 | 2.91 | 2.87 | 3.47 | 3.86 | 4.29 | 4.37 |
| Glacier Peak Wilderness | 5.53 | 4.98 | 4.21 | 3.99 | 3.90 | 3.43 | 3.35 | 3.54 | 4.14 | 5.12 | 5.80 | 5.80 |
| Goat Rocks Wilderness | 5.81 | 5.08 | 4.46 | 4.23 | 3.97 | 3.57 | 3.35 | 3.48 | 4.11 | 5.22 | 5.98 | 6.09 |
| Grand Canyon NP | 2.73 | 2.53 | 2.12 | 1.69 | 1.52 | 1.27 | 1.42 | 1.72 | 1.69 | 1.74 | 2.11 | 2.49 |
| Grand Teton NP | 2.88 | 2.66 | 2.48 | 2.35 | 2.34 | 2.00 | 1.68 | 1.62 | 1.94 | 2.25 | 2.73 | 2.82 |
| Great Gulf Wilderness | 3.34 | 3.02 | 3.12 | 3.23 | 3.31 | 3.46 | 3.76 | 4.03 | 4.22 | 3.90 | 3.64 | 3.50 |
| Great Sand Dunes NP & Pres | 2.66 | 2.55 | 2.27 | 2.16 | 2.22 | 1.92 | 2.04 | 2.47 | 2.41 | 2.07 | 2.57 | 2.63 |
| Great Smoky Mountains NP | 4.01 | 3.52 | 3.43 | 3.14 | 3.76 | 4.20 | 4.21 | 4.39 | 4.45 | 4.05 | 3.76 | 3.99 |
| Guadalupe Mountains NP | 2.85 | 2.28 | 1.74 | 1.57 | 1.73 | 1.69 | 2.16 | 2.48 | 2.74 | 1.90 | 2.20 | 2.71 |
| Haleakala NP | 2.98 | 2.85 | 2.81 | 2.72 | 2.60 | 2.53 | 2.65 | 2.63 | 2.56 | 2.69 | 2.95 | 2.89 |
| Hawaii Volcanoes NP | 3.35 | 3.10 | 3.14 | 3.13 | 3.14 | 3.11 | 3.24 | 3.42 | 3.34 | 3.38 | 3.76 | 3.34 |
| Hells Canyon Wilderness | 4.28 | 3.56 | 2.83 | 2.42 | 2.34 | 2.19 | 1.80 | 1.75 | 2.01 | 2.75 | 4.03 | 4.45 |
| Hercules-Glades Wilderness | 3.70 | 3.33 | 3.01 | 3.01 | 3.47 | 3.48 | 3.41 | 3.51 | 3.67 | 3.43 | 3.46 | 3.73 |
| Hoover Wilderness | 3.63 | 3.18 | 2.89 | 2.33 | 2.16 | 1.82 | 1.66 | 1.68 | 1.81 | 2.02 | 2.62 | 3.25 |
| Isle Royale NP | 3.26 | 2.74 | 2.87 | 2.58 | 2.46 | 3.00 | 3.59 | 3.68 | 3.92 | 2.88 | 3.72 | 3.67 |
| James River Face Wilderness | 3.25 | 3.03 | 3.02 | 2.72 | 3.31 | 3.48 | 3.59 | 3.83 | 3.91 | 3.48 | 3.11 | 3.38 |
| Jarbidge Wilderness | 3.29 | 2.92 | 2.31 | 2.34 | 2.44 | 2.22 | 1.73 | 1.51 | 1.48 | 1.80 | 2.70 | 3.13 |
| John Muir Wilderness | 3.42 | 3.02 | 2.86 | 2.44 | 2.29 | 1.94 | 1.86 | 1.87 | 2.01 | 2.16 | 2.60 | 3.03 |
| Joshua Tree NP | 2.62 | 2.49 | 2.44 | 2.19 | 2.16 | 2.05 | 1.97 | 2.18 | 2.21 | 2.19 | 2.11 | 2.31 |
| Joyce Kilmer-Slickrock Wilderness | 4.02 | 3.54 | 3.42 | 3.15 | 3.74 | 4.19 | 4.21 | 4.35 | 4.41 | 4.04 | 3.77 | 4.00 |
| Kaiser Wilderness | 3.55 | 3.13 | 2.89 | 2.36 | 2.21 | 1.90 | 1.81 | 1.83 | 1.95 | 2.12 | 2.59 | 3.16 |
| Kalmiopsis Wilderness | 5.32 | 4.56 | 4.30 | 4.02 | 3.79 | 3.54 | 3.43 | 3.44 | 3.56 | 4.12 | 5.21 | 5.28 |
| Kings Canyon | 3.35 | 2.97 | 2.82 | 2.42 | 2.28 | 1.93 | 1.85 | 1.87 | 2.01 | 2.15 | 2.56 | 2.96 |
| La Garita Wilderness | 2.71 | 2.54 | 2.21 | 2.04 | 2.05 | 1.72 | 1.93 | 2.31 | 2.26 | 2.00 | 2.46 | 2.62 |
| Lassen Volcanic NP | 4.24 | 3.55 | 3.16 | 2.73 | 2.58 | 2.31 | 2.24 | 2.29 | 2.39 | 2.64 | 3.46 | 4.00 |
| Lava Beds NM | 4.84 | 4.05 | 3.63 | 3.28 | 3.04 | 2.76 | 2.53 | 2.55 | 2.75 | 3.29 | 4.35 | 4.75 |
| Linville Gorge Wilderness | 3.76 | 3.46 | 3.37 | 3.07 | 3.74 | 4.18 | 4.24 | 4.62 | 4.61 | 4.00 | 3.59 | 3.80 |
| Lostwood Wilderness | 3.21 | 3.15 | 3.36 | 2.60 | 2.54 | 2.86 | 2.89 | 2.60 | 2.53 | 2.72 | 3.60 | 3.52 |
| Lye Brook Wilderness | 3.25 | 2.99 | 3.10 | 3.06 | 3.24 | 3.30 | 3.52 | 3.80 | 3.95 | 3.71 | 3.42 | 3.35 |
| Mammoth Cave NP | 3.86 | 3.47 | 3.32 | 3.54 | 4.90 | 5.77 | 5.58 | 4.09 | 4.15 | 3.73 | 3.54 | 3.91 |
| Marble Mountain Wilderness | 5.15 | 4.40 | 4.15 | 3.84 | 3.67 | 3.44 | 3.41 | 3.44 | 3.50 | 3.89 | 4.87 | 5.04 |
| Maroon Bells-Snowmass Wilderness | 2.48 | 2.44 | 2.23 | 2.25 | 2.25 | 1.87 | 2.02 | 2.35 | 2.35 | 2.04 | 2.36 | 2.38 |
| Mazatzal Wilderness | 2.36 | 2.20 | 1.88 | 1.46 | 1.36 | 1.18 | 1.54 | 1.89 | 1.74 | 1.66 | 1.91 | 2.33 |
| Medicine Lake Wilderness | 3.25 | 3.15 | 3.21 | 2.52 | 2.49 | 2.71 | 2.71 | 2.42 | 2.46 | 2.65 | 3.48 | 3.48 |
| Mesa Verde NP | 3.32 | 2.96 | 2.55 | 1.88 | 1.96 | 1.46 | 1.94 | 2.35 | 2.13 | 2.04 | 2.57 | 3.06 |
| Mingo Wilderness | 3.74 | 3.38 | 3.07 | 2.97 | 3.39 | 3.52 | 3.57 | 3.64 | 3.72 | 3.47 | 3.43 | 3.74 |
| Mission Mountains Wilderness | 4.03 | 3.51 | 3.08 | 2.82 | 2.84 | 2.83 | 2.49 | 2.40 | 2.78 | 3.28 | 4.04 | 4.08 |
| Mokelumne Wilderness | 3.75 | 3.23 | 2.86 | 2.29 | 2.12 | 1.81 | 1.68 | 1.72 | 1.84 | 2.08 | 2.71 | 3.41 |
| Moosehorn Wilderness | 3.59 | 3.14 | 3.16 | 3.44 | 3.38 | 3.49 | 3.98 | 4.18 | 4.40 | 3.94 | 3.82 | 3.82 |
| Mount Adams Wilderness | 5.71 | 5.00 | 4.46 | 4.23 | 3.89 | 3.55 | 3.26 | 3.41 | 4.02 | 5.13 | 5.89 | 5.98 |
| Mount Baldy Wilderness | 2.51 | 2.30 | 1.92 | 1.51 | 1.43 | 1.25 | 1.73 | 2.08 | 1.88 | 1.76 | 2.08 | 2.54 |
| Mount Hood Wilderness | 5.56 | 4.87 | 4.40 | 4.19 | 3.79 | 3.44 | 3.07 | 3.22 | 3.79 | 4.93 | 5.76 | 5.81 |
| Mount Jefferson Wilderness | 5.95 | 5.16 | 4.78 | 4.57 | 4.09 | 3.65 | 3.10 | 3.11 | 3.63 | 4.91 | 5.98 | 6.05 |

**Table 8. Monthly $f_S(RH)$ – Small $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mount Rainier NP | 6.01 | 5.29 | 4.71 | 4.51 | 4.23 | 3.82 | 3.59 | 3.73 | 4.39 | 5.55 | 6.23 | 6.27 |
| Mount Washington Wilderness | 6.35 | 5.47 | 5.22 | 5.07 | 4.42 | 3.93 | 3.16 | 3.09 | 3.63 | 5.07 | 6.31 | 6.35 |
| Mount Zirkel Wilderness | 2.43 | 2.44 | 2.31 | 2.37 | 2.51 | 2.07 | 1.92 | 2.02 | 2.23 | 2.12 | 2.41 | 2.37 |
| Mountain Lakes Wilderness | 5.20 | 4.32 | 3.90 | 3.58 | 3.26 | 2.96 | 2.69 | 2.70 | 2.94 | 3.67 | 4.96 | 5.24 |
| North Absaroka Wilderness | 2.68 | 2.51 | 2.50 | 2.42 | 2.40 | 2.13 | 1.83 | 1.72 | 1.98 | 2.31 | 2.65 | 2.65 |
| North Cascades NP | 5.37 | 4.86 | 4.24 | 4.04 | 3.80 | 3.51 | 3.34 | 3.61 | 4.23 | 5.08 | 5.68 | 5.66 |
| Okefenokee Wilderness | 4.16 | 3.79 | 3.80 | 3.65 | 3.79 | 4.46 | 4.24 | 4.55 | 4.55 | 4.35 | 4.18 | 4.33 |
| Olympic NP | 5.76 | 5.20 | 4.81 | 4.64 | 3.81 | 4.04 | 3.52 | 4.16 | 4.70 | 5.63 | 6.11 | 6.02 |
| Otter Creek Wilderness | 3.41 | 3.20 | 3.20 | 2.91 | 3.64 | 3.70 | 3.88 | 4.18 | 4.26 | 3.72 | 3.32 | 3.56 |
| Pasayten Wilderness | 5.46 | 4.89 | 4.20 | 3.96 | 3.77 | 3.42 | 3.28 | 3.49 | 4.08 | 5.00 | 5.72 | 5.74 |
| Pecos Wilderness | 2.65 | 2.40 | 2.10 | 1.85 | 1.88 | 1.65 | 1.96 | 2.34 | 2.27 | 1.94 | 2.36 | 2.60 |
| Petrified Forest NP | 2.67 | 2.43 | 1.96 | 1.59 | 1.46 | 1.26 | 1.67 | 2.06 | 1.85 | 1.79 | 2.20 | 2.66 |
| Pine Mountain Wilderness | 2.44 | 2.29 | 1.95 | 1.51 | 1.41 | 1.20 | 1.54 | 1.91 | 1.77 | 1.70 | 1.96 | 2.39 |
| Pinnacles NM | 4.02 | 4.05 | 4.09 | 3.01 | 2.81 | 2.54 | 2.40 | 2.52 | 2.54 | 2.74 | 2.82 | 3.36 |
| Point Reyes NS | 4.16 | 3.74 | 3.53 | 2.96 | 2.80 | 2.55 | 2.69 | 2.77 | 2.80 | 2.90 | 3.30 | 3.80 |
| Presidential Range-Dry River Wilderness | 3.36 | 3.02 | 3.15 | 3.26 | 3.37 | 3.56 | 3.86 | 4.14 | 4.33 | 3.96 | 3.68 | 3.50 |
| Rawah Wilderness | 2.31 | 2.39 | 2.32 | 2.44 | 2.61 | 2.19 | 2.05 | 2.16 | 2.31 | 2.12 | 2.37 | 2.29 |
| Red Rock Lakes Wilderness | 3.09 | 2.76 | 2.57 | 2.41 | 2.38 | 2.17 | 1.86 | 1.77 | 2.01 | 2.39 | 2.96 | 3.05 |
| Redwood NP | 4.81 | 4.41 | 4.51 | 4.27 | 4.40 | 4.37 | 4.73 | 4.76 | 4.46 | 4.24 | 4.62 | 4.45 |
| Rocky Mountain NP | 2.09 | 2.24 | 2.24 | 2.45 | 2.62 | 2.22 | 2.09 | 2.15 | 2.29 | 2.04 | 2.23 | 2.08 |
| Roosevelt Campobello International Park | 3.61 | 3.14 | 3.16 | 3.45 | 3.37 | 3.49 | 3.95 | 4.15 | 4.36 | 3.93 | 3.84 | 3.85 |
| Saguaro NP | 1.99 | 1.80 | 1.56 | 1.18 | 1.16 | 1.07 | 1.51 | 1.89 | 1.66 | 1.54 | 1.72 | 2.25 |
| Saint Marks Wilderness | 4.24 | 3.89 | 3.79 | 3.72 | 3.79 | 4.32 | 4.56 | 4.63 | 4.43 | 4.19 | 4.16 | 4.39 |
| Salt Creek Wilderness | 2.57 | 2.19 | 1.75 | 1.67 | 1.82 | 1.69 | 1.93 | 2.16 | 2.37 | 1.94 | 2.07 | 2.38 |
| San Gabriel Wilderness | 2.94 | 2.78 | 2.72 | 2.41 | 2.37 | 2.29 | 2.32 | 2.39 | 2.44 | 2.44 | 2.36 | 2.58 |
| San Gorgonio Wilderness | 2.94 | 2.94 | 2.74 | 2.36 | 2.34 | 2.00 | 1.88 | 2.02 | 2.05 | 2.04 | 2.10 | 2.43 |
| San Jacinto Wilderness | 2.73 | 2.65 | 2.59 | 2.33 | 2.30 | 2.16 | 2.02 | 2.26 | 2.30 | 2.28 | 2.19 | 2.38 |
| San Pedro Parks Wilderness | 2.73 | 2.45 | 2.10 | 1.81 | 1.80 | 1.55 | 1.87 | 2.24 | 2.16 | 1.91 | 2.36 | 2.65 |
| San Rafael Wilderness | 3.38 | 3.13 | 3.07 | 2.68 | 2.64 | 2.57 | 2.66 | 2.74 | 2.84 | 2.77 | 2.63 | 2.94 |
| Sawtooth Wilderness | 3.78 | 3.18 | 2.55 | 2.20 | 2.17 | 1.95 | 1.51 | 1.50 | 1.61 | 2.11 | 3.26 | 3.70 |
| Scapegoat Wilderness | 3.70 | 3.24 | 2.97 | 2.79 | 2.78 | 2.75 | 2.41 | 2.31 | 2.65 | 3.09 | 3.67 | 3.68 |
| Selway-Bitterroot Wilderness | 3.99 | 3.41 | 2.90 | 2.56 | 2.54 | 2.43 | 2.00 | 1.93 | 2.21 | 2.82 | 3.78 | 4.01 |
| Seney Wilderness | 3.69 | 3.10 | 3.30 | 3.10 | 3.03 | 3.45 | 3.80 | 4.27 | 4.31 | 3.82 | 3.97 | 3.87 |
| Sequoia NP | 3.25 | 2.91 | 2.87 | 2.59 | 2.46 | 1.97 | 1.85 | 1.84 | 2.02 | 2.18 | 2.64 | 2.85 |
| Shenandoah NP | 3.26 | 2.99 | 3.02 | 2.72 | 3.28 | 3.46 | 3.59 | 3.85 | 3.91 | 3.41 | 3.08 | 3.44 |
| Shining Rock Wilderness | 3.89 | 3.51 | 3.37 | 3.11 | 3.77 | 4.22 | 4.29 | 4.58 | 4.60 | 4.12 | 3.69 | 3.88 |
| Sierra Ancha Wilderness | 2.38 | 2.21 | 1.87 | 1.46 | 1.36 | 1.19 | 1.60 | 1.95 | 1.78 | 1.69 | 1.96 | 2.41 |
| Simeonof Wilderness | 4.86 | 4.88 | 4.44 | 4.64 | 4.92 | 5.46 | 6.08 | 6.35 | 5.30 | 4.29 | 4.52 | 4.98 |
| Sipsey Wilderness | 3.89 | 3.52 | 3.23 | 3.13 | 3.60 | 3.99 | 4.13 | 4.09 | 4.12 | 3.87 | 3.61 | 3.89 |
| South Warner Wilderness | 4.36 | 3.67 | 3.20 | 2.81 | 2.64 | 2.39 | 2.04 | 2.07 | 2.24 | 2.76 | 3.71 | 4.20 |
| Strawberry Mountain Wilderness | 5.26 | 4.45 | 3.71 | 3.32 | 3.18 | 2.70 | 2.26 | 2.24 | 2.66 | 3.84 | 5.11 | 5.44 |
| Superstition Wilderness | 2.25 | 2.06 | 1.77 | 1.38 | 1.29 | 1.15 | 1.52 | 1.81 | 1.66 | 1.58 | 1.83 | 2.28 |
| Swanquarter Wilderness | 3.31 | 3.09 | 3.01 | 2.78 | 3.09 | 3.39 | 3.57 | 3.68 | 3.55 | 3.40 | 3.14 | 3.33 |
| Sycamore Canyon Wilderness | 2.52 | 2.41 | 2.05 | 1.59 | 1.47 | 1.23 | 1.53 | 1.98 | 1.85 | 1.77 | 2.03 | 2.45 |
| Teton Wilderness | 2.78 | 2.59 | 2.49 | 2.37 | 2.36 | 2.06 | 1.75 | 1.67 | 1.96 | 2.28 | 2.70 | 2.73 |

**Table 8. Monthly $f_S(RH)$ – Small $(NH_4)_2SO_4$ and $NH_4NO_3$ Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Theodore Roosevelt NP | 3.17 | 3.11 | 3.22 | 2.71 | 2.74 | 2.85 | 2.73 | 2.49 | 2.48 | 2.66 | 3.42 | 3.37 |
| Thousand Lakes Wilderness | 4.34 | 3.60 | 3.22 | 2.79 | 2.62 | 2.34 | 2.26 | 2.31 | 2.41 | 2.69 | 3.58 | 4.11 |
| Three Sisters Wilderness | 6.22 | 5.38 | 5.09 | 4.92 | 4.35 | 3.89 | 3.21 | 3.17 | 3.68 | 5.02 | 6.20 | 6.24 |
| Tuxedni Wilderness | 4.11 | 3.89 | 3.26 | 3.14 | 3.11 | 3.31 | 4.13 | 4.57 | 4.57 | 4.04 | 4.04 | 4.23 |
| UL Bend Wilderness | 2.94 | 2.75 | 2.77 | 2.55 | 2.44 | 2.41 | 2.19 | 1.97 | 2.12 | 2.50 | 2.96 | 2.95 |
| Upper Buffalo Wilderness | 3.73 | 3.33 | 3.03 | 3.07 | 3.54 | 3.57 | 3.43 | 3.50 | 3.71 | 3.51 | 3.52 | 3.74 |
| Ventana Wilderness | 3.92 | 3.69 | 3.61 | 2.86 | 2.69 | 2.46 | 2.46 | 2.55 | 2.61 | 2.72 | 2.89 | 3.43 |
| Virgin Islands NP | 2.41 | 2.36 | 2.27 | 2.39 | 2.44 | 2.40 | 2.43 | 2.57 | 2.58 | 2.63 | 2.68 | 2.54 |
| Voyageurs NP | 3.16 | 2.77 | 2.82 | 2.59 | 2.65 | 3.28 | 3.25 | 3.48 | 3.66 | 3.02 | 3.37 | 3.32 |
| Washakie Wilderness | 2.68 | 2.52 | 2.49 | 2.40 | 2.40 | 2.09 | 1.77 | 1.68 | 1.98 | 2.29 | 2.66 | 2.65 |
| Weminuche Wilderness | 2.80 | 2.58 | 2.22 | 1.97 | 1.97 | 1.64 | 1.89 | 2.28 | 2.20 | 1.97 | 2.45 | 2.69 |
| West Elk Wilderness | 2.64 | 2.53 | 2.24 | 2.15 | 2.16 | 1.79 | 1.92 | 2.24 | 2.26 | 2.02 | 2.41 | 2.53 |
| Wheeler Peak Wilderness | 2.72 | 2.50 | 2.17 | 1.97 | 2.02 | 1.76 | 1.98 | 2.42 | 2.36 | 2.01 | 2.48 | 2.66 |
| White Mountain Wilderness | 2.54 | 2.19 | 1.76 | 1.58 | 1.65 | 1.53 | 1.94 | 2.20 | 2.29 | 1.87 | 2.07 | 2.45 |
| Wichita Mountains Wilderness | 3.17 | 2.94 | 2.69 | 2.68 | 3.15 | 2.86 | 2.49 | 2.70 | 3.07 | 2.87 | 2.97 | 3.20 |
| Wind Cave NP | 2.81 | 2.81 | 2.86 | 2.82 | 3.06 | 2.81 | 2.50 | 2.46 | 2.44 | 2.52 | 2.97 | 2.83 |
| Wolf Island Wilderness | 4.02 | 3.68 | 3.58 | 3.45 | 3.59 | 4.17 | 4.13 | 4.47 | 4.46 | 4.23 | 4.05 | 4.18 |
| Yellowstone NP | 2.82 | 2.61 | 2.53 | 2.42 | 2.41 | 2.16 | 1.86 | 1.76 | 2.02 | 2.36 | 2.78 | 2.80 |
| Yolla Bolly-Middle Eel Wilderness | 4.48 | 3.82 | 3.53 | 3.13 | 3.00 | 2.75 | 2.81 | 2.87 | 2.93 | 3.11 | 3.84 | 4.24 |
| Yosemite NP | 3.62 | 3.32 | 3.13 | 2.52 | 2.34 | 1.89 | 1.69 | 1.67 | 1.78 | 2.04 | 2.65 | 3.22 |
| Zion NP | 3.05 | 2.81 | 2.26 | 1.84 | 1.67 | 1.37 | 1.33 | 1.54 | 1.58 | 1.75 | 2.25 | 2.72 |

**Table 9. Monthly $f_{SS}(RH)$ – Sea Salt Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acadia NP | 3.90 | 3.48 | 3.40 | 3.66 | 3.71 | 3.81 | 4.19 | 4.27 | 4.44 | 4.13 | 4.10 | 4.19 |
| Agua Tibia Wilderness | 2.94 | 2.95 | 3.02 | 2.85 | 2.88 | 2.81 | 2.78 | 2.90 | 2.90 | 2.83 | 2.56 | 2.69 |
| Alpine Lakes Wilderness | 5.35 | 4.96 | 4.27 | 4.11 | 4.18 | 3.64 | 3.68 | 3.73 | 4.12 | 4.98 | 5.51 | 5.53 |
| Anaconda Pintler Wilderness | 4.00 | 3.56 | 3.18 | 2.90 | 2.85 | 2.75 | 2.33 | 2.25 | 2.52 | 3.10 | 3.81 | 3.97 |
| Ansel Adams Wilderness | 3.55 | 3.25 | 3.04 | 2.54 | 2.38 | 2.05 | 1.91 | 1.91 | 2.03 | 2.21 | 2.72 | 3.21 |
| Arches NP | 3.25 | 2.99 | 2.26 | 1.97 | 1.86 | 1.48 | 1.59 | 1.82 | 1.88 | 1.96 | 2.60 | 3.02 |
| Badlands NP | 3.37 | 3.33 | 3.27 | 3.05 | 3.25 | 3.15 | 2.89 | 2.81 | 2.74 | 2.82 | 3.41 | 3.38 |
| Bandelier NM | 2.91 | 2.59 | 2.22 | 1.87 | 1.90 | 1.67 | 2.11 | 2.54 | 2.37 | 2.00 | 2.49 | 2.78 |
| Bering Sea Wilderness | 4.39 | 4.57 | 4.60 | 4.58 | 4.57 | 4.70 | 5.26 | 5.73 | 5.11 | 4.59 | 4.52 | 4.54 |
| Big Bend NP | 2.20 | 2.03 | 1.75 | 1.67 | 1.84 | 1.87 | 2.03 | 2.34 | 2.47 | 2.09 | 2.10 | 2.22 |
| Black Canyon of the Gunnison NP | 3.05 | 2.89 | 2.47 | 2.31 | 2.28 | 1.89 | 2.04 | 2.36 | 2.37 | 2.18 | 2.71 | 2.92 |
| Bob Marshall Wilderness | 4.08 | 3.66 | 3.35 | 3.11 | 3.08 | 3.04 | 2.68 | 2.59 | 2.94 | 3.42 | 3.98 | 4.05 |
| Bosque del Apache Wilderness | 2.77 | 2.43 | 1.95 | 1.62 | 1.62 | 1.47 | 2.06 | 2.40 | 2.29 | 1.92 | 2.27 | 2.71 |
| Boundary Waters Canoe Area Wilderness | 3.73 | 3.35 | 3.29 | 2.91 | 3.00 | 3.44 | 3.68 | 3.88 | 3.98 | 3.45 | 3.89 | 3.91 |
| Breton Wilderness | 4.10 | 3.89 | 3.87 | 3.85 | 4.02 | 4.21 | 4.44 | 4.38 | 4.23 | 3.99 | 4.01 | 4.11 |
| Bridger Wilderness | 3.25 | 3.05 | 2.90 | 2.67 | 2.62 | 2.17 | 1.81 | 1.79 | 2.17 | 2.43 | 3.15 | 3.17 |
| Brigantine Wilderness | 3.53 | 3.24 | 3.30 | 3.15 | 3.49 | 3.63 | 3.84 | 4.02 | 4.02 | 3.82 | 3.48 | 3.55 |
| Bryce Canyon NP | 3.24 | 3.00 | 2.40 | 1.96 | 1.80 | 1.45 | 1.52 | 1.80 | 1.78 | 1.93 | 2.52 | 2.99 |
| Cabinet Mountains Wilderness | 4.42 | 3.93 | 3.50 | 3.18 | 3.13 | 3.06 | 2.67 | 2.59 | 3.01 | 3.58 | 4.33 | 4.46 |
| Caney Creek Wilderness | 3.90 | 3.52 | 3.31 | 3.41 | 3.83 | 3.88 | 3.69 | 3.68 | 3.82 | 3.76 | 3.77 | 3.93 |
| Canyonlands NP | 3.30 | 3.04 | 2.33 | 1.99 | 1.87 | 1.48 | 1.63 | 1.90 | 1.94 | 2.00 | 2.64 | 3.07 |
| Cape Romain Wilderness | 3.74 | 3.44 | 3.37 | 3.23 | 3.62 | 3.99 | 4.04 | 4.32 | 4.29 | 4.03 | 3.74 | 3.81 |
| Capitol Reef NP | 3.35 | 3.11 | 2.45 | 2.08 | 1.93 | 1.54 | 1.62 | 1.90 | 1.94 | 2.05 | 2.68 | 3.13 |
| Caribou Wilderness | 4.16 | 3.63 | 3.28 | 2.89 | 2.75 | 2.47 | 2.33 | 2.37 | 2.49 | 2.74 | 3.48 | 3.97 |
| Carlsbad Caverns NP | 2.75 | 2.36 | 1.86 | 1.72 | 1.89 | 1.86 | 2.27 | 2.59 | 2.75 | 2.09 | 2.29 | 2.68 |
| Chassahowitzka Wilderness | 4.29 | 3.99 | 3.89 | 3.76 | 3.77 | 4.29 | 4.34 | 4.51 | 4.49 | 4.33 | 4.23 | 4.38 |
| Chiricahua NM | 2.53 | 2.38 | 1.91 | 1.41 | 1.38 | 1.21 | 2.12 | 2.55 | 2.18 | 1.78 | 1.99 | 2.56 |
| Chiricahua Wilderness | 2.48 | 2.33 | 1.86 | 1.37 | 1.35 | 1.20 | 2.12 | 2.54 | 2.16 | 1.75 | 1.94 | 2.52 |
| Cohutta Wilderness | 3.97 | 3.62 | 3.44 | 3.26 | 3.82 | 4.20 | 4.24 | 4.35 | 4.35 | 4.05 | 3.82 | 4.02 |
| Crater Lake NP | 5.15 | 4.56 | 4.31 | 4.12 | 3.80 | 3.52 | 3.20 | 3.23 | 3.44 | 4.17 | 5.10 | 5.19 |
| Craters of the Moon NM | 3.78 | 3.41 | 2.86 | 2.51 | 2.48 | 2.16 | 1.72 | 1.69 | 1.93 | 2.43 | 3.38 | 3.72 |
| Cucamonga Wilderness | 3.07 | 3.01 | 3.03 | 2.79 | 2.80 | 2.72 | 2.72 | 2.80 | 2.81 | 2.76 | 2.58 | 2.77 |
| Denali NP & Pres | 3.68 | 3.57 | 3.07 | 2.74 | 2.74 | 3.01 | 3.53 | 4.13 | 4.19 | 4.09 | 3.92 | 3.94 |
| Desolation Wilderness | 3.85 | 3.39 | 3.02 | 2.48 | 2.32 | 2.01 | 1.84 | 1.87 | 2.02 | 2.28 | 2.94 | 3.58 |
| Diamond Peak Wilderness | 5.29 | 4.72 | 4.45 | 4.27 | 3.92 | 3.65 | 3.23 | 3.26 | 3.56 | 4.43 | 5.26 | 5.34 |
| Dolly Sods Wilderness | 3.60 | 3.35 | 3.31 | 3.03 | 3.66 | 3.76 | 3.91 | 4.12 | 4.16 | 3.72 | 3.47 | 3.72 |
| Dome Land Wilderness | 3.10 | 2.86 | 2.75 | 2.42 | 2.33 | 2.15 | 2.11 | 2.16 | 2.22 | 2.26 | 2.40 | 2.71 |
| Eagle Cap Wilderness | 4.84 | 4.27 | 3.57 | 3.22 | 3.14 | 2.74 | 2.33 | 2.27 | 2.60 | 3.61 | 4.68 | 4.99 |
| Eagles Nest Wilderness | 2.86 | 2.82 | 2.54 | 2.52 | 2.57 | 2.20 | 2.20 | 2.44 | 2.46 | 2.27 | 2.73 | 2.79 |
| Emigrant Wilderness | 3.70 | 3.37 | 3.13 | 2.60 | 2.42 | 2.05 | 1.88 | 1.88 | 2.01 | 2.24 | 2.84 | 3.39 |
| Everglades NP | 3.60 | 3.44 | 3.37 | 3.22 | 3.21 | 3.58 | 3.50 | 3.72 | 3.78 | 3.61 | 3.50 | 3.55 |
| Fitzpatrick Wilderness | 3.25 | 3.05 | 2.88 | 2.66 | 2.62 | 2.18 | 1.82 | 1.79 | 2.16 | 2.43 | 3.13 | 3.18 |
| Flat Tops Wilderness | 2.99 | 2.88 | 2.54 | 2.47 | 2.47 | 2.07 | 2.03 | 2.23 | 2.35 | 2.25 | 2.75 | 2.89 |
| Galiuro Wilderness | 2.42 | 2.19 | 1.82 | 1.35 | 1.31 | 1.16 | 1.76 | 2.18 | 1.94 | 1.73 | 2.00 | 2.52 |
| Gates of the Mountains Wilderness | 3.62 | 3.27 | 3.05 | 2.85 | 2.80 | 2.74 | 2.43 | 2.35 | 2.58 | 2.99 | 3.41 | 3.52 |

**Table 9. Monthly $f_{ss}$(RH) – Sea Salt Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gearhart Mountain Wilderness | 4.63 | 4.06 | 3.67 | 3.40 | 3.16 | 2.90 | 2.49 | 2.50 | 2.70 | 3.39 | 4.31 | 4.60 |
| Gila Wilderness | 2.63 | 2.35 | 1.91 | 1.52 | 1.48 | 1.36 | 2.22 | 2.36 | 2.19 | 1.87 | 2.17 | 2.65 |
| Glacier NP | 4.61 | 4.12 | 3.87 | 3.64 | 3.63 | 3.59 | 3.11 | 3.11 | 3.63 | 4.03 | 4.43 | 4.51 |
| Glacier Peak Wilderness | 5.14 | 4.73 | 4.19 | 4.03 | 3.93 | 3.60 | 3.51 | 3.63 | 4.04 | 4.79 | 5.31 | 5.34 |
| Goat Rocks Wilderness | 5.30 | 4.79 | 4.32 | 4.15 | 3.94 | 3.65 | 3.46 | 3.55 | 3.99 | 4.83 | 5.40 | 5.51 |
| Grand Canyon NP | 2.93 | 2.73 | 2.26 | 1.78 | 1.61 | 1.32 | 1.50 | 1.85 | 1.79 | 1.84 | 2.29 | 2.70 |
| Grand Teton NP | 3.34 | 3.10 | 2.82 | 2.59 | 2.56 | 2.21 | 1.85 | 1.78 | 2.12 | 2.48 | 3.10 | 3.29 |
| Great Gulf Wilderness | 3.60 | 3.29 | 3.29 | 3.34 | 3.41 | 3.58 | 3.85 | 4.07 | 4.20 | 3.96 | 3.81 | 3.73 |
| Great Sand Dunes NP & Pres | 2.98 | 2.84 | 2.48 | 2.33 | 2.36 | 2.08 | 2.24 | 2.66 | 2.56 | 2.26 | 2.82 | 2.94 |
| Great Smoky Mountains NP | 4.01 | 3.57 | 3.47 | 3.22 | 3.82 | 4.23 | 4.24 | 4.37 | 4.38 | 4.03 | 3.81 | 4.02 |
| Guadalupe Mountains NP | 2.82 | 2.35 | 1.84 | 1.64 | 1.82 | 1.83 | 2.36 | 2.72 | 2.85 | 2.01 | 2.28 | 2.76 |
| Haleakala NP | 3.52 | 3.43 | 3.40 | 3.35 | 3.25 | 3.18 | 3.29 | 3.27 | 3.22 | 3.33 | 3.52 | 3.47 |
| Hawaii Volcanoes NP | 3.80 | 3.68 | 3.71 | 3.72 | 3.72 | 3.69 | 3.79 | 3.83 | 3.79 | 3.83 | 4.08 | 3.80 |
| Hells Canyon Wilderness | 4.39 | 3.81 | 3.15 | 2.75 | 2.63 | 2.44 | 1.97 | 1.90 | 2.19 | 3.00 | 4.13 | 4.51 |
| Hercules-Glades Wilderness | 3.86 | 3.51 | 3.23 | 3.22 | 3.66 | 3.72 | 3.69 | 3.73 | 3.81 | 3.57 | 3.65 | 3.88 |
| Hoover Wilderness | 3.66 | 3.31 | 3.05 | 2.53 | 2.36 | 2.00 | 1.82 | 1.82 | 1.96 | 2.18 | 2.79 | 3.34 |
| Isle Royale NP | 3.78 | 3.34 | 3.28 | 2.93 | 2.78 | 3.31 | 3.83 | 3.87 | 4.06 | 3.40 | 4.05 | 4.04 |
| James River Face Wilderness | 3.43 | 3.19 | 3.16 | 2.90 | 3.46 | 3.69 | 3.79 | 3.97 | 4.00 | 3.61 | 3.31 | 3.56 |
| Jarbidge Wilderness | 3.65 | 3.28 | 2.62 | 2.69 | 2.71 | 2.44 | 1.95 | 1.67 | 1.60 | 2.01 | 3.03 | 3.51 |
| John Muir Wilderness | 3.46 | 3.18 | 3.07 | 2.68 | 2.51 | 2.17 | 2.06 | 2.08 | 2.20 | 2.35 | 2.75 | 3.12 |
| Joshua Tree NP | 2.83 | 2.76 | 2.75 | 2.52 | 2.53 | 2.41 | 2.28 | 2.53 | 2.53 | 2.48 | 2.32 | 2.54 |
| Joyce Kilmer-Slickrock Wilderness | 4.01 | 3.58 | 3.46 | 3.24 | 3.81 | 4.22 | 4.23 | 4.35 | 4.35 | 4.03 | 3.82 | 4.02 |
| Kaiser Wilderness | 3.58 | 3.27 | 3.08 | 2.58 | 2.42 | 2.10 | 1.99 | 2.00 | 2.12 | 2.29 | 2.75 | 3.24 |
| Kalmiopsis Wilderness | 4.98 | 4.45 | 4.28 | 4.09 | 3.89 | 3.66 | 3.49 | 3.51 | 3.60 | 4.08 | 4.90 | 4.96 |
| Kings Canyon | 3.40 | 3.13 | 3.03 | 2.66 | 2.50 | 2.16 | 2.05 | 2.07 | 2.20 | 2.33 | 2.71 | 3.05 |
| La Garita Wilderness | 3.03 | 2.83 | 2.41 | 2.21 | 2.19 | 1.86 | 2.10 | 2.50 | 2.42 | 2.16 | 2.72 | 2.93 |
| Lassen Volcanic NP | 4.21 | 3.66 | 3.33 | 2.93 | 2.78 | 2.50 | 2.36 | 2.40 | 2.51 | 2.78 | 3.54 | 4.02 |
| Lava Beds NM | 4.64 | 4.04 | 3.68 | 3.37 | 3.15 | 2.89 | 2.62 | 2.65 | 2.82 | 3.32 | 4.21 | 4.56 |
| Linville Gorge Wilderness | 3.80 | 3.52 | 3.43 | 3.18 | 3.80 | 4.20 | 4.25 | 4.51 | 4.48 | 3.97 | 3.67 | 3.86 |
| Lostwood Wilderness | 3.77 | 3.66 | 3.67 | 2.86 | 2.79 | 3.07 | 3.11 | 2.82 | 2.80 | 2.99 | 3.93 | 3.95 |
| Lye Brook Wilderness | 3.53 | 3.26 | 3.27 | 3.20 | 3.36 | 3.48 | 3.70 | 3.93 | 4.04 | 3.82 | 3.63 | 3.61 |
| Mammoth Cave NP | 3.99 | 3.63 | 3.45 | 3.50 | 4.52 | 5.19 | 5.08 | 4.16 | 4.17 | 3.81 | 3.73 | 4.03 |
| Marble Mountain Wilderness | 4.85 | 4.32 | 4.16 | 3.92 | 3.76 | 3.53 | 3.44 | 3.46 | 3.51 | 3.86 | 4.63 | 4.78 |
| Maroon Bells-Snowmass Wilderness | 2.89 | 2.82 | 2.52 | 2.49 | 2.45 | 2.04 | 2.22 | 2.57 | 2.54 | 2.26 | 2.71 | 2.80 |
| Mazatzal Wilderness | 2.60 | 2.40 | 2.03 | 1.53 | 1.42 | 1.21 | 1.66 | 2.06 | 1.90 | 1.77 | 2.10 | 2.55 |
| Medicine Lake Wilderness | 3.79 | 3.66 | 3.56 | 2.80 | 2.75 | 2.94 | 2.93 | 2.66 | 2.73 | 2.95 | 3.85 | 3.92 |
| Mesa Verde NP | 3.40 | 3.10 | 2.61 | 1.95 | 2.00 | 1.53 | 2.04 | 2.45 | 2.28 | 2.05 | 2.69 | 3.15 |
| Mingo Wilderness | 3.92 | 3.58 | 3.30 | 3.19 | 3.58 | 3.72 | 3.80 | 3.82 | 3.85 | 3.61 | 3.66 | 3.90 |
| Mission Mountains Wilderness | 4.24 | 3.79 | 3.38 | 3.10 | 3.08 | 3.04 | 2.68 | 2.59 | 2.96 | 3.48 | 4.17 | 4.26 |
| Mokelumne Wilderness | 3.81 | 3.38 | 3.04 | 2.51 | 2.34 | 2.02 | 1.86 | 1.88 | 2.02 | 2.27 | 2.91 | 3.52 |
| Moosehorn Wilderness | 3.80 | 3.42 | 3.32 | 3.50 | 3.47 | 3.60 | 3.98 | 4.15 | 4.31 | 4.02 | 3.97 | 3.99 |
| Mount Adams Wilderness | 5.24 | 4.74 | 4.34 | 4.18 | 3.91 | 3.66 | 3.41 | 3.51 | 3.93 | 4.78 | 5.36 | 5.44 |
| Mount Baldy Wilderness | 2.74 | 2.50 | 2.05 | 1.58 | 1.50 | 1.29 | 1.87 | 2.28 | 2.06 | 1.87 | 2.26 | 2.74 |
| Mount Hood Wilderness | 5.16 | 4.67 | 4.33 | 4.18 | 3.87 | 3.61 | 3.29 | 3.38 | 3.78 | 4.67 | 5.29 | 5.33 |
| Mount Jefferson Wilderness | 5.38 | 4.84 | 4.55 | 4.42 | 4.05 | 3.74 | 3.27 | 3.28 | 3.63 | 4.64 | 5.41 | 5.46 |
| Mount Rainier NP | 5.42 | 4.92 | 4.50 | 4.36 | 4.13 | 3.86 | 3.67 | 3.76 | 4.20 | 5.05 | 5.56 | 5.62 |

**Table 9. Monthly $f_{SS}$(RH) – Sea Salt Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mount Washington Wilderness | 5.61 | 5.03 | 4.81 | 4.71 | 4.24 | 3.91 | 3.31 | 3.25 | 3.60 | 4.73 | 5.59 | 5.62 |
| Mount Zirkel Wilderness | 2.85 | 2.83 | 2.61 | 2.61 | 2.67 | 2.24 | 2.10 | 2.23 | 2.38 | 2.31 | 2.75 | 2.78 |
| Mountain Lakes Wilderness | 4.89 | 4.26 | 3.93 | 3.67 | 3.40 | 3.11 | 2.82 | 2.83 | 3.04 | 3.67 | 4.68 | 4.91 |
| North Absaroka Wilderness | 3.18 | 2.97 | 2.83 | 2.66 | 2.64 | 2.35 | 2.02 | 1.89 | 2.16 | 2.53 | 3.03 | 3.13 |
| North Cascades NP | 5.03 | 4.65 | 4.22 | 4.08 | 3.88 | 3.68 | 3.53 | 3.70 | 4.13 | 4.78 | 5.24 | 5.25 |
| Okefenokee Wilderness | 4.13 | 3.83 | 3.82 | 3.69 | 3.85 | 4.38 | 4.28 | 4.51 | 4.48 | 4.31 | 4.18 | 4.27 |
| Olympic NP | 5.27 | 4.87 | 4.61 | 4.51 | 3.94 | 4.12 | 3.76 | 4.16 | 4.51 | 5.17 | 5.51 | 5.46 |
| Otter Creek Wilderness | 3.63 | 3.40 | 3.34 | 3.06 | 3.67 | 3.82 | 3.98 | 4.19 | 4.23 | 3.78 | 3.51 | 3.76 |
| Pasayten Wilderness | 5.09 | 4.67 | 4.18 | 4.00 | 3.84 | 3.58 | 3.45 | 3.58 | 3.99 | 4.71 | 5.25 | 5.30 |
| Pecos Wilderness | 2.91 | 2.64 | 2.25 | 1.97 | 2.00 | 1.78 | 2.15 | 2.57 | 2.44 | 2.09 | 2.56 | 2.83 |
| Petrified Forest NP | 2.93 | 2.66 | 2.11 | 1.66 | 1.53 | 1.30 | 1.81 | 2.26 | 2.03 | 1.91 | 2.40 | 2.88 |
| Pine Mountain Wilderness | 2.69 | 2.50 | 2.11 | 1.60 | 1.47 | 1.24 | 1.67 | 2.09 | 1.92 | 1.82 | 2.16 | 2.62 |
| Pinnacles NM | 3.94 | 3.97 | 3.99 | 3.12 | 2.94 | 2.67 | 2.54 | 2.63 | 2.65 | 2.80 | 2.96 | 3.36 |
| Point Reyes NS | 4.20 | 3.88 | 3.72 | 3.25 | 3.12 | 2.88 | 2.96 | 3.01 | 3.05 | 3.12 | 3.48 | 3.90 |
| Presidential Range-Dry River Wilderness | 3.60 | 3.28 | 3.31 | 3.36 | 3.45 | 3.66 | 3.92 | 4.14 | 4.27 | 3.99 | 3.83 | 3.72 |
| Rawah Wilderness | 2.70 | 2.74 | 2.58 | 2.65 | 2.76 | 2.36 | 2.23 | 2.37 | 2.45 | 2.31 | 2.69 | 2.66 |
| Red Rock Lakes Wilderness | 3.51 | 3.18 | 2.91 | 2.67 | 2.63 | 2.41 | 2.06 | 1.94 | 2.20 | 2.63 | 3.29 | 3.46 |
| Redwood NP | 4.66 | 4.38 | 4.48 | 4.34 | 4.41 | 4.35 | 4.56 | 4.59 | 4.34 | 4.19 | 4.51 | 4.44 |
| Rocky Mountain NP | 2.44 | 2.56 | 2.47 | 2.64 | 2.75 | 2.37 | 2.26 | 2.36 | 2.41 | 2.20 | 2.51 | 2.41 |
| Roosevelt Campobello International Park | 3.82 | 3.43 | 3.32 | 3.52 | 3.47 | 3.61 | 3.96 | 4.13 | 4.29 | 4.02 | 3.99 | 4.01 |
| Saguaro NP | 2.24 | 2.00 | 1.69 | 1.21 | 1.20 | 1.08 | 1.67 | 2.13 | 1.86 | 1.65 | 1.89 | 2.44 |
| Saint Marks Wilderness | 4.18 | 3.89 | 3.82 | 3.76 | 3.85 | 4.30 | 4.49 | 4.54 | 4.39 | 4.19 | 4.15 | 4.30 |
| Salt Creek Wilderness | 2.72 | 2.37 | 1.88 | 1.77 | 1.96 | 1.87 | 2.15 | 2.44 | 2.59 | 2.12 | 2.26 | 2.56 |
| San Gabriel Wilderness | 3.12 | 3.04 | 3.04 | 2.77 | 2.78 | 2.69 | 2.69 | 2.77 | 2.79 | 2.74 | 2.59 | 2.79 |
| San Gorgonio Wilderness | 2.97 | 3.06 | 2.93 | 2.60 | 2.63 | 2.28 | 2.13 | 2.30 | 2.31 | 2.24 | 2.25 | 2.55 |
| San Jacinto Wilderness | 2.92 | 2.91 | 2.91 | 2.67 | 2.69 | 2.55 | 2.33 | 2.64 | 2.64 | 2.57 | 2.40 | 2.60 |
| San Pedro Parks Wilderness | 3.00 | 2.71 | 2.25 | 1.94 | 1.91 | 1.66 | 2.04 | 2.45 | 2.33 | 2.05 | 2.57 | 2.88 |
| San Rafael Wilderness | 3.49 | 3.35 | 3.34 | 3.00 | 2.99 | 2.90 | 2.97 | 3.04 | 3.09 | 3.00 | 2.86 | 3.12 |
| Sawtooth Wilderness | 4.05 | 3.53 | 2.89 | 2.53 | 2.44 | 2.18 | 1.66 | 1.61 | 1.76 | 2.38 | 3.55 | 4.00 |
| Scapegoat Wilderness | 3.97 | 3.57 | 3.27 | 3.04 | 3.01 | 2.96 | 2.60 | 2.51 | 2.83 | 3.30 | 3.86 | 3.93 |
| Selway-Bitterroot Wilderness | 4.20 | 3.71 | 3.21 | 2.86 | 2.80 | 2.66 | 2.18 | 2.09 | 2.39 | 3.06 | 3.96 | 4.20 |
| Seney Wilderness | 4.05 | 3.60 | 3.60 | 3.30 | 3.20 | 3.58 | 3.91 | 4.28 | 4.30 | 4.00 | 4.19 | 4.16 |
| Sequoia NP | 3.27 | 3.07 | 3.10 | 2.84 | 2.66 | 2.21 | 2.06 | 2.05 | 2.21 | 2.35 | 2.75 | 2.93 |
| Shenandoah NP | 3.44 | 3.17 | 3.17 | 2.90 | 3.42 | 3.66 | 3.78 | 3.97 | 3.98 | 3.56 | 3.28 | 3.62 |
| Shining Rock Wilderness | 3.90 | 3.55 | 3.43 | 3.21 | 3.82 | 4.22 | 4.28 | 4.48 | 4.48 | 4.06 | 3.76 | 3.92 |
| Sierra Ancha Wilderness | 2.62 | 2.42 | 2.02 | 1.53 | 1.42 | 1.22 | 1.73 | 2.14 | 1.95 | 1.81 | 2.15 | 2.62 |
| Simeonof Wilderness | 4.83 | 4.85 | 4.54 | 4.68 | 4.83 | 5.20 | 5.57 | 5.72 | 5.11 | 4.48 | 4.62 | 4.89 |
| Sipsey Wilderness | 3.94 | 3.60 | 3.36 | 3.28 | 3.72 | 4.06 | 4.18 | 4.14 | 4.13 | 3.91 | 3.74 | 3.96 |
| South Warner Wilderness | 4.32 | 3.75 | 3.31 | 2.94 | 2.77 | 2.51 | 2.13 | 2.15 | 2.31 | 2.83 | 3.71 | 4.19 |
| Strawberry Mountain Wilderness | 4.97 | 4.37 | 3.77 | 3.44 | 3.28 | 2.88 | 2.41 | 2.38 | 2.73 | 3.77 | 4.82 | 5.10 |
| Superstition Wilderness | 2.49 | 2.27 | 1.92 | 1.44 | 1.34 | 1.17 | 1.64 | 1.98 | 1.82 | 1.69 | 2.01 | 2.49 |
| Swanquarter Wilderness | 3.52 | 3.30 | 3.25 | 3.09 | 3.42 | 3.71 | 3.88 | 3.96 | 3.83 | 3.67 | 3.43 | 3.55 |
| Sycamore Canyon Wilderness | 2.78 | 2.62 | 2.22 | 1.68 | 1.55 | 1.27 | 1.67 | 2.17 | 2.00 | 1.90 | 2.25 | 2.69 |
| Teton Wilderness | 3.26 | 3.04 | 2.83 | 2.61 | 2.59 | 2.27 | 1.93 | 1.83 | 2.14 | 2.50 | 3.07 | 3.21 |
| Theodore Roosevelt NP | 3.67 | 3.56 | 3.51 | 2.93 | 2.97 | 3.09 | 2.96 | 2.72 | 2.72 | 2.93 | 3.75 | 3.78 |

**Table 9. Monthly $f_{SS}$(RH) – Sea Salt Relative Humidity Adjustment Factor**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Thousand Lakes Wilderness | 4.27 | 3.70 | 3.38 | 2.99 | 2.82 | 2.52 | 2.37 | 2.42 | 2.53 | 2.82 | 3.62 | 4.08 |
| Three Sisters Wilderness | 5.53 | 4.97 | 4.74 | 4.63 | 4.20 | 3.89 | 3.35 | 3.31 | 3.65 | 4.70 | 5.53 | 5.56 |
| Tuxedni Wilderness | 4.28 | 4.06 | 3.53 | 3.46 | 3.44 | 3.64 | 4.26 | 4.56 | 4.51 | 4.17 | 4.17 | 4.37 |
| UL Bend Wilderness | 3.44 | 3.22 | 3.12 | 2.79 | 2.70 | 2.67 | 2.42 | 2.18 | 2.35 | 2.77 | 3.34 | 3.40 |
| Upper Buffalo Wilderness | 3.85 | 3.47 | 3.23 | 3.27 | 3.72 | 3.78 | 3.69 | 3.70 | 3.84 | 3.64 | 3.67 | 3.86 |
| Ventana Wilderness | 3.91 | 3.76 | 3.70 | 3.08 | 2.93 | 2.69 | 2.69 | 2.75 | 2.80 | 2.87 | 3.06 | 3.48 |
| Virgin Islands NP | 3.17 | 3.12 | 3.04 | 3.15 | 3.19 | 3.17 | 3.18 | 3.31 | 3.30 | 3.36 | 3.39 | 3.28 |
| Voyageurs NP | 3.69 | 3.31 | 3.20 | 2.90 | 2.89 | 3.46 | 3.55 | 3.71 | 3.87 | 3.42 | 3.83 | 3.80 |
| Washakie Wilderness | 3.18 | 2.98 | 2.83 | 2.64 | 2.62 | 2.31 | 1.96 | 1.85 | 2.15 | 2.50 | 3.04 | 3.14 |
| Weminuche Wilderness | 3.08 | 2.85 | 2.39 | 2.11 | 2.09 | 1.77 | 2.05 | 2.46 | 2.36 | 2.12 | 2.69 | 2.95 |
| West Elk Wilderness | 3.00 | 2.87 | 2.49 | 2.36 | 2.33 | 1.94 | 2.10 | 2.44 | 2.43 | 2.20 | 2.72 | 2.89 |
| Wheeler Peak Wilderness | 3.00 | 2.76 | 2.35 | 2.11 | 2.15 | 1.92 | 2.17 | 2.63 | 2.52 | 2.18 | 2.71 | 2.93 |
| White Mountain Wilderness | 2.71 | 2.37 | 1.89 | 1.68 | 1.76 | 1.66 | 2.14 | 2.46 | 2.49 | 2.02 | 2.25 | 2.63 |
| Wichita Mountains Wilderness | 3.35 | 3.12 | 2.91 | 2.94 | 3.40 | 3.21 | 2.84 | 3.01 | 3.32 | 3.10 | 3.20 | 3.40 |
| Wind Cave NP | 3.25 | 3.20 | 3.13 | 3.01 | 3.22 | 3.06 | 2.75 | 2.68 | 2.63 | 2.75 | 3.28 | 3.24 |
| Wolf Island Wilderness | 4.03 | 3.74 | 3.66 | 3.55 | 3.72 | 4.20 | 4.20 | 4.46 | 4.42 | 4.22 | 4.08 | 4.15 |
| Yellowstone NP | 3.29 | 3.05 | 2.87 | 2.66 | 2.65 | 2.39 | 2.05 | 1.93 | 2.21 | 2.59 | 3.14 | 3.25 |
| Yolla Bolly-Middle Eel Wilderness | 4.38 | 3.89 | 3.66 | 3.31 | 3.18 | 2.92 | 2.89 | 2.94 | 3.00 | 3.20 | 3.84 | 4.19 |
| Yosemite NP | 3.58 | 3.38 | 3.23 | 2.71 | 2.54 | 2.08 | 1.84 | 1.79 | 1.93 | 2.18 | 2.78 | 3.25 |
| Zion NP | 3.26 | 3.03 | 2.44 | 1.96 | 1.78 | 1.44 | 1.41 | 1.66 | 1.67 | 1.88 | 2.48 | 2.98 |

**Table 10. Monthly Average Natural Conditions Visual Range In Kilometers**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acadia NP | 173 | 177 | 177 | 174 | 174 | 173 | 170 | 169 | 167 | 171 | 171 | 170 |
| Agua Tibia Wilderness | 226 | 227 | 226 | 228 | 228 | 229 | 229 | 228 | 228 | 228 | 230 | 229 |
| Alpine Lakes Wilderness | 224 | 228 | 236 | 238 | 236 | 243 | 242 | 242 | 237 | 227 | 222 | 222 |
| Anaconda Pintler Wilderness | 256 | 259 | 262 | 267 | 268 | 271 | 273 | 272 | 271 | 269 | 265 | 259 |
| Ansel Adams Wilderness | 258 | 263 | 266 | 269 | 269 | 270 | 274 | 275 | 272 | 267 | 259 | 258 |
| Arches NP | 265 | 268 | 274 | 276 | 277 | 281 | 280 | 278 | 277 | 276 | 271 | 268 |
| Badlands NP | 233 | 233 | 233 | 234 | 232 | 233 | 235 | 236 | 236 | 236 | 232 | 233 |
| Bandelier NM | 269 | 272 | 276 | 280 | 281 | 283 | 278 | 274 | 276 | 277 | 274 | 269 |
| Bering Sea Wilderness |  |  |  |  |  |  |  |  |  |  |  |  |
| Big Bend NP | 236 | 234 | 233 | 234 | 233 | 231 | 225 | 220 | 227 | 233 | 235 | 235 |
| Black Canyon of the Gunnison NP | 278 | 280 | 282 | 283 | 282 | 282 | 281 | 278 | 276 | 280 | 280 | 278 |
| Bob Marshall Wilderness | 257 | 259 | 262 | 263 | 263 | 266 | 265 | 262 | 262 | 264 | 260 | 258 |
| Bosque del Apache Wilderness | 249 | 252 | 256 | 259 | 259 | 260 | 255 | 252 | 253 | 256 | 253 | 249 |
| Boundary Waters Canoe Area Wilderness | 184 | 187 | 189 | 190 | 190 | 191 | 193 | 194 | 191 | 188 | 184 | 184 |
| Breton Wilderness | 173 | 176 | 176 | 179 | 177 | 174 | 172 | 170 | 169 | 174 | 171 | 171 |
| Bridger Wilderness | 278 | 280 | 286 | 290 | 292 | 296 | 295 | 292 | 292 | 291 | 285 | 280 |
| Brigantine Wilderness | 159 | 161 | 161 | 161 | 160 | 158 | 156 | 157 | 158 | 160 | 160 | 159 |
| Bryce Canyon NP | 268 | 269 | 270 | 271 | 271 | 275 | 279 | 279 | 275 | 273 | 268 | 268 |
| Cabinet Mountains Wilderness | 252 | 254 | 253 | 255 | 251 | 251 | 249 | 247 | 247 | 248 | 252 | 251 |
| Caney Creek Wilderness | 174 | 177 | 180 | 183 | 183 | 183 | 186 | 186 | 183 | 179 | 174 | 173 |
| Canyonlands NP | 257 | 261 | 264 | 263 | 259 | 259 | 260 | 260 | 258 | 258 | 259 | 257 |
| Cape Romain Wilderness | 167 | 169 | 174 | 177 | 178 | 181 | 180 | 178 | 177 | 177 | 172 | 169 |
| Capitol Reef NP | 269 | 271 | 277 | 280 | 281 | 285 | 284 | 281 | 281 | 280 | 275 | 271 |
| Caribou Wilderness | 250 | 256 | 259 | 263 | 264 | 267 | 267 | 267 | 266 | 264 | 257 | 252 |
| Carlsbad Caverns NP | 266 | 271 | 276 | 277 | 275 | 276 | 272 | 270 | 267 | 274 | 271 | 267 |
| Chassahowitzka Wilderness | 171 | 173 | 174 | 175 | 175 | 171 | 171 | 169 | 169 | 171 | 171 | 170 |
| Chiricahua NM | 253 | 254 | 258 | 261 | 262 | 263 | 256 | 253 | 256 | 259 | 257 | 252 |
| Chiricahua Wilderness | 253 | 254 | 258 | 262 | 262 | 263 | 256 | 253 | 256 | 259 | 258 | 252 |
| Cohutta Wilderness | 181 | 184 | 185 | 187 | 183 | 180 | 180 | 179 | 179 | 181 | 183 | 181 |
| Crater Lake NP | 255 | 263 | 266 | 269 | 273 | 276 | 280 | 279 | 276 | 267 | 256 | 255 |
| Craters of the Moon NM | 245 | 248 | 252 | 255 | 255 | 257 | 261 | 261 | 259 | 255 | 248 | 246 |
| Cucamonga Wilderness | 263 | 264 | 264 | 267 | 267 | 268 | 268 | 267 | 267 | 267 | 268 | 266 |
| Denali NP & Pres | 257 | 257 | 261 | 263 | 263 | 261 | 257 | 251 | 250 | 252 | 254 | 254 |
| Desolation Wilderness | 270 | 275 | 279 | 285 | 287 | 290 | 292 | 292 | 290 | 287 | 280 | 273 |
| Diamond Peak Wilderness | 253 | 261 | 264 | 267 | 271 | 275 | 279 | 279 | 275 | 264 | 254 | 253 |
| Dolly Sods Wilderness | 197 | 200 | 201 | 203 | 204 | 206 | 206 | 205 | 205 | 204 | 203 | 200 |
| Dome Land Wilderness | 242 | 244 | 244 | 247 | 241 | 241 | 239 | 237 | 236 | 241 | 243 | 241 |
| Eagle Cap Wilderness | 229 | 234 | 241 | 245 | 245 | 249 | 252 | 253 | 249 | 240 | 230 | 227 |
| Eagles Nest Wilderness | 302 | 302 | 304 | 304 | 303 | 308 | 308 | 305 | 304 | 307 | 303 | 303 |
| Emigrant Wilderness | 242 | 245 | 248 | 253 | 254 | 258 | 259 | 259 | 258 | 256 | 250 | 245 |
| Everglades NP | 168 | 170 | 171 | 172 | 172 | 169 | 170 | 167 | 166 | 168 | 169 | 168 |
| Fitzpatrick Wilderness | 280 | 282 | 283 | 284 | 284 | 289 | 292 | 293 | 288 | 286 | 280 | 281 |
| Flat Tops Wilderness | 301 | 302 | 305 | 305 | 304 | 309 | 310 | 307 | 306 | 307 | 303 | 302 |
| Galiuro Wilderness | 254 | 255 | 258 | 262 | 262 | 263 | 259 | 256 | 258 | 259 | 257 | 252 |
| Gates of the Mountains Wilderness | 281 | 285 | 287 | 288 | 289 | 289 | 292 | 293 | 291 | 286 | 283 | 282 |

**Table 10. Monthly Average Natural Conditions Visual Range In Kilometers**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gearhart Mountain Wilderness | 262 | 269 | 274 | 277 | 280 | 283 | 287 | 287 | 285 | 277 | 266 | 263 |
| Gila Wilderness | 275 | 278 | 282 | 285 | 285 | 286 | 278 | 278 | 279 | 282 | 279 | 275 |
| Glacier NP | 224 | 228 | 230 | 231 | 231 | 231 | 235 | 235 | 231 | 228 | 225 | 225 |
| Glacier Peak Wilderness | 233 | 237 | 243 | 245 | 245 | 249 | 250 | 248 | 244 | 236 | 231 | 231 |
| Goat Rocks Wilderness | 243 | 249 | 254 | 256 | 259 | 263 | 265 | 263 | 258 | 248 | 241 | 241 |
| Grand Canyon NP | 267 | 269 | 273 | 278 | 280 | 282 | 281 | 277 | 278 | 277 | 273 | 269 |
| Grand Teton NP | 274 | 278 | 277 | 276 | 275 | 273 | 270 | 268 | 266 | 269 | 272 | 273 |
| Great Gulf Wilderness | 192 | 192 | 195 | 195 | 195 | 197 | 196 | 193 | 193 | 196 | 192 | 192 |
| Great Sand Dunes NP & Pres | 255 | 260 | 260 | 263 | 257 | 254 | 253 | 252 | 251 | 255 | 257 | 255 |
| Great Smoky Mountains NP | 184 | 185 | 187 | 188 | 188 | 190 | 192 | 193 | 190 | 188 | 185 | 184 |
| Guadalupe Mountains NP | 265 | 270 | 276 | 278 | 276 | 276 | 271 | 268 | 266 | 274 | 271 | 266 |
| Haleakala NP | 232 | 234 | 234 | 235 | 237 | 238 | 236 | 236 | 237 | 235 | 232 | 233 |
| Hawaii Volcanoes NP | 243 | 246 | 246 | 246 | 246 | 246 | 244 | 243 | 244 | 243 | 238 | 243 |
| Hells Canyon Wilderness | 224 | 229 | 234 | 237 | 238 | 239 | 242 | 243 | 241 | 235 | 226 | 223 |
| Hercules-Glades Wilderness | 178 | 180 | 182 | 182 | 179 | 179 | 180 | 179 | 178 | 180 | 179 | 178 |
| Hoover Wilderness | 259 | 263 | 265 | 271 | 273 | 276 | 278 | 277 | 276 | 274 | 268 | 262 |
| Isle Royale NP | 182 | 185 | 184 | 186 | 187 | 183 | 179 | 179 | 177 | 184 | 179 | 179 |
| James River Face Wilderness | 181 | 183 | 187 | 187 | 186 | 188 | 192 | 193 | 193 | 191 | 185 | 182 |
| Jarbidge Wilderness | 245 | 246 | 246 | 249 | 244 | 243 | 242 | 240 | 239 | 243 | 246 | 243 |
| John Muir Wilderness | 256 | 260 | 261 | 264 | 258 | 254 | 254 | 253 | 252 | 255 | 258 | 256 |
| Joshua Tree NP | 242 | 246 | 247 | 251 | 252 | 255 | 256 | 256 | 255 | 253 | 249 | 246 |
| Joyce Kilmer-Slickrock Wilderness | 186 | 187 | 187 | 189 | 189 | 190 | 190 | 189 | 188 | 189 | 189 | 188 |
| Kaiser Wilderness | 260 | 264 | 266 | 272 | 273 | 277 | 278 | 278 | 276 | 274 | 269 | 264 |
| Kalmiopsis Wilderness | 194 | 200 | 202 | 205 | 207 | 209 | 211 | 210 | 209 | 204 | 195 | 195 |
| Kings Canyon | 229 | 232 | 233 | 236 | 237 | 240 | 240 | 240 | 239 | 238 | 235 | 232 |
| La Garita Wilderness | 252 | 259 | 263 | 266 | 268 | 271 | 273 | 273 | 271 | 266 | 256 | 253 |
| Lassen Volcanic NP | 263 | 264 | 267 | 269 | 269 | 272 | 270 | 266 | 267 | 269 | 265 | 263 |
| Lava Beds NM | 244 | 250 | 253 | 257 | 258 | 261 | 261 | 261 | 260 | 258 | 251 | 246 |
| Linville Gorge Wilderness | 180 | 182 | 183 | 185 | 180 | 177 | 177 | 175 | 175 | 178 | 181 | 180 |
| Lostwood Wilderness | 229 | 230 | 228 | 234 | 235 | 232 | 232 | 234 | 235 | 233 | 227 | 227 |
| Lye Brook Wilderness | 196 | 198 | 197 | 197 | 196 | 195 | 194 | 192 | 191 | 192 | 195 | 195 |
| Mammoth Cave NP | 187 | 188 | 189 | 189 | 189 | 192 | 191 | 188 | 188 | 191 | 188 | 188 |
| Marble Mountain Wilderness | 251 | 255 | 256 | 254 | 242 | 235 | 237 | 249 | 248 | 252 | 254 | 250 |
| Maroon Bells-Snowmass Wilderness | 274 | 281 | 284 | 287 | 289 | 291 | 292 | 291 | 291 | 286 | 276 | 275 |
| Mazatzal Wilderness | 252 | 253 | 256 | 260 | 261 | 263 | 259 | 256 | 258 | 258 | 256 | 252 |
| Medicine Lake Wilderness | 231 | 232 | 231 | 236 | 237 | 235 | 235 | 237 | 237 | 236 | 230 | 229 |
| Mesa Verde NP | 264 | 267 | 271 | 277 | 276 | 281 | 276 | 272 | 275 | 275 | 270 | 266 |
| Mingo Wilderness | 166 | 169 | 172 | 174 | 173 | 173 | 176 | 176 | 174 | 171 | 166 | 166 |
| Mission Mountains Wilderness | 249 | 252 | 254 | 255 | 251 | 250 | 250 | 249 | 249 | 251 | 251 | 249 |
| Mokelumne Wilderness | 252 | 259 | 263 | 266 | 269 | 272 | 275 | 273 | 268 | 257 | 251 | 250 |
| Moosehorn Wilderness | 159 | 163 | 166 | 167 | 170 | 172 | 174 | 173 | 170 | 162 | 158 | 157 |
| Mount Adams Wilderness | 242 | 248 | 251 | 253 | 258 | 262 | 267 | 267 | 262 | 250 | 241 | 241 |
| Mount Baldy Wilderness | 261 | 266 | 269 | 275 | 276 | 280 | 281 | 281 | 279 | 277 | 271 | 264 |
| Mount Hood Wilderness | 241 | 249 | 253 | 256 | 259 | 262 | 265 | 265 | 262 | 255 | 243 | 241 |
| Mount Jefferson Wilderness | 237 | 240 | 240 | 238 | 239 | 238 | 234 | 232 | 230 | 234 | 235 | 235 |

**Table 10. Monthly Average Natural Conditions Visual Range In Kilometers**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mount Rainier NP | 215 | 220 | 224 | 226 | 228 | 231 | 233 | 232 | 227 | 218 | 213 | 213 |
| Mount Washington Wilderness | 216 | 223 | 224 | 225 | 230 | 234 | 240 | 241 | 237 | 225 | 217 | 216 |
| Mount Zirkel Wilderness | 296 | 296 | 297 | 296 | 295 | 300 | 301 | 300 | 298 | 299 | 296 | 296 |
| Mountain Lakes Wilderness | 284 | 285 | 286 | 287 | 287 | 290 | 294 | 295 | 292 | 288 | 284 | 284 |
| North Absaroka Wilderness | 246 | 251 | 256 | 258 | 260 | 262 | 264 | 261 | 256 | 249 | 244 | 244 |
| North Cascades NP | 243 | 246 | 246 | 247 | 246 | 241 | 243 | 240 | 240 | 242 | 243 | 242 |
| Okefenokee Wilderness | 162 | 166 | 168 | 169 | 174 | 173 | 176 | 172 | 169 | 163 | 160 | 161 |
| Olympic NP | 233 | 235 | 235 | 238 | 231 | 230 | 228 | 226 | 225 | 230 | 234 | 231 |
| Otter Creek Wilderness | 180 | 183 | 188 | 190 | 191 | 194 | 195 | 193 | 189 | 183 | 178 | 178 |
| Pasayten Wilderness | 269 | 271 | 274 | 277 | 276 | 279 | 276 | 272 | 272 | 276 | 272 | 269 |
| Pecos Wilderness | 294 | 297 | 303 | 308 | 310 | 313 | 307 | 302 | 304 | 305 | 300 | 294 |
| Petrified Forest NP | 269 | 271 | 274 | 279 | 280 | 282 | 278 | 275 | 276 | 277 | 274 | 270 |
| Pine Mountain Wilderness | 238 | 238 | 238 | 247 | 248 | 251 | 252 | 251 | 251 | 249 | 248 | 244 |
| Pinnacles NM | 211 | 215 | 216 | 222 | 223 | 226 | 225 | 224 | 224 | 223 | 219 | 214 |
| Point Reyes NS | 128 | 134 | 133 | 132 | 130 | 127 | 122 | 119 | 117 | 121 | 124 | 126 |
| Presidential Range-Dry River Wilderness | 186 | 188 | 189 | 191 | 192 | 192 | 192 | 191 | 190 | 191 | 192 | 190 |
| Rawah Wilderness | 297 | 296 | 297 | 296 | 294 | 298 | 300 | 299 | 297 | 299 | 296 | 297 |
| Red Rock Lakes Wilderness | 261 | 264 | 263 | 266 | 264 | 265 | 261 | 261 | 264 | 266 | 262 | 264 |
| Redwood NP | 176 | 182 | 187 | 191 | 192 | 196 | 204 | 206 | 201 | 192 | 180 | 177 |
| Rocky Mountain NP | 261 | 265 | 265 | 262 | 263 | 262 | 258 | 256 | 254 | 258 | 259 | 259 |
| Roosevelt Campobello Int Pk | 170 | 173 | 173 | 175 | 172 | 169 | 169 | 166 | 166 | 168 | 171 | 170 |
| Saguaro NP | 252 | 250 | 250 | 248 | 247 | 251 | 252 | 251 | 250 | 252 | 250 | 252 |
| Saint Marks Wilderness | 182 | 185 | 189 | 190 | 188 | 189 | 187 | 185 | 184 | 187 | 186 | 184 |
| Salt Creek Wilderness | 245 | 247 | 247 | 250 | 250 | 251 | 251 | 250 | 250 | 250 | 251 | 249 |
| San Gabriel Wilderness | 262 | 262 | 264 | 268 | 268 | 272 | 273 | 271 | 271 | 271 | 271 | 267 |
| San Gorgonio Wilderness | 253 | 255 | 258 | 262 | 262 | 263 | 258 | 254 | 257 | 258 | 256 | 251 |
| San Jacinto Wilderness | 247 | 247 | 248 | 250 | 250 | 252 | 253 | 251 | 250 | 251 | 252 | 250 |
| San Pedro Parks Wilderness | 280 | 284 | 285 | 286 | 285 | 279 | 277 | 276 | 278 | 281 | 281 | 279 |
| San Rafael Wilderness | 243 | 246 | 250 | 253 | 253 | 256 | 252 | 248 | 249 | 252 | 247 | 244 |
| Sawtooth Wilderness | 259 | 263 | 269 | 272 | 272 | 274 | 278 | 278 | 277 | 273 | 263 | 259 |
| Scapegoat Wilderness | 249 | 253 | 255 | 257 | 257 | 257 | 260 | 261 | 258 | 254 | 249 | 249 |
| Selway-Bitterroot Wilderness | 251 | 256 | 261 | 264 | 265 | 266 | 270 | 271 | 268 | 262 | 253 | 251 |
| Seney Wilderness | 179 | 182 | 181 | 182 | 183 | 180 | 178 | 175 | 175 | 178 | 177 | 177 |
| Sequoia NP | 230 | 232 | 232 | 234 | 236 | 239 | 240 | 240 | 239 | 238 | 234 | 233 |
| Shenandoah NP | 191 | 193 | 193 | 195 | 191 | 190 | 189 | 187 | 186 | 190 | 192 | 190 |
| Shining Rock Wilderness | 193 | 196 | 197 | 199 | 194 | 191 | 190 | 188 | 188 | 192 | 195 | 193 |
| Sierra Ancha Wilderness | 252 | 253 | 256 | 260 | 261 | 263 | 259 | 256 | 257 | 258 | 256 | 252 |
| Simeonof Wilderness | 138 | 138 | 143 | 141 | 138 | 133 | 128 | 127 | 135 | 144 | 142 | 138 |
| Sipsey Wilderness | 176 | 178 | 180 | 181 | 178 | 175 | 174 | 174 | 174 | 176 | 178 | 176 |
| South Warner Wilderness | 243 | 249 | 253 | 256 | 258 | 260 | 263 | 263 | 261 | 257 | 249 | 245 |
| Strawberry Mountain Wilderness | 227 | 233 | 239 | 242 | 244 | 248 | 252 | 252 | 248 | 238 | 228 | 226 |
| Superstition Wilderness | 254 | 256 | 259 | 262 | 263 | 264 | 261 | 258 | 259 | 260 | 258 | 254 |
| Swanquarter Wilderness | 172 | 174 | 174 | 176 | 174 | 171 | 170 | 169 | 170 | 171 | 173 | 172 |
| Sycamore Canyon Wilderness | 267 | 268 | 272 | 277 | 278 | 281 | 277 | 273 | 274 | 275 | 272 | 268 |
| Teton Wilderness | 280 | 282 | 283 | 285 | 285 | 288 | 291 | 292 | 289 | 286 | 281 | 281 |

**Table 10. Monthly Average Natural Conditions Visual Range In Kilometers**

| Class I Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Theodore Roosevelt NP | 223 | 228 | 231 | 234 | 235 | 238 | 238 | 238 | 237 | 235 | 229 | 225 |
| Thousand Lakes Wilderness | 258 | 259 | 258 | 263 | 262 | 261 | 262 | 265 | 265 | 263 | 256 | 257 |
| Three Sisters Wilderness | 217 | 223 | 225 | 227 | 231 | 234 | 240 | 240 | 236 | 226 | 217 | 217 |
| Tuxedni Wilderness | 195 | 198 | 205 | 206 | 206 | 204 | 195 | 192 | 192 | 196 | 196 | 194 |
| UL Bend Wilderness | 235 | 236 | 236 | 237 | 238 | 238 | 240 | 242 | 241 | 238 | 234 | 235 |
| Upper Buffalo Wilderness | 177 | 180 | 182 | 182 | 178 | 178 | 179 | 179 | 177 | 179 | 179 | 177 |
| Ventana Wilderness | 213 | 215 | 216 | 223 | 225 | 227 | 227 | 227 | 226 | 225 | 223 | 218 |
| Virgin Islands NP | 188 | 189 | 190 | 188 | 187 | 188 | 187 | 185 | 185 | 184 | 183 | 185 |
| Voyageurs NP | 177 | 179 | 179 | 181 | 180 | 176 | 176 | 175 | 174 | 178 | 175 | 176 |
| Washakie Wilderness | 270 | 272 | 272 | 273 | 273 | 276 | 279 | 280 | 277 | 274 | 270 | 270 |
| Weminuche Wilderness | 272 | 273 | 276 | 277 | 277 | 281 | 280 | 276 | 276 | 279 | 275 | 273 |
| West Elk Wilderness | 298 | 301 | 305 | 308 | 308 | 312 | 309 | 305 | 306 | 308 | 303 | 300 |
| Wheeler Peak Wilderness | 296 | 300 | 306 | 308 | 307 | 309 | 303 | 300 | 299 | 304 | 301 | 297 |
| White Mountain Wilderness | 265 | 267 | 271 | 273 | 272 | 275 | 273 | 268 | 269 | 272 | 267 | 265 |
| Wichita Mountains Wilderness | 232 | 233 | 232 | 233 | 231 | 233 | 235 | 235 | 236 | 235 | 231 | 232 |
| Wind Cave NP | 246 | 248 | 250 | 250 | 247 | 249 | 252 | 250 | 247 | 249 | 248 | 246 |
| Wolf Island Wilderness | 173 | 175 | 176 | 177 | 176 | 172 | 172 | 170 | 170 | 171 | 173 | 172 |
| Yellowstone NP | 280 | 282 | 283 | 284 | 284 | 287 | 290 | 291 | 288 | 285 | 280 | 280 |
| Yolla Bolly-Middle Eel Wilderness | 246 | 251 | 254 | 258 | 259 | 262 | 261 | 260 | 260 | 258 | 251 | 248 |
| Yosemite NP | 243 | 245 | 246 | 252 | 253 | 257 | 259 | 259 | 258 | 256 | 251 | 246 |
| Zion NP | 247 | 249 | 254 | 257 | 259 | 262 | 262 | 260 | 260 | 258 | 254 | 250 |

## 3.4. Ozone

### 3.4.1. Introduction (Revised)

Ozone is an air pollutant that forms on warm, sunny days when precursor emissions—nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs)—react in the presence of sunlight. Because ozone is a regional pollutant, precursor sources both near and far from FLM areas can contribute to ozone formation.

Ozone is phytotoxic, causing damage to vegetation throughout the world (Ashmore et al. 2004). Some plant species are more sensitive to ozone than are humans (EPA 2007b). Ozone pollution has been shown to reduce plant growth, alter species composition, and predispose trees to insect and disease attack. Ozone also causes direct foliar injury to many plant species. Affected leaves are often marked with discoloration and lesions, and they age more rapidly than normal leaves (EPA 2007b).

FLAG is intended to provide information to assist the FLMs in identifying ozone impacts to vegetation on lands they manage. Therefore, the objectives of this chapter are to document information currently known about vegetation response to ozone exposure, and to describe FLM procedures for responding to new source review (NSR) permit applications. If the FLMs have evidence that ozone is adversely impacting an area they manage, they will recommend that additional emissions of ozone precursors are minimized until those adverse impacts are mitigated.

### 3.4.2. Ozone Effects on Vegetation (Revised)

Most ozone effects research has focused on agricultural crops. However, research has identified many native plants in natural ecosystems that are sensitive to ozone (EPA 1996e). Some of these ozone-sensitive plant species have been used as "bioindicators" of ozone to document phytotoxicity of ozone in the field due to ambient ozone. A listing of key literature describing known ozone effects on native vegetation is provided in Appendix G.

The definitions for ozone injury and damage used by FLMs are based on the classical definitions (for example, see Guderian 1977). Injury is all physical or biological responses to pollutants, such as change in metabolism, reduced photosynthesis, leaf necrosis, premature leaf drop, and chlorosis. Damage is reduction in the intended use or value of the biological or physical resource; for example, economic production, ecological structure and function, aesthetic value, and biological or genetic diversity that may be altered through the impact of pollutants.

Ozone enters plants through leaf stomata. It oxidizes plant tissue, causing changes in biochemical and physiological processes. These biochemical and physiological changes occur within the leaf long before visible necrotic symptoms appear (Guderian et al. 1985). Plants must expend energy to detoxify ozone and repair injured tissue that could otherwise be used for growth or for maintenance of plant health. The injured plant cells eventually die if detoxification and repair cannot keep up with ozone uptake. The mesophyll cells under the upper epidermis of leaves are the most sensitive to ozone, and those are the first cells to die. The adjacent epidermal cells then die, forming a small black or brown interveinal necrotic lesion that becomes visible on the upper surface of the leaf. These visible lesions most frequently begin to develop on leaves that have just become fully matured, with older leaves on a stem showing increased amounts of injury. These lesions, termed oxidant stipple[7], are quite specific indicators that the plant has been exposed to ozone. Other plant symptoms that can result from exposure to ozone, with or without the presence of oxidant stipple, include chlorosis, premature senescence, and reduced growth. However, these symptoms are non-specific for ozone since other stressors (e.g., disease, insects) can also cause them to occur. Further, these non-specific symptoms are difficult to quantify in natural ecosystems, although limited data are available from exposure response experiments to estimate growth losses from specific ozone exposures. In general, the only indicator that a FLM has to document that ozone has impacted vegetation is visible symptoms of injury such as oxidant stipple.

In addition to affecting individual plants, ozone can also affect entire ecosystems. Research shows that plants growing in areas with high exposure to ambient ozone may undergo natural selection for ozone tolerance (EPA 2007b). The final result could be the elimination of the most ozone-sensitive genotypes from the area. Regardless of the amount of ozone exposure, the magnitude of plant response may vary depending on the geographic area because of changes in meteorological and climatic conditions, and differences in plant conditions in space and time. Factors of most importance that influence plant response to ozone are the species/genotype, soil moisture, and nitrogen availability. Other factors influencing plant response to ozone include nutrient status, atmospheric humidity, temperature, solar radiation, phenological stage of development, carbon dioxide concentrations, day length, regional climatic differences, other pollutant interactions, and population/ecosystem interactions (EPA 2007b).

Changes in growth, ecosystem form or function, or biological or genetic diversity caused by ozone have been difficult to document in natural ecosystems. However, recent research in Great Smoky Mountains National Park showed that in years with high ozone, tree growth was

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[7] Specific symptoms of ozone injury in some plant species are different. A few species develop white or tan rather than brown or black lesions. This is termed "fleck" or "weather fleck" instead of oxidant stipple. In conifers, ozone causes banding of necrotic and green tissue near the tips of older needles, termed "chlorotic mottle."

significantly reduced and trees had increased rates of water loss (McLaughlin et al. 2007a). Increased water loss resulted in soil moisture depletion and reduced late-season streamflows (McLaughlin et al. 2007b). The experiment was conducted over a range of forest types and included several different tree species. These findings may have implications for climate change. Climate change is predicted to increase temperatures and drought conditions in some areas. Ozone may exacerbate the effects of drought by increasing water loss from trees.

Given the difficulty in determining ozone-induced physiological or growth changes in natural ecosystems, FLMs will utilize as indicators of ozone effects on vegetation (1) symptoms that are clearly ozone induced such as oxidant stipple, and (2) ozone exposures that have been shown to be phytotoxic.

### 3.4.3. Established Metrics to Determine Phytotoxic Ozone Concentrations (Revised)

EPA has set primary and secondary ozone standards to protect human health and welfare. On March 12, 2008, EPA revised the primary and secondary ozone standards to 0.075 ppm (8-hour standard). On January 6, 2010, the EPA proposed further strengthening of the primary (human health) ozone standard and establishing a new secondary ozone standard to protect ecosystems and sensitive plants (EPA 2010b). For questions regarding site specific issues the applicant is encouraged to consult with the FLM. More detailed discussions regarding other ozone metrics may be available on the respective agency web sites provided in section 3.4.7.

### 3.4.4. Identification of Ozone Sensitive AQRVs or Sensitive Receptors (Revised)

FLMs have determined that given the high ecological, aesthetic, and intrinsic value of federal lands, special attention should be given to native species. Ideally, protection efforts would focus on the identification and protection of at risk native species in an area. Unfortunately, AQRV identification is limited by incomplete species inventories and/or lack of exposure/response data for most species of native vegetation. Sensitive species identification will improve as more information becomes available. In the meantime, the Agencies are providing lists of sensitive plant species for each Class I area, i.e., those species that have been observed to exhibit ozone symptoms at ambient ozone exposures. This information is available at the respective agency web sites (see below). However, those ambient levels have not necessarily occurred at the specific Class I area where the plants occur.

Since FLAG 2000, the FLMs have acquired additional information regarding ozone effects to vegetation, including lists of ozone sensitive species. Much of this information is included in the NPS and FWS ARIS data base referenced previously, and will be updated as necessary. The ARIS web site is as follows:

- http://www.nature.nps.gov/air/permits/aris/index.cfm

In addition, the NPS has evaluated the risk to vegetation from ozone exposure at approximately 270 park units. The ozone risk assessment can be found at:

- http://www.nature.nps.gov/air/Permits/ARIS/networks/ozonerisk.cfm

Forest Service pertinent ozone information, including a list of ozone sensitive species, can be found at:

- http://www.fs.fed.us/air

### 3.4.5. Review Process for Sources that Could Affect Ozone Levels or Vegetation in FLM Areas (Revised)

As mentioned above, $NO_x$ and VOC are ozone precursors. States and the EPA have based ozone control strategies in various parts of the country on the determination of which precursor is most likely to influence the formation of ozone. Information suggests that in areas where ozone formation is driven by VOC emissions, i.e., VOC-limited areas, VOC to $NO_x$ ratios are less than 4:1. In VOC-limited areas, minimizing or reducing VOC emissions is the most effective means of limiting or lowering ozone concentrations. Conversely, in $NO_x$-limited areas, where VOC to $NO_x$ ratios are greater than 15:1, controlling $NO_x$ emissions is most effective. It is generally thought that most rural areas of the U.S. are $NO_x$-limited, most or all of the time, with the possible exception of the rural areas of southern California. The FLMs do not have current data to show that all areas are not $NO_x$ limited, nor do they consider VOCs to be unimportant as ozone precursors. However, until there is enough information available for FLAG to determine whether ozone formation in each FLM area is primarily limited by $NO_x$ or VOC emissions, we will assume all FLM areas are $NO_x$-limited and will focus on control of $NO_x$ emissions. Where FLMs have information indicating a specific area is VOC limited, they will shift the ozone protection strategy to focus on VOC rather than $NO_x$ emissions.

The FLMs recognize that oxidant stipple can occur at hourly ozone concentrations that can be considered natural background levels (Singh et al. 1978). Many of the high hourly background concentrations can be attributed to stratospheric intrusions or stratospheric mixing in the upper troposphere (Singh et al. 1978); but stratospheric intrusions rarely occur in the middle and southern latitudes after May (Singh et al. 1980, Wooldridge et al. 1997), and thus do not coincide with the major portion of the growing season.

However, oxidant stipple has been observed on foliage in the spring when these intrusions can occur. In general, oxidant stipple observed on foliage from June through September cannot be attributed to natural background ozone from stratospheric sources. Low levels of ambient ozone may occasionally occur in the troposphere from non-anthropogenic and non-stratospheric sources.

The occurrence of oxidant stipple necrosis on plant foliage may indicate further ozone induced physiological and growth impacts. Point sources emit precursors that could produce ozone at the FLM area, and increased ozone could induce further injury or damage to vegetation. However, we assume that restriction on increases in ozone precursors will prevent additional ambient ozone and subsequent increases in injury or damage to vegetation in FLM managed areas. It is important that ambient ozone monitoring be conducted by the State or Local air pollution control agency or by the FLM to determine the seasonal ozone exposure.

FLM actions or specific requests on a permit application will be based on the existing air pollution situation at the FLM area(s) that may be affected by the source. Some FLMs may, with appropriate documentation, rely on growth loss rather than foliar necrosis to make an adverse impact finding. Each FLM will determine if actions are warranted to limit emissions that might lead to increased ambient ozone, based on the expected impact of ozone in their particular area.

FLM response will depend on whether or not:

- ozone specific vegetation effects have been documented in the area (as evidenced by foliar injury or damage to vegetation);
- ozone exposure levels occurring in the area are high enough that they could affect vegetation (i.e., ozone exposures are at levels shown to be phytotoxic).

For a project that exceeds the initial annual emissions over distance (Q/D) screening criteria, Figure 6 outlines the general FLM review process for responding to NSR permit applications based on ozone exposure and vegetation effects at the receptor site. As noted in Figure 6, ambient ozone concentrations are considered along with data from exposure response studies (EPA 2007b) to determine whether a source will cause or contribute to phytotoxic ozone levels (i.e., levels toxic to plants) at the affected site. The FLM may ask the applicant to calculate the ozone exposure values if these data are not already available. Ozone damage to vegetation is determined from field observations at the impacted site.

Management decisions regarding acceptance of an existing or future ozone exposure will be area-specific and may differ significantly between agencies, or even regionally within agencies. Each FLM will determine if injury and/or damage are necessary to warrant action, based on the expected impact in the area they manage. The decisions are based on the FLM interpretation of regulations, past experience in the NSR arena, availability of ozone effect exposure/response information for species that occur in the area, and other factors. The FLM may also consider current trends in ozone exposures and meteorological conditions during peak ozone exposures (because dry soil conditions may induce plants to close stomates to limit water loss, thus limiting ozone uptake), as well as expected reductions in ozone precursor emissions. The FLM will negotiate with the NSR permit applicant and the permitting authority regarding possible mitigation strategies (e.g., using more efficient emissions control technologies, obtaining emission offsets, etc.).

### 3.4.6. Further Guidance to FLMs (Revised)

As mentioned above, limited information about ozone exposure/response relationships in plants and lack of an ozone source/receptor model make it difficult to protect FLM areas from the effects of ozone from new sources. However, there are other area-specific gaps in information that also limit protection efforts. It is important for local land managers to attempt to collect the missing information. This section provides guidance specifically to FLMs on what types of data should be collected and how the data could be collected.

#### *Identifying and Monitoring Ozone-sensitive AQRVs*

Although many FLM areas have identified ozone-sensitive plant species in their areas, most areas need more details regarding plant species location and abundance. FLAG recommends FLMs gather this information, where needed, and refine their lists of area-specific ozone-sensitive plants. The FLMs have placed ozone sensitive plant species lists for many of their areas in the NRIS-AIR or Air Resources Information System databases.

FLAG recommends that once local FLMs have developed lists of potentially sensitive AQRVs specific for their site, they conduct surveys to detect the presence of ozone-induced foliar injury on the selected species. The USFS Forest Health Monitoring (FHM) Program and the National Park Service Inventory and Monitoring Program have developed foliar injury survey protocols and QA/QC procedures that can be used to collect this information. Another resource is the foliar injury training module developed by the NPS Air Resources Division and The Pennsylvania State University, available at http://www.nature.nps.gov/air/edu/O3Training/index.cfm. This module helps field staff identify and quantify ozone injury symptoms on plant foliage. Field crews should obtain proper training and field experience in identifying foliar injury symptoms before surveys can be conducted.

Ideally, to verify ozone-induced foliar injury symptoms in the field, exposure/response fumigation studies should be conducted on these species, using concentrations that reflect current ambient exposure. Plants should also be tested at higher exposures, simulating increased levels of ambient ozone that might occur in the future. Due to the expense of constructing and operating such systems, it would be most appropriate for agencies to join resources and develop regional fumigation facilities. At a minimum, such facilities should be constructed both in the eastern and western U.S., since ambient conditions at an eastern facility might not be appropriate for western species and vice versa.

### *Ambient Ozone Monitoring*

Many FLM areas do not currently have either on-site or nearby ambient ozone monitoring data. FLAG recommends that local FLMs make every effort to collect this information and that they use quality-assured ambient ozone monitoring protocols developed by the EPA and the state air quality agency. Continuous monitoring is desirable to determine the temporal dynamics of ozone exposure for vegetation. Unfortunately, continuous monitoring is expensive and requires electric power that is often not available in or near remote FLM areas. When installing a continuous monitor is not an option, FLAG recommends use of passive monitors. Passive monitors give total exposure loading values (SUM00) for a specified period of time. The data are useful for indicating year-to-year changes in total ozone exposure at an individual site, and for indicating where continuous monitors should be installed. However, FLMs recognize the limitation of passive samplers in relating ozone exposure to plant response.

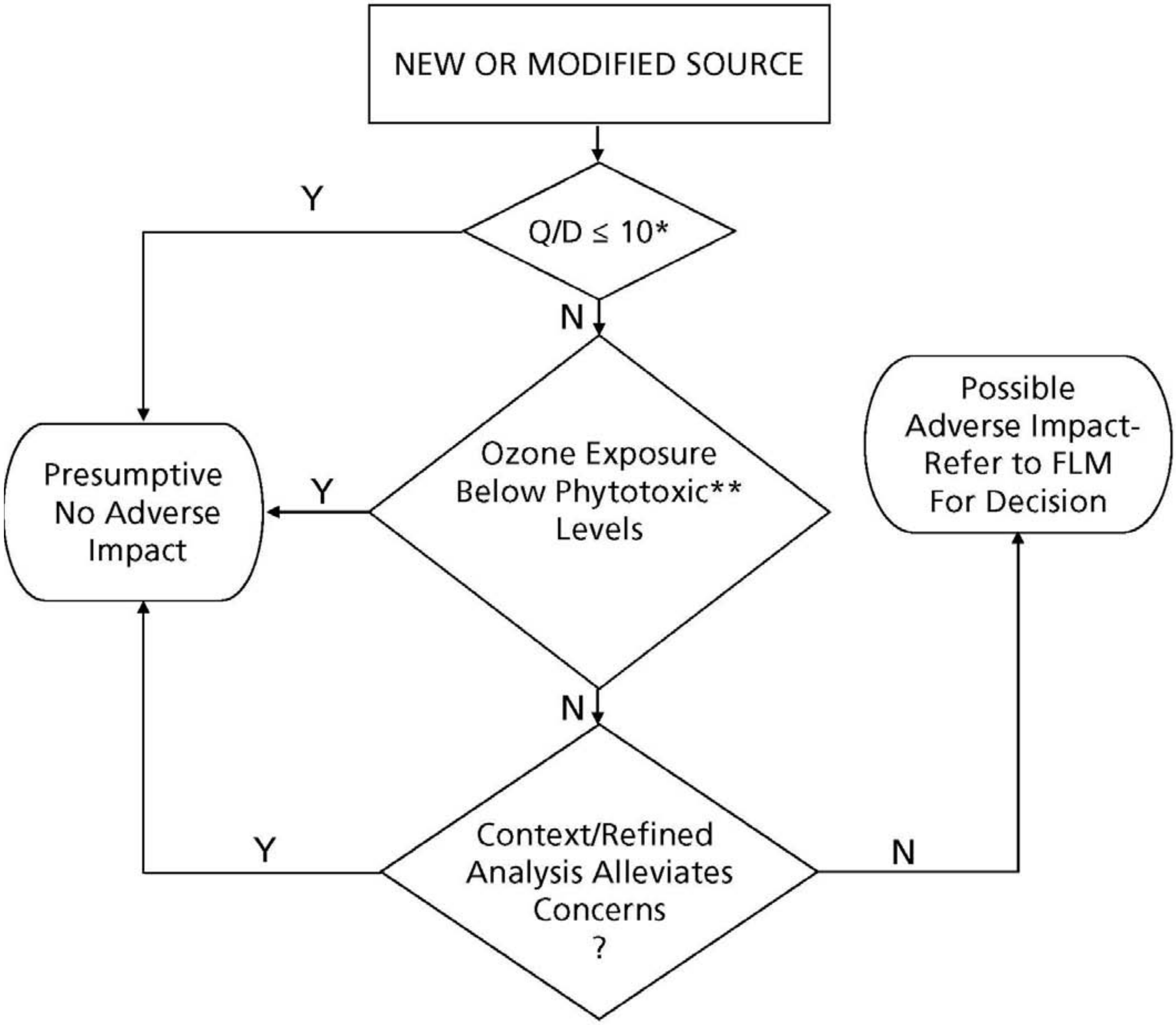

**Figure 6. FLM Assessment of Potential Ozone Effects from New Emissions Source (Revised)**
*Q/D test only applies to sources located greater that 50 km from a Class I area.
**Note: Ambient ozone concentrations are considered along with data from exposure response studies (EPA 2007b) to determine whether a source will cause or contribute to phytotoxic ozone levels (i.e., levels toxic to plants) at the affected site.

### 3.4.7. Ozone Air Pollution Web Sites (Revised)

EPA ozone information:

- http://www.epa.gov/ozone
- http://www.epa.gov/castnet

NPS ozone information:

- http://www.nature.nps.gov/air/permits/aris/index.cfm
- http://www.nature.nps.gov/air/Monitoring/network.cfm
- http://www.nature.nps.gov/air/studies/ecoOzone.cfm

FWS Information:

- http://www.fws.gov/refuges/whm/AirQuality/index.html

U.S. Forest Service information:

- http://www.fs.fed.us/air
- http://www.fs.fed.us/psw/programs/atdep

Ozone effects research, USDA ARS, North Carolina:

- http://www.ars.usda.gov/Main/docs.htm?docid=8453

Ozone exposure metrics for vegetation:

- http://www.asl-associates.com/

## 3.5. Deposition

### 3.5.1. Introduction (Revised)

Atmospheric deposition has been studied extensively throughout the world, beginning in the 1800's in England, Sweden, Norway, and Germany. Research has primarily focused on the deposition of acidic pollutants and long-term acidification. Many publications describe current conditions, monitoring and modeling methods, and the results of acidification experiments. In the United States, research on acidification was first begun in 1962 at Hubbard Brook, New Hampshire. Subsequent work in the Adirondack lakes and other areas furthered the understanding of acid deposition effects. It is now recognized that, in addition to causing acidification, deposition of pollutants can affect many ecosystem characteristics, including nutrient cycling and biological diversity.

Although much progress has been made to control sulfur dioxide and nitrogen oxide emissions, deposition of sulfur (S) and nitrogen (N) compounds continues to be a problem in North America and Europe (EPA 2007a). As a result, certain sensitive freshwater lakes and streams continue to lose acid-neutralizing capacity (ANC) and sensitive soils continue to be acidified. Other ecosystems, including forests, grasslands, estuaries, and N-limited lakes exhibit unwanted fertilization and other effects from excess N deposition.

In this section, the Agencies focus on S and N deposition and associated effects to ecosystems, but other potentially damaging pollutants are routinely deposited. For example, mercury emitted from coal-fired powerplants, incinerators, and other sources deposits into ecosystems and accumulates to sometimes toxic levels in fish and wildlife (EPA 1997). EPA sampled fish from over 75,000 lakes nationwide and found that mercury concentrations in large predatory fish exceeded the human health screening value for mercury in nearly half the lakes (EPA 2009b). The Great Waters Program found that, in addition to mercury, airborne toxics including dioxins, furans, polycyclic organic matter, polychlorinated biphenyls (PCBs), and pesticides are deposited widely across the Great Lakes, the Chesapeake Bay, Lake Champlain, and many coastal estuaries, posing ecological and human health risks (EPA 2000a). Even in relatively remote western and Alaska national parks, deposition has increased concentrations of certain toxic compounds in fish and wildlife above health thresholds (Landers et al. 2008).

Federal Land Managers (FLMs) have documented the effects of S and N deposition on many air quality related values (AQRVs). Documented effects include acidification of lakes, streams, and soils; leaching of nutrients from soils; injury to high-elevation spruce forests; changes in terrestrial and aquatic species composition and abundance; changes in nutrient cycling; unnatural fertilization of terrestrial ecosystems; and eutrophication of estuarine and some lake systems. FLMs recognize that other undocumented effects may also be occurring.

The FLAG deposition subgroup was formed to identify common approaches among these agencies for evaluating atmospheric deposition and its effects on AQRVs. In addition, the subgroup was directed to recommend methods for establishing critical deposition loading values ("critical loads") and, where possible, recommend such critical loads for specific areas. These tasks were assigned to Phase I or Phase II, depending on their degree of difficulty.

During the scoping process, the FLAG Deposition Subgroup determined that Phase I tasks would include the summarization of information currently available about deposition and its effects on FLM areas and the development of recommendations on methods to model and evaluate current and future deposition and its effects on AQRVs. In addition, critical load values, where available from previous FLM guidance documents, would be referenced. FLMs agreed that site-specific AQRV and critical load information would be maintained on FLM web sites, rather than included in the Phase I report. In this way, the information can be updated and the most recent versions made quickly available to the public. Some of this information is already available on FLM web sites, and the FLMs are committed to entering remaining available information as soon as possible.

The subgroup recognizes that the development and refinement of site-specific critical load values for all FLM areas are crucial for AQRV protection. However, because of the complexity of this undertaking, and the lack of information for many areas, it was deferred to future FLAG development.

Future deposition effects work will involve developing methods for establishing critical deposition loading values for FLM areas, and establishing critical loads for areas with adequate information. For areas lacking sufficient information to determine critical loads, strategies will be developed to obtain needed information. Previously established critical loads will be reviewed and refined as necessary. The subgroup will also explore alternative methods for estimating background deposition rates, including extrapolation techniques or modeling that considers the spatial scale of ecosystems and differences in elevation. Methods for addressing problems with dry deposition and cloud and fog deposition measurements will also be considered. In addition, future work may provide research or monitoring recommendations to improve our understanding of deposition and its effects, including effects on cultural resources.

### 3.5.2. Current Trends in Deposition (Revised)

Title IV of the Clean Air Act was passed by Congress as part of the 1990 Clean Air Act Amendments to reduce emissions of sulfur dioxide and nitrogen oxides from fossil fuel-burning power plants in order to reduce deposition of S and N compounds and protect ecosystems suffering damage from acid deposition. Since the implementation of Title IV, wet sulfate deposition, a major component of acid rain, has significantly decreased. Average annual sulfate deposition in the Northeast in 2000–2002 was 40% lower than it was in 1989–1991, deposition in the mid-Atlantic and Midwest was 35% lower, and deposition in the Southeast was 25% lower (NAPAP 2005).

Wet nitrate deposition, on the other hand, has not decreased regionally from historical levels because of the relatively moderate reduction in nitrogen oxides from power plants and the continuing large contribution (over 50% of total nitrogen oxides emissions) from other sources of nitrogen oxides such as vehicles and nonroad vehicles (NAPAP 2005).

Deposition monitoring data can be used to identify decreases in S and N deposition due to decreases in emissions. The National Atmospheric Deposition Program (NADP) provides one of the best and most comprehensive long-term records of wet deposition chemistry in the U.S. Annual reports on deposition nationwide as well as deposition trend plots for all NADP sites are available at http://nadp.sws.uiuc.edu/. An analysis of long-term trends (1985-2004) in precipitation chemistry from NADP sites across the U.S. found that concentrations of sulfate have decreased in nearly all parts of the country. Nitrate, however, has increased in many areas and ammonium, another component of N deposition, has also increased significantly in many areas, particularly in the West (Lehmann et al. 2005). Publications on trends in deposition are available from NADP at:

- http://nadp.sws.uiuc.edu/lib/

In this chapter, it is assumed that S is deposited into the environment primarily as sulfate ion and N is deposited primarily as inorganic nitrate and ammonium ions. Other ionic forms of S and N occur in the atmosphere, but information on their deposition into ecosystems is limited. For example, organic N in deposition is not routinely measured because of the expense and complexity of the measurements. Organic N includes peroxyacetyl nitrate (PAN) (produced in the atmosphere by nitrogen oxides and hydrocarbon reactions), urea, and amino acids. Both natural and anthropogenic processes contribute to organic N formation, including industry, agriculture, biomass burning, and biological activity. Limited monitoring suggests that organic N deposition varies widely, but on average constitutes about 30 percent of total N (Neff et al. 2002)

### 3.5.3. Identification and Assessment of AQRVs (Revised)

AQRVs sensitive to pollutant deposition have been identified in various documents published by the USFS, NPS, and FWS, which are listed in the 'General References' of Appendix G of this report. The FLMs have previously used a combination of approaches to identify AQRVs, including national and regional workshops, regional reviews, and site-specific studies. AQRV identification was based on information from peer-reviewed scientific literature and expert judgment. Because information on AQRVs may change as new data become available, the FLMs agree that AQRV information will be made available on FLM web sites to allow for updating and improve accessibility, as discussed in the Introduction to this chapter.

Information on AQRVs for many USFS Class I areas can be found at

- http://www.fs.fed.us/air

The USFS is currently adding to and updating this information.

Information on AQRVs for NPS Class I areas and some FWS Class I areas is available from NPS Air Web at:

- http://www.nature.nps.gov/air

Information on AQRVs for FWS Class I areas is under development at:

- http://www.fws.gov/refuges/whm/AirQuality/index.html

**Table 11. Indicators for monitoring and evaluating effects from deposition of S and N (Revised)**

| Ecosystem | Indicators for Sulfur Deposition |
|---|---|
| Freshwater | Chemical change (ANC depression), changes in phytoplankton and benthic community composition, species diversity, biomass |
| Terrestrial | Leaching of soil cations, soil acidification, mobilization of aluminum ions; Lichen species and vitality |
| Estuarine | Saltwater not sensitive to S deposition; leaching of nutrients may occur in sandy nearshore soils |
| **Ecosystem** | **Indicators for Nitrogen Deposition** |
| Freshwater | Chemical change (ANC depression), changes in phytoplankton and benthic community composition, species diversity, biomass |
| Terrestrial | Changes in: litter and soil carbon and N dynamics; biomass; soil N processes; litter decomposition rates; soil microbe functional groups; soil organic matter quality and quantity; soil water chemistry; Lichen species and vitality |
| Estuarine | Changes in: phytoplankton species composition and biomass; aquatic invertebrates; seagrass health and distribution; nutrient ratios; dissolved oxygen; trophic status |

FLMs recommend that permit applicants consult with the appropriate FLM to determine the need for an AQRV analysis and, if applicable, the methods for the analysis.

All FLMs use a similar conceptual approach to identify AQRVs that reflects the FLMs' interest in maintaining the integrity of ecosystem structure and function and protecting the most sensitive ecosystem components. AQRVs can be categorized by the type of ecosystem in which they are found, such as terrestrial, freshwater, and estuarine ecosystems. Each ecosystem and its AQRVs responds somewhat differently to deposition and approaches to evaluating deposition effects must therefore be developed accordingly. In terrestrial ecosystems, detection of changes in production, decomposition, and nutrient cycling processes provide information on deposition stress. In aquatic and estuarine ecosystems, detection of changes in water chemistry and aquatic community composition and structure provide similar information. Table 11 summarizes AQRV indicators that may be used to assess effects in various ecosystems.

Terrestrial, freshwater, and estuarine AQRVs are discussed below. In addition, methods to evaluate S- and N-induced deposition stress are discussed.

### *Terrestrial Ecosystems*

Terrestrial ecosystem AQRVs include flora, fauna, and soils. FLMs have identified, where possible, AQRVs, or characteristics of AQRVs, most likely to be sensitive to S and N deposition ("sensitive receptors"). For example, high-elevation spruce forests may be sensitive receptors. FLMs assess the condition of these sensitive receptors by evaluating some aspect of the receptor (the "sensitive receptor indicator" or "indicator"). For example, an indicator for high-elevation red spruce forests is the occurrence and extent of winter foliar injury. In general, the FLM has focused on deposition effects to vegetation and chemical receptors in terrestrial ecosystems, with little emphasis on fauna. In addition, there is increasing awareness among FLMs that certain soil fauna (e.g., microorganisms and invertebrates) are very sensitive to deposition and can be used as sensitive receptors.

In terrestrial ecosystems, sulfate production is regulated primarily by chemical processes (Johnson et al. 1983) and it is rarely a limiting nutrient. Soil response to acidic deposition can be evaluated by monitoring the leaching of essential soil cations, soil acidification, and mobilization of ionic aluminum. These processes have been studied both in field and laboratory experiments, and are defined in detail in the literature (Mollitor and Raynal 1983; Richter et al. 1983; Johnson et al. 1983; Reuss and Johnson 1986). Effects of S deposition can be detected by monitoring calcium and magnesium ions and S in the litter layer and surface soils; calcium, magnesium, potassium, and sulfate ions in soil solution; cation exchange capacity (CEC); and base saturation.

In general, biological AQRVs do not provide reliable indicators of S deposition in terrestrial ecosystems except under extreme S deposition. Lichens have been used in some areas as biomonitors to demonstrate spatial trends in S deposition, particularly in areas with pronounced S deposition gradients. For example, isotopic analysis of lichens from Mt. Zirkel Wilderness, Colorado, indicated that power plants in the nearby Yampa Valley were the source of elevated S in the lichens (Jackson et al. 1996).

Unlike S, the production and mobility of N in ecosystems is regulated almost entirely by biological processes. N is a limiting nutrient in many terrestrial ecosystems. In these ecosystems, growth of plants is limited by N availability; additional N from atmospheric inputs increases plant growth. Most ecosystems can retain and process significant additions of N, with resulting increases in production and changes in species diversity, biomass, and nutrient cycling. However, these changes are usually considered to be inconsistent with desired ecosystem conditions for natural areas. The ability to retain and process N varies significantly depending on watershed successional status, site and fire history, soil conditions, vegetation, and other non-human factors. When N inputs exceed an ecosystem's assimilation capacity, N is lost or leached, usually as nitrate, from the soil and can be detected in adjacent streams or lakes. This may occur following a major disturbance such as fire, logging, land use change, grazing, agriculture, or where atmospheric N deposition or experimental inputs exceed what the ecosystem can assimilate (Fenn and Dunn 1989; Fenn 1991, Fenn et al. 1996; Adams et al. 1997).

Studies in northern Europe (Dise and Wright 1995) found that European forests leached detectable levels of nitrate at inputs of about 10-25 kilograms N per hectare per year (kg N $ha^{-}1yr^{-1}$). Tundra and high-elevation alpine sites may leach N at much lower levels of input. Mountain watersheds in the western U.S. show signs of N leakage at wet deposition levels of 3-5 kg N $ha^{-1}yr^{-1}$ (Eilers et al. 1994; Williams et al. 1996; Williams and Tonnessen, in review). However, even high elevation, poorly vegetated ecosystems with limited soil development can process more than 80% of the atmospheric N input before it reaches the aquatic system (Campbell et al. 1995, Kendall et al. 1995). Although nitrogen leaching has often been used as an indicator of excess N deposition, major changes occur in below- and above-ground biomass, species diversity, and nutrient cycling long before N input levels are sufficient to cause nitrate leaching (NAPAP 1993; Tilman et al. 1997; Vitousek et al. 1997). For example, with ambient deposition rates of 7-10 kg N $ha^{-1}yr^{-1}$, a Minnesota Long-Term Ecological Research (LTER) grassland study observed shifts from native, warm-season grasses to low diversity mixtures dominated by cool-season grasses and a greater than 50% decline in species richness (Wedin and Tilman 1996; Tilman et al. 1997). Significant losses in terrestrial diversity may have already occurred over extensive areas of the U.S., particularly in forest understories, shrublands, grasslands, and in soil microbial communities. (Suding et al. 2005; Weiss 2006).

Because significant ecological changes may occur before nitrate loss can be detected, more sensitive indicators than nitrate leaching are needed to evaluate N deposition effects. Such indicators include changes in carbon and N dynamics of litter and soil and biomass (Aber and Driscoll 1997; Magill et al. 1997). With knowledge of inputs and small-scale N fertilization studies, changes in soil organic matter quality and quantity in response to N deposition can be evaluated. Soil microbial communities control the quantity and quality of N available to ecosystems and may be very sensitive indicators of N deposition. Changes in soil microbe functional groups or biomass may provide good estimates of ecosystem critical loads and incremental effects. Soil N mineralization, small root growth, and carbon:nitrogen ratios of soil and microbial biomass are also sensitive to N deposition. Evidence suggests that current deposition rates may alter the production of dissolved organic carbon and organic N compounds in soils, which are important nutrient and energy sources for both terrestrial and aquatic ecosystems (Grandy et al. 2008; Aber et al. 1995; Sinsabaugh et al. 2005). These could also be used as indicators of N deposition effects. However, because there are many other variables that also affect soil processes, it may be very difficult to discern effects on any soil indicators that are solely attributable to N.

### *Freshwater Ecosystems*

AQRVs in freshwater ecosystems include lakes and streams and their associated flora and fauna. Sensitive receptors include water chemistry and clarity, phytoplankton, zooplankton, fish, amphibians, macroinvertebrates, and benthic organisms. Water chemistry indicators that respond to deposition include pH, ANC, conductance, cations and anions, metals, and dissolved oxygen. Physical indicators, such as water clarity, and biological indicators, including species diversity, abundance, condition factor and productivity of fish, amphibians, macroinvertebrates, and plankton can also be used to detect deposition effects in aquatic ecosystems. Much research has been done on the sensitivity of aquatic species to deposition, many of which are discussed in the 1990 National Acid Precipitation Assessment Program (NAPAP) State of Science report (NAPAP 1991a) and the 1998 NAPAP report (NAPAP 1998).

Sulfur is not a limiting nutrient in freshwater ecosystems. However, there are regions of the U.S. where a relatively high percentage of surface water is sensitive to current acidic inputs. These include portions of the Northeast (particularly Maine and the Adirondack and Catskill Mountains), southeastern streams, and some high elevation western lakes, particularly in the Rocky Mountains (NAPAP 2005). There are a number of FLM areas in acid-sensitive regions, including national parks, national forests, and wilderness areas. In these areas, S deposition can cause decreases in ANC and pH. For these sensitive or low-ANC waters, the best approach to quantify S deposition effects is the procedure currently used, monitoring changes in ANC and pH.

Nitrogen deposition, like S deposition, can cause episodic acidification of surface water in certain sensitive high-elevation ecosystems that have low-ANC headwater lakes and streams. Episodic acidification occurs in these areas when deposition is as low as 3-5 kg N $ha^{-1}yr^{-1}$ (Williams et al. 1996).

### *Estuarine Ecosystems*

AQRV sensitive receptors in estuarine ecosystems include plankton, sea grasses, and water chemistry and clarity. Associated coastal forest and dune soils may also be useful as sensitive receptors. Water and soil nutrient concentrations, phytoplankton species composition and abundance, sea grass health, and dissolved oxygen concentrations can be used to evaluate deposition effects.

In estuaries, S is not a limiting nutrient. In addition, estuarine waters are highly buffered and, therefore, not subject to acidification. However, many coastal forest and dune soils are dominated by sandy soils that are sensitive to leaching of limiting nutrients because of very low cation exchange capacity (Au 1974). Monitoring for change in estuarine areas with high S deposition should therefore focus on soil ion mobility. As soil calcium and magnesium levels are generally adequate because of deposition from marine sources, potassium is likely the only limiting nutrient subject to significant loss by sulfate leaching.

The role of N in estuaries is probably the best-documented example of anthropogenic alteration with a literature record dating back to the 1950s. Production and use of fertilizers, land use changes, and fossil fuel combustion have greatly increased the available N, normally a limiting nutrient, which enters coastal waters (Galloway et al. 2003). This has increased estuarine production and accelerated the process of eutrophication. Eutrophication can result in dramatic algae blooms, anoxia, the production of toxic hydrogen sulfide gas, and species extirpation in estuarine ecosystems. Human induced eutrophication has been documented for many areas along the Atlantic and Gulf coasts, including the Chesapeake Bay, Tampa Bay, Sarasota Bay, Florida Bay, and Long Island Sound.

A number of FLM areas along the Atlantic and Gulf coasts contain significant coastal waters that may be sensitive to eutrophication. Little is known about excess N effects in most of these areas, although eutrophication is well documented in Florida Bay, located in Everglades National Park. Also, recent evidence indicates that coastal waters in Chassahowitzka Wilderness (Florida) experience N-induced algal blooms (Dixon and Estevez in draft). In most coastal waters, 10-45% of the N entering the system is atmospheric, either from direct deposition to surface water or deposition to the watershed. Complete elimination of atmospheric N inputs would not entirely mitigate ecosystem change due to N because of the substantial contributions from agricultural and urban runoff. However, for most estuaries, any reduction in N input would be beneficial in restoring ecosystem structure and function.

The monitoring procedures recommended, and currently used, in estuaries are similar to those used in freshwater, with emphasis on incremental changes in plankton, aquatic plant, benthic, and invertebrate community composition; species diversity, distribution, and biomass; and ecosystem trophic status.

#### *Significance of Long-Term Monitoring to Evaluate Trends and Validate Modeling*

Long-term monitoring is critical to evaluate trends in deposition and deposition effects. Monitoring programs should concentrate not only on areas with high past and/or present sulfate, nitrate, or ammonium deposition, but also in areas that are very sensitive to deposition and in areas where deposition is expected to increase. For selected monitoring sites, the FLM should (1) obtain ion deposition data for the site, as from NADP or CASTNet, (2) identify sensitive AQRVs and appropriate variables to monitor, (3) evaluate the present condition of the sensitive AQRVs, (4) determine the degree to which results from one site can be extrapolated to other FLM areas in the region, and lastly (5) implement a long-term monitoring program, using carefully selected variables.

Long-term monitoring data are also needed to support and validate models used to predict deposition and deposition effects, including the effects of increases or decreases of S and N on ecosystems. Long term studies in both aquatic and terrestrial ecosystems such as Hubbard Brook, Lake Tahoe, and the Experimental Lakes Area have provided useful information for modeling (Bormann and Likens 1967; Holm-Hanson et al. 1976; Likens and Bormann 1977, Leonard et al. 1979; Byron and Eloranta 1984; Schindler et al. 1985; Schindler 1987; Schindler et al. 1990; Jassby et al. 1995). NAPAP and the National Science Foundation LTER program have addressed monitoring to meet modeling needs in both terrestrial and aquatic ecosystems.

Data requirements to support models vary, but the quality of input data will determine the quality of a model's predictions. Modeling is further discussed in the 'Other AQRV Identification and Assessment Tools' (see section 3.5.5).

### 3.5.4. Determining Critical Loads (Revised)

FLAG 2000 introduced the concept of critical loads as it relates to air resource management in Class I areas. Since FLAG 2000 was published, the Agencies have adopted the widely used definition of critical load, "the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson and Grennfelt 1988). Critical loads have been widely accepted in Europe and Canada as a basis for negotiating control strategies for transboundary air pollution (Posch et al. 1997).

In Canada, researchers have estimated the critical loads of S in wet deposition necessary to protect moderately sensitive lakes in eastern provinces. That value, equivalent to 6.7 kg $ha^{-1}yr^{-1}$ of S in wet deposition, was used by Canada to argue for the U.S. to implement the Clean Air Act Amendments of 1990, which call for the initial reduction of sulfur dioxide emissions in the eastern U.S. and later from all electric utilities nationwide. With additional data on lake and stream chemistry available for sensitive systems in Nova Scotia, Ontario, and Quebec, the Canadians are now recommending a more stringent critical load, equivalent to 2.7 kg $ha^{-1}yr^{-1}$ of wet deposition S.

In both European countries and in North America, attention has expanded beyond ecosystem damage caused by S deposition to ecosystem damage caused by N deposition. In some European forests, chronically high N deposition has exceeded the assimilation capacity of local ecosystems, resulting in the release of nitrate into surface waters (Dise and Wright 1995). Watersheds that are leaking nitrate into surface waters during the growing season, are referred to as "N saturated" (Aber et al. 1989). Nitrogen saturation has been linked to forest decline in Europe (Schulze 1989). Based on a set of regional N addition experiments conducted at sites in northern Europe (NITREX), Wright (1995) recommended a N critical load of less than 10 kg $ha^{-1}yr^{-1}$ to protect European forests and fresh waters from N saturation. However, this critical load does not protect ecosystems from the changes caused by N deposition prior to actual N saturation, including shifts in composition and abundance of soil fauna species and alterations in soil chemistry. (Fenn et al. 2003; Driscoll et al. 2003)

In the United States, two states have attempted to set deposition standards or critical loads to protect sensitive ecosystems. In 1982, the State of Minnesota passed the Acid Deposition Control Act to limit wet sulfate deposition to 11 kg $ha^{-1}yr^{-1}$, which is equivalent to 3.7 kg S $ha^{-1}yr^{-1}$. At this sulfate level, precipitation pH was likely to remain above 4.7, which would protect lakes with ANC less than 50 microequivalents per liter ($\mu eq\ l^{-1}$).

In 1989, the California legislature adopted the Atmospheric Acidity Protection Act, which required the Air Resources Board (CARB) to "develop and adopt standards, to the extent supportable by scientific data, at levels which are necessary and appropriate to protect public health and sensitive ecosystems from adverse effects resulting from atmospheric acidity" (CARB 1993). An assessment of existing data identified the high elevation watersheds, surface waters, and mixed conifer forests of the Sierra Nevada and the Los Angeles Basin as sensitive ecosystems. CARB analyses suggested that appropriate standards would include a critical load value for inorganic N to protect forests, and critical loads for both N and S to protect poorly buffered lakes and streams. However, no acidity standards to protect human health or critical loads to protect ecosystems have been set in California to date.

The Clean Air Act Amendments of 1990, Title IV, section 404, called on the Environmental Protection Agency (EPA) to prepare a report on the feasibility and effectiveness of setting deposition standards nationwide to protect sensitive aquatic and terrestrial resources. The completed report includes a number of modeling analyses that project the effect of reductions in both S and N deposition in areas studied during NAPAP. EPA concluded that deposition standards could not be set at this time because of 1) the lack of clearly defined policy regarding appropriate or desired goals for protecting sensitive aquatic or terrestrial resources, and 2) key scientific uncertainties, particularly regarding nitrogen watershed processes. In addition, EPA recognized that a national deposition standard might be inappropriate because of differences among ecosystems. However, in response to public comments on the report, EPA stated that "Given an adequate level of monitoring and assessment data, Class I areas could serve as potential targets for standard setting activities." (EPA 1995)

Since FLAG 2000, other U.S. agencies and organizations have started considering how to work with critical loads. A National Academy of Sciences Report, *Air Quality Management in the United States* (2004), recognized the potential of critical loads for establishing standards to protect ecosystems, prompting the EPA to explore critical loads as an accountability tool to assess ongoing programs. Also, in the 2005 Prevention of Significant Deterioration for Nitrogen Oxides Final Rule, EPA stated it would consider critical loads information from any state as part of their air quality management approach, including whether such an approach satisfies PSD requirements. (EPA 2005.) The U.S. has signed, but not ratified, the European Union's protocol for establishing critical loads, contained in the 1999 *Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (AKA The Gothenburg Protocol)*, available at:

- http://www.unece.org/env/lrtap/multi_h1.htm

In 2006, EPA held the Multiagency Critical Loads Workshop to share information on critical loads and to develop a broad federal strategy for planning, executing, and evaluating critical loads projects, and to consider critical load use in a policy or management framework. As a result of recommendations from the workshop, the Critical Loads Ad-Hoc Committee (CLAD) was formed to foster critical loads science and development. Information on CLAD and the Multiagency Critical Loads Workshop Report are available at:

- http://nadp.sws.uiuc.edu/clad/

In 2008, EPA used critical loads to assess progress under the Acid Rain and related programs. For the analysis, EPA compared critical loads exceedances in Adirondack lakes before and after implementation of acid rain controls (EPA 2009a).

### *Critical Loads in FLM Areas (Revised)*

In the Clean Air Act, as amended in 1977, Congress gave FLMs an "affirmative responsibility" to protect AQRVs in Class I areas from the adverse effects of air pollution.

Congress' intent was, "…In cases of doubt the land manager should err on the side of protecting the air quality-related values for future generations…" (Senate Report No. 95-127, 95th Congress, 1st Session 1977). In an effort to ensure AQRV protection, FLMs have established critical loads for many FLM areas. FLMs agree that a critical load should protect the most sensitive AQRVs within each FLM area and should be based on the best science available. As new scientific information becomes available, critical loads should be reviewed and updated. Critical loads should ensure that no unacceptable change occurs to the resource.

A journal article published in the July 2005 issue of *BioScience*, entitled "Protecting Resources on Federal Lands: Implications of Critical Loads for Atmospheric Deposition of Nitrogen and Sulfur" (Porter, Blett, Potter, Huber 2005) provides an update on the Agencies' perspectives with respect to critical loads. Among other things, the article describes the history of critical loads, the advances in science related to critical loads, and how to apply the concept of critical loads (including some specific case studies). Subsequent articles provide additional information and perspectives on critical loads (Burns et al. 2008; Dennis et al. 2007). These and other articles and reports on critical loads are available from:

- http://www.nature.nps.gov/air/Studies/criticalLoads/index.cfm
- http://www.nrs.fs.fed.us/clean_air_water/clean_water/critical_loads/

FLMs have used a combination of approaches to establish critical loads, including national and regional workshops, regional reviews, and site-specific studies (see Appendix G). In all cases, the FLMs have used peer-reviewed scientific literature and expert judgment to make their decisions. For example, the NPS has compiled regional reviews that have evaluated existing information on air quality, deposition, and effects on AQRVs in national parks. For these reviews, NPS grouped parks by region and ecosystem type, including the Pacific Northwest, the Colorado Plateau, and the Rocky Mountains, and conducted an empirical assessment of the status of aquatic and terrestrial resources. An analysis of deposition effects was done, using current deposition data for S and N and effects information from field observations and research. These reviews provide the basis for critical load development by identifying sensitive resources and impacts to those resources. Park-specific information on sensitive resources, impacts, and critical loads is available at:

- http://www.nature.nps.gov/air/permits/aris/index.cfm

The USFS has conducted a series of national and regional workshops to establish critical loads and concern thresholds. In the late 1980s, the USFS published prototype methods for evaluating the effects of acid deposition on AQRVs (Fox et al. 1989; Fox et al. 1987). Subsequently, the USFS held regional workshops to develop updated and more area-specific screening procedures for new air pollutant emissions sources (Adams et al. 1991; Peterson et al. 1992; Haddow et al. 1998; Peterson et al. 1993; Stanford et al. 1997). These workshops were comprised of national and regional USFS land managers, deposition experts from the academic and air pollution research community, and agency air quality professionals. Dependent on the workshop leadership, each regional workshop followed a slightly different process and a variety of outputs and formats resulted. However, all workshops used a collaborative process to determine S and N deposition rates that would pose a risk to the aquatic and terrestrial ecosystems protected in FLM areas, while addressing the scientific uncertainty inherent in ecosystem response to acidic deposition. Critical load guidelines for many USFS Class I areas are published in the regional workshop reports (see Appendix G) and are available at:

- http://www.fs.fed.us/air

As resources permit, the Agencies will develop methods and a process for establishing critical deposition loading values for all FLM areas and for recommending critical loads for areas where adequate information exists. For areas lacking sufficient information to determine critical loads, the Agencies are developing strategies to obtain needed information.

Current information and links on critical loads work being done by the U.S. Forest Service can be found at the following web site:

- http://www.fs.fed.us/air

The Agencies anticipate using critical loads as they are developed as an assessment tool, and, in concert with the Deposition Analysis Thresholds and Concern Thresholds (see below), a tool for assessing new source impacts. The Agencies also intend to continue to consult with States and the EPA as critical load development work progresses.

### 3.5.5. Other AQRV Identification and Assessment Tools (Revised)

In addition to AQRV monitoring, there are several tools available to the FLM for identifying AQRVs and assessing the response of sensitive AQRVs to pollutant deposition. These include the Air Resources Information System (ARIS), the Natural Resource Information System – Air Module (NRIS-Air), and deposition models such as the Model of Acidification of Groundwater in Catchments (MAGIC) and MAGIC-With Aggregated Nitrogen Dynamics (MAGIC-WAND).

### *Air Resources Information System (ARIS)*

FLAG 2000 also introduced "Air Synthesis" as an information management and decision-support computer system under development by NPS and FWS. The NPS and FWS have since redesigned and renamed Air Synthesis, now called Air Resources Information System (ARIS). ARIS provides information on air quality related values in NPS and FWS Class I areas, as well as in many NPS Class II areas. Information can be accessed for specific areas or for all units within NPS Inventory & Monitoring (I & M) networks.[8] ARIS identifies specific AQRVs, and provides information on air quality and its effects in parks and wildernesses. ARIS maintains information for all 48 NPS Class I air quality areas and several FWS Class I areas. Information is being developed for the remaining FWS Class I areas, and additional Class II areas. Additional information on ARIS can be found at:

- http://www.nature.nps.gov/air/permits/aris/index.cfm

Information for FWS Class I areas is under development at:

- http://www.fws.gov/refuges/whm/AirQuality/index.html

### *Natural Resource Information System – Air Module (NRIS-Air)*

Publicly available USDA Forest Service Class I and II area information and related resource data can be linked to or found at http://www.fs.fed.us/air. If desired information and data cannot be found, contact any air program manager or specialist at national or regional offices for assistance.

Information from NRIS-Air, including USFS Class I area AQRV information, is available at:

- http://www.fs.fed.us/air

### *Deposition Effects Models*

A number of watershed process models have been developed and tested in an attempt to simulate the effects of S and N on soils, forests, and surface waters. These models are used by FLMs to predict effects from increases in deposition and vary from detailed, compartment models of watersheds to lumped parameter models that do not track different ions through each soil compartment. For a review of models developed under NAPAP see NAPAP 1991.

A commonly applied watershed model is MAGIC. MAGIC was first developed for eastern U.S. watersheds and then extensively tested and validated throughout Europe and North America (Cosby et al. 1985, 1995, 1996). The model was used by NAPAP in its 1990 Integrated Assessment to project surface water chemistry resulting from various deposition scenarios (NAPAP 1991b). In another application in the eastern U.S., MAGIC has been linked with a simple, empirical, dose/response fish model developed at University of Virginia that makes it possible to predict changes in fish productivity based on modeled changes in stream water chemistry.

As a result of NAPAP, there was increased awareness of the potential impacts of inorganic N deposition on watersheds and surface waters. In response, the MAGIC model was updated with a module called With Aggregated Nitrogen Dynamics (WAND). MAGIC-WAND is a process-based model that uses site-specific information on hydrology, soils, and hydrochemistry. The model predicts changes through time in lake or stream chemistry. These time-series of changes in pH and ANC can subsequently be used by FLMs to calculate critical S or N loads for watersheds.

MAGIC-WAND has been extensively tested in the Adirondacks and at watersheds in Maine. For example, the Bear Brook Watershed Manipulation Project uses MAGIC-WAND to predict the effects of experimentally added N and S on a test watershed. MAGIC-WAND has also been applied to watersheds in FLM areas in the Cascades, the Sierra Nevada, the Rocky Mountains, and the Wind River Range in an effort to quantify critical S and N loads to aquatic and terrestrial resources. In the southeastern U.S., MAGIC-WAND is being used under the auspices of the Southern Appalachian Mountains Initiative (SAMI) to predict the effects of future deposition scenarios on FLM areas. Future SAMI modeling efforts will link watershed model results with fish dose/response models. The ultimate goal is to calibrate MAGIC-WAND with landscape level data in order to set regional critical loads.

Other models are also in use. For example, the USFS Rocky Mountain Region recommends using either CALPUFF or AERMOD (or other approved models) to estimate S and N deposition. *The Screening Methodology for Calculating ANC Change to High Elevation Lakes* (USDA Forest Service 2000) summarizes procedures for estimating total deposition of S and N. The document also recommends computations for estimating alkalinity changes in lakes caused by increases in S and N deposition. Another model, the Nutrient Cycling Model (NuCM) has been used in the East to predict the effect of changes in deposition on nutrient concentrations in soils and vegetation.

## 3.5.6. Recommendations for Evaluating Potential Effects from Proposed Increases in Deposition to an FLM Area (Revised)

FLAG 2000 described a process to help the Agencies and permit applicants assess the total sulfur and/or total nitrogen deposition impacts of proposed new or modified sources.

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[8] The NPS I & M program consists of over 270 park units organized into 32 networks to conduct long-term natural resource monitoring on park "vital signs," that is, selected physical, chemical, and biological elements and processes of park ecosystems that represent the overall health or condition of the park.

Since that time, the Agencies have refined the concept of using concern thresholds, pollutant exposures, and deposition analysis thresholds in the permit review process. The approaches used by the respective agencies may vary somewhat, but in essence are all similar.

### *Deposition Analysis Thresholds (DATs)*

The NPS and FWS have introduced and developed the concept of Deposition Analysis Thresholds (DATs) to use as screening level values for the additional modeled amount of sulfur and nitrogen deposition within FLM areas from new or modified PSD sources. A DAT is defined as the additional amount of nitrogen or sulfur deposition within an FLM area, below which estimated impacts from a proposed new or modified source are considered negligible. In other words, if the new or modified source has a predicted nitrogen or sulfur deposition impact below the respective DAT, the NPS and FWS will consider that impact to be negligible, and no further analysis would be required for that pollutant. In cases where a source's impact equals or exceeds the DAT, the NPS/FWS will make a project specific assessment of whether the projected increase in deposition would likely result in an "adverse impact" on resources considering existing AQRV conditions, the magnitude of the expected increase, and other factors.

The DATs are based on "naturally occurring deposition" that park and wilderness ecosystems may have experienced prior to anthropogenic influences and are scaled to enable assessment of the impacts of individual sources of air pollution. The DAT established for both nitrogen and sulfur in eastern and western FLM areas and wildernesses is 0.010 and 0.005 kilograms/hectare/year (kg/ha/yr), respectively. More information regarding the sulfur and nitrogen DATs can be found at:

- http://www.nature.nps.gov/air/Pubs/pdf/flag/nsDATGuidance.pdf

While DATs are a tool to assess the impact of a single new source, these levels may not be protective in areas that are already impaired or where there are multiple new sources impacting a single area. The critical load concept, discussed above, may be a more effective tool for assessing cumulative impacts.

### *Concern Thresholds and Pollutant Exposures*

The Forest Service has continued to develop AQRV concern thresholds and pollutant exposure(s) thresholds (for sulfur or nitrogen deposition) that when exceeded may indicate an adverse impact to one or more AQRVs. These thresholds are very similar to the NPS/FWS Deposition Analysis Thresholds (DATs) in that they establish a point below which adverse impacts are not expected. Impacts above the thresholds may or may not cause an adverse impact; depending on current levels of deposition and resource condition. The values for these thresholds vary between FS Class I areas; therefore an applicant will need to check for Class I area-specific thresholds on the following Internet site:

- http://www.fs.fed.us/air/technical/class_1/alpha.php

### *FLM Response to Potential Deposition Impacts*

For a project that exceeds the initial annual emissions over distance (Q/D) screening criteria, the permit applicant should consult with the appropriate regulatory agency and FLM for the affected area(s) to determine if a deposition impact analysis should be done (e.g., expected sulfur and/or nitrogen deposition impacts are above the DAT) or respective concern threshold). For such cases, FLMs request that proponents provide sufficient information for the FLM to evaluate the potential effects of emissions increases on AQRVs. FLMs have provided information to applicants through guidance documents, correspondence, meetings, and phone consultations. This chapter summarizes current information for evaluating new emissions on deposition and sensitive AQRVs and includes recommendations for:

- the types of data, information, and analysis needed before a permit application can be considered complete, including analytical and modeling protocols for a proponent's use in conducting an AQRV impact analysis;
- approaches and sources of appropriate values for estimating wet and dry deposition; and
- permit conditions to mitigate source impacts.

The process begins with the question "Q/D ≤ 10?" as the first level screening criteria (see Figure 7). The next question is whether or not the DAT/concern threshold is exceeded. If not, no adverse impacts are expected. If so, the Agencies will determine if the contextual considerations (see section 4.3) or any refined analyses alleviate any deposition concerns. If not, the Agencies will defer to the FLM to make a case-by-case adverse impact finding. In determining if the proposed action will cause or contribute to an adverse effect to AQRVs, the FLM will consider information on deposition-sensitive AQRVs, deposition loads at which these AQRVs are affected (i.e., critical loads), the current pollutant deposition rates in the area, and the expected impacts from the proposed source. Procedures for estimating the source's impacts are found in 'Estimation of Current and Future Deposition Rates' section of this report. In areas where no information is available, information from a nearby, or ecologically similar area, may be used. An adverse effect may occur if the critical load is exceeded for an area, and the new source impact is above the levels of concern (i.e., DAT/concern threshold). AQRV and critical load information are discussed earlier in this report.

If the available information is insufficient for the FLM to determine if the proposed action will cause or contribute to an adverse effect to AQRVs, the FLM may ask for deposition and deposition effects monitoring and/or research in the FLM area. If the proposed action will likely cause or contribute to an adverse effect to AQRVs, the FLM may recommend permit conditions that ensure mitigation, including stricter emissions controls and effective emissions offsets. If no mitigation is possible, the FLM may recommend denial of the permit.

### *Available Deposition Monitoring Data*

Atmospheric pollutants are deposited to ecosystems primarily through wet deposition and dry deposition. FLMs participate in national monitoring programs to monitor wet and dry deposition, including the National Atmospheric Deposition Program (NADP) and the Clean Air Status and Trends Network (CASTNet). A 1999 report, "The Role of Monitoring Networks in the Management of the Nation's Air Quality," (CENR, 1999) identified these two networks as being critical for characterizing baseline air quality data in the U.S.

### Wet Deposition (Revised)

Wet deposition includes rain, snow, fog, cloud water, and dew. In most FLM areas, rain and snow are the primary contributors to wet deposition. However, in some high elevation areas, fog, cloud water, and dew are significant contributors, as discussed below.

Because rain and snow are the primary constituents of wet deposition at most FLM areas, the FLM generally relies on data from NADP to evaluate wet deposition of pollutants. NADP samplers collect rain and snow and NADP has documented deposition for many years in a nationwide network that currently includes over 220 monitoring

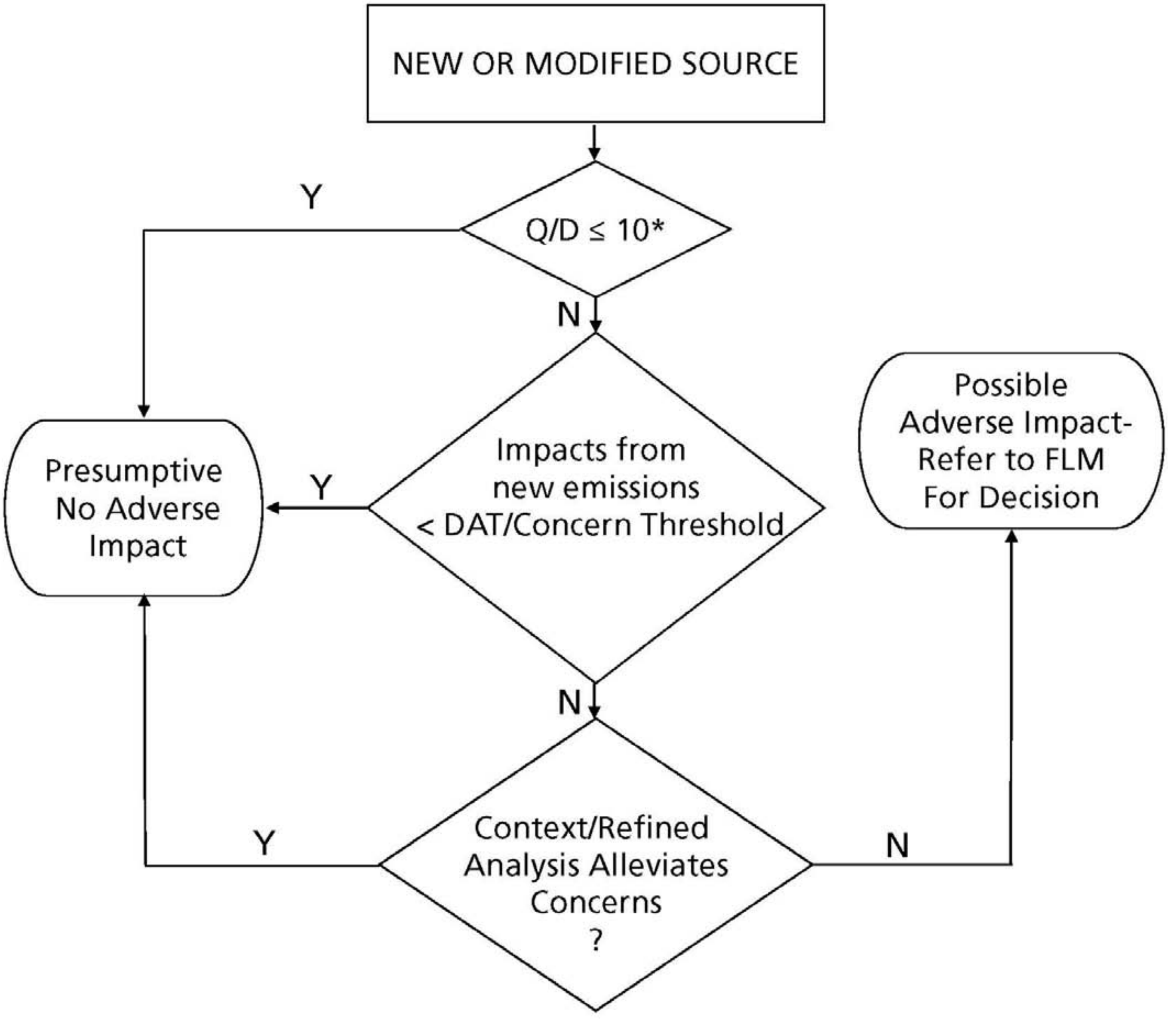

**Figure 7. FLM Assessment of Potential Deposition Effects from New Emissions Sources (Revised)**
*Q/D test only applies to sources located greater that 50 km from a Class I area.

sites. The network collects data to evaluate spatial and temporal long-term trends in precipitation chemistry. The precipitation at each site is collected weekly and sent to a central analytical laboratory for analysis of hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations, including calcium, magnesium, potassium, and sodium. Data and isopleth maps of pollutant concentrations and deposition are available on the NADP web site at:

- http://nadp.sws.uiuc.edu/

FLMs agree that it is preferable to obtain NADP data from the web site, rather than summarizing wet deposition data in this report. In this way, current data can be easily accessed by FLMs and the public.

Approximately 50 FLM areas have NADP samplers in or immediately adjacent to them. Because some of these areas are classified as wilderness, FLMs install sampling equipment in adjacent non-wilderness areas in order to preserve the wilderness character of the area. Ambient air in these adjacent areas is considered representative of air in the wilderness area.

A number of FLM areas do not have an NADP sampler in or adjacent to them. Where possible, the FLM has identified an NADP site whose data may be used to characterize deposition at the area. Deposition rates generally increase with elevation and deposition in high-elevation areas may be difficult to characterize with data from a lower-elevation NADP site. FLM consultation may be necessary to estimate deposition in these areas.

Areas that experience significant deposition from fog and cloud water or large amounts of snow may need to use alternate sampling methods and data in addition to NADP protocols and NADP data to characterize them. Wet deposition in these areas may need to be sampled with alternate methods, including cloud water samplers and snowpack sampling or estimated by modeling. At sites where such data or modeled estimates are available, they should be used to calculate total deposition. At mountain sites frequented by clouds and fog, deposition from clouds may equal or exceed that from precipitation. Cloud water is generally more acidic and contains higher concentrations of base cations than rain water; therefore, it can contribute significantly to total loadings of S and N (Hemmerlein and Perkins 1992). Various methods have been developed to measure deposition from cloud water. The Mountain Acid Deposition Program (MADPro) used automated cloud water collectors to sample at three high-elevation eastern sites (Anderson et al. 1999). Forests covered by fog for significant periods of time may be especially susceptible to injury from acid deposition. Acidic cloud water has predisposed red spruce in the high elevations of the northeast U.S. Appalachians to winter injury and cumulative impacts with other biotic and abiotic stresses have caused mortality. The contribution of clouds and fog to deposition at high elevations may overshadow both deposition from precipitation and dry deposition (Hidy 1998). The EPA estimated that as a result of cloud cover, high elevation forests might experience four times the amount of total pollutant deposition as lower elevation forests without cloud cover (NAPAP 1991). High elevation lakes are also impacted by fog and clouds, as well as rain and snow. Measurements in high elevation areas that do not include all contributions to wet deposition will result in under-estimates.

Modeling has been used to estimate total wet deposition in some areas. For example, the Southern Appalachian Man and the Biosphere Cooperative (as part of the Southern Appalachian Assessment) has used NADP data, topographical data, and meteorological data to model wet deposition loading at locations in the southeastern U.S.

### Dry Deposition (Revised)

Dry deposition includes gases, aerosols and particles. The primary gases involved with N and S deposition are ammonia ($NH_3$), nitric oxide (NO), nitrogen dioxide ($NO_2$), nitric acid ($HNO_3$), and sulfur dioxide ($SO_2$), while the primary particles are nitrate ($NO_3^-$), ammonium ($NH_4^+$), and sulfate ($SO_4^{2-}$) ions (Hanson and Lindberg 1991). Ammonia, NO, $NO_2$ and $SO_2$ are taken up by plants through stomata, while $HNO_3$, due to its high deposition velocity, is deposited to plant surfaces in addition to being taken up by stomata. Nitrate, ammonium, and sulfate particles deposit to surfaces (Bytnerowicz and Fenn 1996).

Dry deposition is much more difficult to estimate than wet deposition. The estimation of dry deposition rates requires information on the ambient concentrations of pollutants, meteorological data, and information on land use, vegetation, and surface conditions, all of which are site-specific. Because of this site-specificity, it is difficult to spatially extrapolate dry deposition data as is often done for wet deposition data.

In general, FLMs rely on data from CASTNet for estimates of dry deposition in FLM areas (http://www.epa.gov/castnet). CASTNet was developed by EPA, as a result of the Clean Air Act Amendments of 1990, and currently includes over 70 sites. These include a combination of former National Dry Deposition Network sites, Park Research and Intensive Monitoring of Ecosystems Network sites (PRIMENet), and others. Dry deposition is measured at 26 NPS areas and 2 USFS areas. FLMs agree that it is preferable to obtain CASTNet data from the web site, rather than summarizing dry deposition data in this report. In this way, current data can be easily accessed by FLMs and the public.

Other methods for measuring dry deposition are available. For example, information on vertical changes in concentrations of major gases and particles of interest over plant canopies can be used for calculation of deposition of these compounds to forests and other ecosystems (Hicks et al. 1987). Models, such as "Big-Leaf" (Baldocchi et al. 1987) allow estimating dry deposition to uniform canopies, such as agricultural crops or lowland forests. However, no models have been developed so far for reliable estimates of deposition of gases and particles to forests and other ecosystems in complex mountain terrain (Bytnerowicz et al. 1997). Therefore, no good large-scale estimates of dry deposition are available for western U.S. forests.

Another approach to evaluating dry deposition is net throughfall technique. By measuring concentrations of ions in throughfall (bulk precipitation) and after subtracting concentrations of the same ions in precipitation in an open area, fluxes of ions such as nitrate, ammonium, and sulfate can be calculated. A branch washing technique is similar to the net throughfall approach and is used when no wet precipitation is present. The pre-washed branches are exposed to ambient air for a certain time period and then carefully rinsed with water (Lindberg and Lovett 1985). Information about amounts of nitrate, ammonium and sulfate rinsed from branches of a known surface area, time of exposure, and leaf area index of a given forest stand allow the calculation of fluxes of the measured ions to trees. Adding stomatal uptake of gases (calculated from information on gas concentration and stomatal conductance), and estimates of deposition to other landscape forms (such as soils and rocks) allow for quite reliable estimates of dry deposition at a forest stand level (Bytnerowicz et al. 2000). Such estimates have been made for the subalpine zone of the eastern Sierra Nevada and mixed conifer forests on the western Sierra Nevada and the San Bernardino Mountains (Bytnerowicz and Fenn 1996; Bytnerowicz et al. 1999). Both the net throughfall and branch washing techniques, although providing relatively accurate estimates of deposition to certain ecosystems, cannot be applied to every type of vegetation. These techniques work well for conifers with relatively thick cuticles. For plants with thinner cuticle, extraction of ions from plant interior or transcuticular uptake of deposited ions may not allow for making good estimates of dry deposition to plant surfaces.

Recent developments, such as passive samplers that allow for relatively inexpensive determinations of nitric oxide, nitrogen dioxide, ammonia, nitric acid and sulfur dioxide concentrations, provide some promising opportunities for large-scale estimates of distribution of these pollutants. This, together with information on landscape-level vegetation coverage, leaf area index, and deposition velocity of the monitored pollutants, will allow calculating deposition of the measured gases to various landscape forms. Although this approach would not include deposition fluxes of particulate pollutants, a large portion of dry N and S deposition (gases) would be covered. Information on fluxes of the N and S particulate component (nitrate, ammonium, and sulfate ion concentrations) can be estimated based on their concentrations from annular denuder/filter pack systems or other comparable techniques and literature values of deposition velocities of these ions.

For many FLM areas, detailed site-specific information and monitoring needed for dry deposition measurements are not available. Therefore, the FLM may choose to recommend a reasonable estimate of dry deposition. NAPAP's 1991 summary report concluded that dry deposition of sulfur is 30-60% of the total (wet plus dry) deposition at regionally representative sites; dry deposition of nitrogen is 30-70% of the total (wet plus dry) deposition at regionally representative sites (NAPAP 1991a). An analysis of one year (1991) of NADP, CASTNet, and IMPROVE (Interagency Monitoring of Protected Visual Environments) data from national parks and wildernesses found that wet deposition dominated total deposition in both the East and the West. Dry deposition of sulfur was 20-50% of the total; dry deposition of nitrogen was 30-60% of the total (Hidy 1998). These estimates, and similar ones, have led to the common assumption that dry deposition is approximately 50% of the total deposition. Therefore, for many FLM areas without on-site or nearby representative dry deposition sampling, the FLM may recommend that dry deposition is equal to wet deposition. The FLM recommends this as a "best available estimate," recognizing that in some areas it may result in under- or over-estimating total deposition. Total deposition, which is the sum of wet plus dry deposition, therefore equals twice the wet deposition.

In summary,

Total Deposition = Wet Deposition + Dry Deposition
Or,
Total Deposition = 2 x Wet Deposition (assuming Dry Deposition = Wet Deposition)

There are numerous monitoring stations in or near FLM areas for estimating wet and dry deposition values. For some areas the FLM assumes that dry deposition equals wet deposition, recognizing that this may result in under- or over-estimates of total deposition. Deposition monitoring data and information on the appropriate dry deposition data to use at sites where data are available are included on the respective Agencies web sites referenced previously.

FLMs will continue to participate in monitoring and research to further our understanding of dry deposition dynamics and improve our measurements of dry deposition.

### Other Deposition Measurement Methods

Pollutant deposition, particularly in areas where traditional wet and dry deposition sampling is impractical, can also be estimated by other methods. These methods include bulk samplers that collect both wet and dry deposition and snowpack measurements that estimate the total amount of pollutants in the snow column at the time of maximum snow accumulation. Special methods have also been developed for collecting fog and cloud water (Anderson et al. 1999).

In addition, methods are being developed to estimate dry deposition rates from pollutant concentrations obtained by IMPROVE fine particle samplers. IMPROVE samplers are located at many FLM areas and expanded coverage is planned for 1999.

### Modeling Deposition Rates

Deposition from existing sources can be estimated from deposition monitoring data, but contributions to deposition from the proposed source and other sources permitted but not yet operating should be modeled.

Modeling should be done in accordance with recommendations developed by the Interagency Work Group on Air Quality Modeling (IWAQM) Phase 2:

- http://www.epa.gov/scram001/7thconf/calpuff/phase2.pdf

IWAQM provides the procedures that can be used to estimate S and N deposition from a proposed source and other sources permitted but not yet operating. The FLMs propose that these procedures be used to estimate S and N deposition. For S deposition, the wet and dry fluxes of sulfur dioxide and sulfate are calculated, normalized by the molecular weight of S, and expressed as total S. For N deposition, IWAQM recommends that the wet and dry fluxes of nitric acid ($HNO_3$) and nitrate ($NO_3^-$) and the dry flux of nitrogen oxides ($NO_x$) be calculated, normalized by the molecular weight of N, and expressed as total N. In addition, the FLMs agree that wet and dry fluxes of ammonium sulfate ($(NH_4)_2SO_4$) and ammonium nitrate ($NH_4NO_3$) should be calculated, normalized by the molecular weight of N, and added to the estimate of total N. Therefore, total N deposition is the sum of N contributed by dry and wet fluxes of $HNO_3$, $NO_3^-$, $(NH_4)_2SO_4$, and $NH_4NO_3$ and the dry flux of $NO_x$.

The FLMs recognize that the ammonia ($NH_3$) in these compounds is derived from both man-made and natural sources. Free gaseous $NH_3$ has a high deposition velocity and tends to deposit quickly. However, if sulfates and nitrates (which are primarily man-made) are present in the atmosphere, free $NH_3$ quickly reacts to form $(NH_4)_2SO_4$ and $NH_4NO_3$. These compounds, because of their fine particle size and slower deposition velocity than free gaseous $NH_3$, can be transported long distances and deposited in a FLM area, adding to the total N deposition loading.

An appropriate estimate of ambient free gaseous $NH_3$ is needed for the modeling analysis. IWAQM refers to Langford et al. (1992), who suggest that typical (within a factor of 2) background values of $NH_3$ are: 10 parts per billion (ppb) for grasslands, 0.5 ppb for forest, and 1 ppb for arid lands at 20°C. Langford et al. (1992) provide strong evidence that background levels of $NH_3$ show strong dependence with ambient temperature (variations of a factor of 3 or 4) and a strong dependence on the soil pH. However, given all the uncertainties in $NH_3$ data, IWAQM recommends use of the background levels provided above, unless better data are available for the specific modeling domain. IWAQM notes that in areas where there are high ambient levels of sulfate, values such as 10 ppb might overestimate the formation of particulate nitrate from a given source, for these polluted conditions. IWAQM further notes that areas in the vicinity of strong point sources of $NH_3$, such as feed lots or other agricultural areas, may experience locally high levels of background $NH_3$.

Questions regarding these recommendations should be resolved through consultation with the appropriate FLM and the appropriate State and/or EPA modeling representative. Applicants should provide a modeling protocol to the appropriate FLM prior to conducting modeling analyses.

### Estimation of Current and Future Deposition Rates (Revised)

In order to evaluate a proposed source's contribution to total (wet + dry) deposition in a FLM area, it is necessary to first estimate current pollutant deposition rates. The current rate is a result of deposition from all existing natural and anthropogenic sources. FLMs use two approaches to estimating the current rate of deposition. One approach estimates the current rate by averaging data from an appropriate monitoring site for the pollutant of interest, using all years with complete data records. The second, more conservative, approach assumes that the current rate is equivalent to the highest rate for the pollutant of interest in the data record.

The method for estimating future total deposition rates is:

- From the respective Agency web sites, identify available on-site or representative wet and dry deposition data for the FLM area. Wet deposition data can be obtained through NADP (http://nadp.sws.uiuc.edu/). For NPS sites without an NADP sampler, use estimates of total wet nitrogen and total wet sulfur from the Air Quality Estimates for 1999-2003 at http://www.nature.nps.gov/air/Maps/AirAtlas/index.cfm.

  Dry deposition data can be obtained through CASTNet at (http://www.epa.gov/castnet).

  Verify if dry deposition is assumed to equal wet deposition for the site. For high-elevation sites, consult with the FLM to determine if deposition from cloud water, fog, dew, or snowpack should be considered. For sites without on-site data, consult FLM for further guidance.

- After consulting with the FLM, estimate either:

  - the average annual or seasonal wet and dry deposition rates for the appropriate pollutant using all years with complete data records; or
  - the highest annual or seasonal wet and dry deposition rates for the appropriate pollutant using all years with complete data records.
- Calculate current total deposition (wet + dry = total).
- Estimate, using the appropriate dispersion model as described in the 'Modeling Deposition Rates' section above, the proposed source's contribution to future total deposition on an annual or seasonal basis.
- Estimate, using appropriate dispersion model as described in the 'Modeling Deposition Rates' section above, the contribution of any sources permitted but not yet operating to future total deposition and the affect of any enforceable emission reductions. This estimate may be available from the State permitting authority.
- The current pollutant deposition rate plus the proposed source's contribution to deposition plus the contribution from other sources permitted but not yet operating minus credit for enforceable emission reductions equals the future total deposition rate.

Current + Proposed + Permitted (not yet operating) – credit for enforceable reductions = Future Total Deposition

This future total deposition rate for a given pollutant can then be used to determine the potential for adverse effects to AQRVs. If appropriate, the change in deposition rate can be used to estimate changes in pH or ANC in an ecosystem. If the future total deposition rate is expected to cause an adverse effect to AQRVs and/or exceeds the critical load established for a FLM area, the FLM may recommend mitigation. If no critical load has been established for the FLM area, the FLM will use the best information available in determining whether to recommend mitigation.

### 3.5.7. Summary (Revised)

- Deposition of S and N has the potential to affect terrestrial, freshwater, and estuarine ecosystems on FLM lands.
- The FLM has identified, where possible, AQRVs sensitive to deposition of S and N on FLM lands and the critical loads associated with those AQRVs.
- A proponent of a source of new emissions with the potential to contribute to S or N deposition in an FLM area should consult with the FLM to determine what analyses are needed to assess AQRV effects. The FLM may request a deposition impact analysis, described in detail in this chapter and summarized below.
  - Estimate the current deposition rate to the FLM area. A list of monitoring sites providing data to characterize deposition in FLM areas is included on the respective Agencies web sites.
  - Estimate the future deposition rate by adding the existing rate, the new emissions' contribution to deposition, the contribution of sources permitted but not yet operating, and then subtracting the credit for enforceable emission reductions. Modeling of new, reduced, and permitted but not yet operating emissions' contribution to deposition should be conducted following current EPA modeling guidance.
  - Compare the future deposition rate with the recommended screening criteria (e.g., critical load, concern threshold, or screening level value) for the affected FLM area. A list of documents summarizing these screening criteria, where available, can be found in Appendix G.

  Information for USFS Class I areas is also available at:

  http://www.fs.fed.us/air

  Information for NPS and FWS Class I areas is available at:

  http://www.nature.nps.gov/air/Permits/ARIS/

  Information for FWS Class I areas is under development at:

  http://www.fws.gov/refuges/whm/AirQuality/index.html

  The appropriate FLM should be contacted for additional information.

### 3.5.8. Web sites for Deposition and Related Information (Revised)

Clean Air Status and Trends Network (CASTNet) dry deposition data:

- http://www.epa.gov/castnet

National Acid Precipitation Assessment Program 2005 Report:

- http://www.esrl.noaa.gov/csd/AQRS/reports/napapreport05.pdf

National Atmospheric Deposition Program (NADP) wet deposition data:

- http://nadp.sws.uiuc.edu/

National Park Service Airweb:

- http://www.nature.nps.gov/air/

Natural Resources Conservation Service, Snow Water Equivalent Information (SNOTEL):

- http://www.wcc.nrcs.usda.gov/snow

Southern Appalachian Mountain Initiative:

- http://www.tva.gov/sami

USDA Forest Service National Air Resource Management Web Site:

- http://www.fs.fed.us/air/

EPA Office of Air and Radiation:

- http://www.epa.gov/oar

EPA, Deposition to Estuaries:

- http://epa.gov/owow/airdeposition/

EPA, STOrage and RETrieval System for Water and Biological Monitoring Data (STORET):

- http://www.epa.gov/storet

U.S. Fish and Wildlife Service Air Quality Branch:

- http://www.fws.gov/refuges/whm/AirQuality/index.html

U.S. Geological Survey, National Water-Quality Assessment (NAWQA) Program:

- http://water.usgs.gov/nawqa

U.S. Geological Survey, Acid Rain Program:

- http://bqs.usgs.gov/acidrain

U.S. Geological Survey, Water Data Storage and Retrieval System (WATSTORE):

- http://water.usgs.gov/owq/data.html

# 4. Expansion of Discussion of Process for Adverse Impact Determination (New Chapter)

Based on feedback from permit applicants and State permitting authorities, the Agencies are providing a more detailed description of the adverse impact decision making process once a source analysis has raised concerns during a first-level and any subsequent analyses.

If the first-level analysis yields impacts above the defined threshold(s), the applicant may propose to address preliminary FLM concerns directly through proposed emission reductions for the project, or through implementation of other measures to mitigate emission impacts. Alternatively, the applicant may undertake a more refined analysis to potentially alleviate preliminary concerns. Of course, this refined analysis should occur in a time-frame that enables permitting authorities to adhere to their regulatory guidelines.

Additional emission reductions, mitigation proposals, or more refined analysis are not legal requirements. They are options that can be utilized to help alleviate preliminary FLM concerns about emission impacts on Class I areas. Permit applicants can request that FLMs conduct their evaluation based on information provided in the application.

## 4.1. Background

The FLAG visibility thresholds have been interpreted by some as a one-dimensional or bright line test that inevitably leads to an adverse impact determination. This, however, is not the intent; these screening-levels were envisioned as a “visibility analysis threshold” similar to the newer deposition analysis thresholds (DATs) discussed above for sulfur and nitrogen deposition.

The Agencies want to emphasize that the FLAG report provides criteria as to when the FLMs will definitively not object to, or declare an adverse impact for, a proposed new source. FLAG assures an applicant that, if they conduct their analyses correctly and demonstrate that change in extinction or deposition falls below the specified thresholds, the FLMs will not raise concerns regarding the project. However, the converse does not necessarily apply — a FLAG threshold exceedance does not mean the FLM will certainly find that a project will adversely affect air quality related values. If a threshold is exceeded, the FLMs will consider the factors discussed below and make a project-specific determination as to whether or not the impacts are adverse.

**Seney National Wildlife Refuge, Michigan.**
Credit: Atlee Hart

## 4.2. Regulatory Factors

According to the EPA definition of “adverse impact on visibility,” the FLM must determine whether the proposed source’s predicted impact “interferes with the management, protection, preservation, or enjoyment of the visitor’s visual experience” taking into account the “geographic extent, intensity, duration, frequency and time of visibility impairments, and how these factors correlate with (1) times of visitor use of the Federal Class I area, and (2) the frequency and timing of natural conditions that reduce visibility.” (40 C.F.R. §51.301).

Considering the regulatory factors is inherent in the first-level modeling exercise. The model describes the geographic area predicted to be impacted. The visibility extinction values describe the intensity of the impact. Similarly, the model provides some level of assessment regarding duration, frequency, and time of impact. A more refined modeling analysis should further inform consideration of these factors. Regarding how these factors correlate with visitor use, the responsibilities of the Agencies include protecting the resources for all visitors. Visitor data show that nearly all Class I areas have some level of visitation each month. Regarding correlation with the frequency and timing of natural conditions that reduce visibility, the first-level modeling analysis will not provide this information directly, but, by using the percentile approach and monthly relative humidity values, the Agencies have attempted to provide a reasonable approach to addressing weather impacts.

Similarly, if the sulfur or nitrogen DAT is exceeded, or if high ozone levels are anticipated, the FLMs should determine if those impacts would adversely affect sensitive AQRVs. This adverse impact determination should be made on a project-specific basis and will be largely driven by management objectives for the area.

## 4.3. Contextual Considerations

The Agencies recognize that the context within which new source permitting occurs is shifting. Many older major stationary sources will be installing pollution controls over the next 10 to 15 years (e.g., in response to the Regional Haze Rule). New motor vehicle emission and fuel standards will reduce tailpipe pollution from mobile sources gradually, but significantly, over a similar time frame. States are developing visibility protection plans that ensure “reasonable progress” toward natural conditions, pursuant to the EPA’s Regional Haze Rule. These plans will be reviewed and revised every five to ten years, and thus provide a mechanism for revisiting sources as better technology becomes available or as otherwise needed to maintain progress toward visibility goals. The location and effect of pending pollution control programs on specific Class I areas remains somewhat uncertain; however, the Agencies recognize and appreciate that significant emission reductions are anticipated, especially in the eastern U.S.

As part of the discussions with permitting authorities or permit applicants when screening level thresholds are exceeded, the Agencies will consider contextual information, including, for example:

- Current pollutant concentrations and AQRV impacts in the Class I area
- Air quality trends in the Class I area
- Emission changes that have occurred or would occur (i.e., enforceable) by the time the new source begins operation
- Whether there are approved SIPs that account for new source growth and demonstrate attainment of national ambient air quality standards and “reasonable progress” toward visibility goals
- The expected useful life of the source
- The stringency of the emission limits (e.g., Best Available Control Technology)
- Other considerations such as options put forth by the applicant that would produce ancillary environmental benefits to AQRVs (e.g., reductions in toxic air contaminants, pollution prevention investments)
- Comments received from the public or other agencies during the comment period prior to issuing the permit.

## 4.4. Preliminary Adverse Impact Concerns

After considering the regulatory factors and contextual considerations listed above, the Agencies, in consultation with the FLM, will evaluate, on a project-specific basis, whether the evidence supports a finding that the new source would possibly cause or contribute to an adverse impact on air quality related values. If so, the Agencies will notify the permit applicant and the permitting agency and provide the permit applicant the opportunity to consider mitigation strategies that will alleviate the potential adverse impact concerns. These strategies may include:

- Obtaining emission offsets for pollutants that cause or contribute to the potential adverse impacts on Class I area resources;
- Reducing emission rates through more stringent pollution control technology or operational or design changes; and
- Monitoring or special studies that increase understanding of how Class I area resources or visitors are affected by air pollution, which may serve as a basis for revisiting permit conditions in future years. (Note: monitoring and study alone does not constitute mitigation.)

Again, proposing any such mitigation strategy is voluntary. Nevertheless, if the FLMs deem a proposed mitigation strategy as adequate to protect AQRVs, and the mitigation strategy is made enforceable via the PSD permit or some other mechanism, the FLM will not make an adverse impact finding with respect to the issues addressed by the mitigation strategy.

## 4.5. Adverse Impact Determination

If an applicant is unable or unwilling to implement an appropriate mitigation strategy to alleviate potential adverse impact concerns, the FLM will determine whether or not the potential impacts of the project as proposed should be formally deemed adverse to air quality related values in the affected Class I areas. If the FLM concludes that there are potential adverse impacts, he will inform the permitting authority of this decision.

Historically, the FLMs have made adverse impact findings for less that one percent of the permit applications that the Agencies review. In those rare cases, the FLMs will strive to provide the permitting authority with an ample technical and policy/management-related foundation, including a discussion of the analysis results and the regulatory and contextual factors discussed above. The FLMs’ ability to provide this foundation will depend on the completeness and adequacy of information provided by the permit applicant. Where information is lacking, or uncertain, the FLMs will err on the side of protecting air quality related values.

**Denali National Park and Preserve, Alaska.**
Credit: National Park Service/Trey Simmons.

# 5. Future FLAG Work

## 5.1. Implementing FLAG Recommendations (Revised)

FLAG participants believe that the recommendations in this revised document should be implemented as soon as possible. Therefore, an attempt has been made to present thorough and clear information on the processes that will be used to protect and improve AQRVs in FLM areas.

Many of the issues and recommendations discussed herein are complex and require specialized knowledge. Consequently, State agencies and others who intend to use this information in NSR/PSD permitting, land planning and use, and other activities, may want or require further guidance and implementation assistance. The Agencies anticipate that much of this guidance and assistance will be provided locally through established formal and informal links between FLMs, States, EPA and others. For example, the Agencies intend to provide further information through their respective web sites, and through participating in related training sessions and/or workshops.

## 5.2. Phase I Updates (Revised)

This revised *FLAG Phase I Report* is intended to clearly state FLM positions regarding NSR/PSD as it currently exists. As the FLMs learn more about how to better assess the health and status of AQRVs, and as EPA produces new modeling tools, the FLAG report may be revised again. Any such revisions to the report will be announced on the Agencies' web sites.

## 5.3. Phase II Tasks (Revised)

FLAG Phase I focused on issues that could be resolved relatively quickly, without extensive research or the collection of new data. The FLMs envisioned a Phase II that would address the more complex issues and concerns, including those that may require additional data collection. Unfortunately, lack of available resources has prevented the Agencies from embarking on a formal FLAG Phase II process. Nevertheless, the Agencies continue to gather effects-based information as part of their ongoing resource protection responsibilities. The new information gathered since FLAG 2000 is reflected in this revision. As the Agencies generate additional data or information, they will make that available to interested parties via their respective web sites.

# Appendix A: Glossary

The list below contains definitions for some of the terms used in the *FLAG Phase I Report*. These terms are defined in the sense that they relate to the work of the Federal Land Managers (FLMs) in protecting air resources.

For terms whose definition is lengthy or complex, the associated *Code of Federal Regulations* (CFR) section or other reference is cited.

**Air Quality Related Value (AQRV).** A resource, as identified by the FLM for one or more Federal areas, that may be adversely affected by a change in air quality. The resource may include visibility or a specific scenic, cultural, physical, biological, ecological, or recreational resource identified by the FLM for a particular area.

**Adverse Impact on an AQRV.** An unacceptable effect, as identified by an FLM, that results from current, or would result from predicted, deterioration of air quality in a Federal Class I or Class II area. A determination of unacceptable effect shall be made on a case-by-case basis for each area taking into account existing air quality conditions. It should be based on a demonstration that the current or predicted deterioration of air quality will cause or contribute to a diminishment of the area's national significance, impairment of the structure and functioning of the area's ecosystem, or impairment of the quality of the visitor experience in the area.

**Adverse Impact on Visibility.** Visibility impairment which interferes with the management, protection, preservation, or enjoyment of a visitor's visual experience of a Federal Class I or Class II area. This determination must be made on a case-by-case basis taking into account the geographic extent, intensity, duration, frequency and time of visibility impairments, and how these factors correlate with (1) times of visitor use of the Class I area, and (2) the frequency and timing of natural conditions that reduce visibility. This term does not include effects on integral vistas. [40 CFR §51.301(a)]

**Absorption.** The process by which incident light is removed from the atmosphere and retained by a particle.

**Absorption Coefficient.** A number that is proportional to the "amount" of light removed from a sight path by absorption per unit distance.

**Acidification.** The decrease of acid neutralizing capacity in water or base saturation in soil caused by natural or anthropogenic processes.

**Aerosol.** A mixture of microscopic solid or liquid particles in a gaseous medium. Smoke, haze, and fog are aerosol examples.

**Airshed.** A geographic area that, because of topography, meteorology, and/or climate, is frequently affected by the same air mass.

**AOT40.** Sum of all hourly average concentrations after subtracting 40 ppb from each hourly value.

**BACT (Best Available Control Technology).** The control level (or control measures) required for sources subject to PSD. (See 40 CFR §52.21(b)(12), or 40 CFR §51.166(b)(12)).

**Class I Area.** As defined in the Clean Air Act, the following areas that were in existence as of August 7, 1977: national parks over 6,000 acres, national wilderness areas and national memorial parks over 5,000 acres, and international parks.

**Critical Load.** The quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.

**Cumulative.** The impact on an AQRV resulting from the total pollutant loading from all sources including the contributing effects of known and reasonably foreseeable new and modified sources of air pollution. A single source may cause individually minor, but cumulatively significant, effects on AQRVs.

**Damage.** Any reduction in the intended use or value of a biological or physical resource. For example, economic production, ecological structure or function, aesthetic value, or biological or genetic diversity that may be altered by a pollutant.

**Deposition Analysis Threshold.** A screening threshold developed by NPS and FWS that defines the additional amount of nitrogen or sulfur deposition within an FLM area, below which estimated impacts from a proposed new or modified source are considered negligible.

**Emission Offset.** A Federally enforceable reduction in emissions from an existing source that mitigates the impacts of a proposed new or modified source on AQRVs, PSD increments, and/or NAAQS. Also, Federally enforceable reductions in actual emissions from existing sources in a nonattainment area such that the total allowable emissions from a new or modified source and existing sources will be sufficiently less than the total emissions from existing sources before the application for a permit to construct so as to represent reasonable further progress towards attainment of the NAAQS. (See 42 U.S.C. § 7503(a)(1)(A))

**Extinction.** The attenuation of light due to scattering and absorption as it passes through a medium.

**Fugitive Emissions**. Emissions which do not pass through a stack, chimney, vent, or other functionally equivalent opening.

**Federal Land Manager (FLM)**. The Secretary of the Department with authority over such lands. [40 CFR §51.166(b)(24)] The FLM for the Department of the Interior has been delegated to the Assistant Secretary for Fish and Wildlife and Parks; the FLM for the Department of Agriculture has been delegated to the Forest Service, and has been redelegated to the Regional Forester or individual Forest Supervisor.

**Flux.** Gaseous uptake into plant tissue.

**Green Line.** The total pollutant loading (contributions from existing and proposed sources) below which there is a very high degree of certainty that no AQRV will be adversely affected.

**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 attenuating light and reducing visual range.

**Hydrocarbons.** Compounds containing only hydrogen and carbon. Examples: methane, benzene, and decane.

**Hygroscopic.** Readily absorbing moisture, as from the atmosphere.

**Injury.** Any physical or biological response to pollutants, such as a change in metabolism, reduced photosynthesis, leaf necrosis, premature leaf drop, or chlorosis.

**LAER (Lowest Achievable Emissions Rate.** The control level required of a source subject to nonattainment review. (See 40 CFR §51.165(a)(1)(xiii))

**Limit of Acceptable Change**. The amount of change that could occur without significantly altering an AQRV or sensitive receptor.

**Micrometer.** A unit of length equal to one millionth of a meter; the unit of measure for particle size.

**Mie Theory.** A complex mathematical model that allows the computation of the amount of energy (light) scattered by spherical particles.

**N100.** Number of hourly average concentrations ≥100 ppb.

**Natural Conditions.** Conditions substantially unaltered by humans or human activities. As applied in the context of visibility, natural conditions include naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration.

**Natural Visibility Conditions.** Visibility conditions attributable to Rayleigh scattering and aerosol associated with natural processes.

**Nephelometer.** An instrument that measures the amount of light scattered.

**Nitrates.** Those gases and aerosols that have origins in the gas-to-aerosol conversion of nitrogen oxides, e.g., $NO_2$ ; of primary interest are nitric acid and ammonium nitrate. Ammonium nitrate is very hygroscopic so its contribution to visibility impairment is magnified in the presence of water vapor.

**Nitrogen Dioxide ($NO_2$).** A gas consisting of one nitrogen and two oxygen atoms It absorbs blue light and therefore has a reddish-brown color associated with it.

**Nonattainment Area.** An area designated by the EPA Administrator pursuant to Section 107(d) of the Clean Air Act as having air quality which does not meet one or more National Ambient Air Quality Standard (NAAQS). For a list of nonattainment areas, see 40 CFR Part 81, Subpart C.

**Oxidant Stipple**. Small brown or black interveinal necrotic lesions on the adaxial surface of leaf tissue that can be attributed to exposure to ozone.

**Phytotoxic.** Poisonous to plants.

**Post-Construction Monitoring.** Monitoring required as a permit condition that the permitting authority considers necessary to determine the effect emissions from a stationary source may have, or are having, on the air quality or on the AQRVs of an area. Such monitoring includes both “ambient” monitoring and “AQRV” monitoring and may involve short-term and long-term measurements made at locations representative of the greatest expected impacts.

**PSD Increments.** The maximum increases in ambient pollution concentrations allowed over baselines concentrations. See 40 CFR §51.166 (c) for increments for specific pollutants.

**RACT (Reasonable Available Control Technology).** The lowest emissions limit that a particular source can meet by the application of control technology that is reasonably available considering technological and economic feasibility.

**Rayleigh Scattering.** The scattering of light by particles much smaller than the wavelength of the light, e.g., molecular scattering in the natural atmosphere.

**Reconstructed Extinction.** Extinction estimate that results from summing up the product of the mass of each measured particle species and the appropriate absorption or extinction coefficient.

**Red Line.** The total pollutant loading (contributions from existing and proposed sources) at which there is a very high degree of certainty that at least one AQRV will be adversely affected.

**Regional Haze Visibility Impairment.** Any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions, caused predominantly by a combination of many sources from, and occurring over, a wide geographic area.

**Re-opener.** A permit condition that requires the permitting authority, at a specified time after permit issuance, to review and revise, if necessary, the permit based on new information such as the findings from post-construction monitoring, updated emissions inventories, updated modeling, research, or information on air pollution effects to terrestrial, aquatic, and visibility resources.

**Scattering.** An interaction of a light with an object (e.g., a fine particle) that causes the light to be redirected in its path.

**Scattering Coefficient.** Measure of the ability of particles to scatter light; measured in number proportional to the "amount" of light scattered per unit distance.

**Screening Level or Screening Level Value (SLV).** The concentration or dose of air pollution below which estimated impacts from a proposed new or modified source are considered insignificant. The SLV is dependent on existing air quality and on the condition of the AQRV of concern.

**Sensitive Receptor.** The AQRV, or part thereof, that is the most responsive to, or the most easily affected by the type of air pollution in question. For example, at Great Smoky Mountains National Park, spruce-fir forest is a sensitive receptor of the AQRV flora.

**Sensitive Receptor Indicator.** A measurable physical, chemical, biological, or social (e.g., odor) characteristic of a sensitive receptor. For example, for the sensitive receptor, Crater Lake, water clarity is a sensitive receptor indicator.

**Stationary Source.** A source of pollution that is well defined, such as the smokestack of a coal-fired power plant or smelter.

**Sulfates.** Those aerosols that have origins in the gas-to-aerosol conversion of sulfur dioxide; of primary interest are sulfuric acid and ammonium sulfate. Sulfuric acid and ammonium sulfate are very hygroscopic so their contribution to visibility impairment is magnified in the presence of water vapor.

**Sulfur Dioxide ($SO_2$).** A gas consisting of one sulfur and two oxygen atoms. Of interest because sulfur dioxide converts to an aerosol.

**SUM00**. The sum of all hourly average concentrations above 0 ppb.

**SUM06.** The sum of all hourly average concentrations at or above 60 ppb.

**Target Load.** The acceptable concentration or dose of an air pollutant that provides a reasonable margin of safety below the critical load. The target load should be achievable under existing conditions.

**Transmissometer.** An instrument that measures the amount of light extinction over a fixed, specified path length.

**Visibility Impairment.** Any humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions. [40 CFR §51.301(x)]

**Visual Range.** The distance at which a large black object would just disappear from view.

**Volatile Organic Compound (VOC).** Any compound of carbon, except those excluded by EPA that participates in atmospheric photochemical reactions. (See 40 CFR §51.100(s))

**W126.** An ozone index that multiplies each specific concentration by a sigmoidal weighted function, then sums all values. $Wi = 1/[1 + Me^{-(A \times Ci)}]$, where M and A are constants 4403 and 126 $ppm^{-1}$, respectively, $w_i$ is the weighting factor for $c_i$, and $c_i$ is concentration in ppm.

# Appendix B: Legal Framework for Managing Air Quality and Air Quality Effects on Federal Lands

## Introduction

The regulation of air pollution sources has clearly been delegated to EPA, and as applicable, the States. However, Federal Land Managers (FLMs) have the responsibility to protect the particular values of the lands over which they have jurisdiction, to the extent they have been delegated the authority, from the adverse impacts of activities inside and outside these areas.

This Appendix sets out the basic legal authorities and responsibilities with which the FLMs comprising FLAG must comply, in addition to those authorities which they can utilize to protect AQRVs on public lands.

For the purposes of this Appendix only, the term "public lands" is defined to include units of the National Park, National Wildlife Refuge, and National Forest Systems.

## Agency Organic Acts

### Department of the Interior: National Park Service (NPS):

This Organic Act is very specific in that it mandates national park unit managers:

[T]o conserve the scenery and the natural and historic objects and wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

16 U.S.C. §1(1997); and

[T]he authorization of activities shall be construed and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided for by Congress.

16 U.S.C. § 1a-1 (1997)

### Department of the Interior: Fish and Wildlife Service (FWS):

With respect to National Wildlife Refuge System lands (Refuge System lands under the jurisdiction of the United States Fish and Wildlife Service (FWS)), FWS managers are required to manage Refuge System lands so to:

[E]nsure that the biological integrity, diversity, and environmental health of the System are maintained for the benefit of present and future generations of Americans.

16 U.S.C. §668dd(a)(4)(B)(1997)

### Department of Agriculture: Forest Service (Forest Service)

National Forest System lands are defined as:

[A]ll National Forests reserved or withdrawn from the public domain of the United States, all national forests acquired through purchase, exchange, donation, or other means, all national grasslands and land utilization projects...and all lands waters, and other interests administered by the Forest Service.

16 U.S.C. §1609(a)(1997)

The Forest Service's Organic Administration Act of 1897 directs the Secretary of Agriculture to:

[M]ake provisions for the protection against destruction by fire and depredations upon the public forests and national forests...

16 U.S.C. Sec. §551(1997)

The National Forest units are managed consistent with Land and Resource Management Plans (LRMPs) under the provisions of the National Forest Management Act (NFMA). 16 §U.S.C. 1604 (1997). Any measures addressing AQRVs on National Forest System lands will be implemented through, and be consistent with, the provisions of an applicable LRMP or its revision (16 U.S.C. §1604(i)).

The Secretary of Agriculture is required by law to prepare a Renewable Resource Assessment by 1979, and every 10 years thereafter. By law this Assessment is required to address:

- A description of Forest Service programs in research, cooperative programs and management of the National Forest System, their relationships, and the relationships of these programs and responsibilities to public and private activities; and
- An analysis of the potential effects of global climate change on the condition of renewable resources on the Forests and rangelands of the United States; and
- An analysis of the rural and urban forestry opportunities to mitigate the buildup of atmospheric carbon dioxide and reduce the risk of global climate change.

16 U.S.C. §1601(a) (1997)

In addition, the Secretary of Agriculture is required to prepare and transmit to the President, a Renewable Resource Program (the Program) every 5 years. This Program must include program recommendations which recognize the fundamental need to protect, and where appropriate, improve the quality of ... air resources. 16 U.S.C. §1602(5)(C).

The Forest Service's implementing regulations for NFMA are found at 36 C.F.R. §219 et seq. LRMPs are, in part, specifically based on:

[R]ecognition that the National Forests are ecosystems and their management for goods and services requires an awareness and consideration of the interrelationships among plants, animals, soil, water, air, and other environmental factors within such ecosystems.

36 C.F.R. §219.1(b)(3)

## The Wilderness Act. 16 U.S.C. §1131 (1997)

AQRVs in Wilderness areas may receive further protection by the language of the Wilderness Act itself which states:

Wilderness areas... shall be administered for the use of the American people in such a manner as will leave them unimpaired for future use and enjoyment as wilderness .... (16 U.S.C. Sec. §1131).

For Wilderness Areas in the National Forest System, the Act's implementing regulations are found at 36 C.F.R. §293. These Wilderness Areas shall be administered:

...[For] such other purposes for which it may have been established in such a manner as to preserve and protect [their] wilderness character. In carrying out such purposes, National Forest Wilderness resources shall be managed to promote, perpetuate, and, where necessary, restore the wilderness character of the land...

36 C.F.R. §293.2 (1997)

## The Clean Air Act, 42 U.S.C. §7401 et seq.

Because of a perceived need for national and regional air quality research to support State programs, Congress passed its first federal air quality initiative in 1955. (Air Pollution Control Act of 1955, Ch. 360, 69 Stat. 322). In response to increasing harm to public health and welfare and to inadequate controls and enforcement, Congress has slowly but steadily expanded and refined the law, now known as the Clean Air Act (CAA), to cover more types of pollutants and emitters; e.g., stationary and mobile sources of pollution. These efforts have culminated in the 1990 Amendments to the CAA, which represent the most comprehensive and detailed set of measures to date to both prevent and curtail air pollution.

The declaration of purpose, as revised in 1990 states in part:

The purposes of this subchapter are: to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population.

42 U.S.C. § 7401(b)(1); and

A primary goal of this Act is to encourage or otherwise promote reasonable Federal, State, and local government actions, consistent with the provisions of this Act, for pollution prevention.

42 U.S.C. §7401(c)

The CAA provides an additional legal framework for FLMs to preserve and protect AQRVs from pollution sources emanating both within and outside National Park, Forest, and Refuge boundaries.

### National Ambient Air Quality Standards (NAAQS) and State Implementation Plans (SIPs):

The CAA establishes a regulatory program with the goal of achieving and maintaining "national ambient air quality standards" (NAAQS) through state or, if necessary, federal implementation plans (SIPs or FIPs).[1]

The U.S. Environmental Protection Agency (EPA) is charged with promulgating:

- "primary" NAAQS for "criteria" pollutants "to protect the public health," allowing an adequate margin of safety;" and
- "secondary" NAAQS "to protect the public welfare from any known or anticipated adverse effects associated with the presence of such air pollutant in the ambient air."[2]

The above secondary standards may help protect public land AQRVs.[3] To date, EPA has promulgated NAAQS for six criteria pollutants: sulfur dioxide, particulate matter, nitrogen dioxide, carbon monoxide, ozone and lead. In 2006, EPA issued revised, and more stringent NAAQS for "fine particulate matter." In 2008 EPA revised the ozone standard, to address human health and welfare concerns. In 2010, EPA promulgated one-hour standards for nitrogen dioxide and sulfur dioxide. However, EPA openly acknowledged that these revised NAAQS were not fully adequate to protect the above "secondary" values, in particular those sensitive AQRVs on public lands. EPA proposed further revisions to the primary and secondary ozone standards in January 2010 and is currently developing a proposal for secondary $NO_x$ and $SO_x$ standards that are intended to address aquatic acidification due to acid deposition.

### Prevention of Significant Deterioration (PSD):

The CAA, as amended in 1977, includes the following major purposes regarding the "prevention of significant deterioration" (PSD) provisions:

[T]o protect public health and welfare from any actual or potential adverse effect . . . from air pollution . . .

notwithstanding attainment and maintenance of all national ambient air quality standards.

42 U.S.C. § 7470(1)

[T]o preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value.

42 U.S.C. §7470(2)

The PSD section provides some protection for park and wilderness AQRVs through establishment of ceilings on additional amounts of air pollution over baseline levels in clean air areas (increments). It requires EPA or the State to provide to the FLM notice of any proposed major emitting facility[4] whose emissions may affect a Class I area (42 U.S.C. §7475(d)(2)(A), and also by charging:

[T]he Federal Land Manager [1] and the Federal official charged with direct responsibility for management of such lands with "an affirmative responsibility to protect the air quality related values (including visibility) of any such lands within a class I area and to consider, in consultation with the Administrator, whether a proposed major emitting facility will have an adverse impact on such values.

42 U.S.C. §7475(d)(2)(B).

Class I areas include national parks larger than 6,000 acres and national wilderness areas and national memorial parks which exceed 5,000 acres, in existence on August 7, 1977. The 1990 Amendments provided that subsequent additions to the boundaries of such areas are also Class I areas. Currently, 48 areas in the National Park system, 21 Refuge System units, and 88 areas under the administration of the Forest Service are designated as Class I.

Under the PSD provisions and implementing regulations (40 C.F.R. §51.166(p)), for Class I areas, once baseline concentrations come under review by submission of a PSD preconstruction permit application for a major new or modified emissions source, only the smallest increment of certain pollutants — sulfur dioxide, nitrogen oxide and particulate matter — may be added to the air by the proposed new source, and other "increment consuming" sources.

Under the PSD provisions a FLM has several tools he/she may use to protect AQRVs.

A state may not issue a PSD permit to allow construction or modification of a major emitting facility when the applicable Federal Land Manager files a notice alleging the facility may cause or contribute to a change in the Class I area's air quality and by identifying the potential adverse impact of such a change, unless:

The facility owner demonstrates that the facility's emissions of particulate matter, sulfur dioxide, and nitrogen oxides will not cause or contribute to concentrations which will exceed the maximum allowable increases for that Class I area.

42 U.S.C. §7475(d)(2)(C)(i)(paraphrased) and 42 U.S.C. §7476.

Even if no increment violation is predicted,

[T]he state may not issue a PSD permit, if the Federal Land Manager demonstrates to the satisfaction of the State that the emissions from such facility will have an adverse impact on the air quality-related values (including visibility) of Class I lands.

42 U.S.C. §7475(d)(2)(C)(ii)(paraphrased)

Neither the CAA nor the implementing regulations specify criteria for the FLM to "satisfy" state permitting agencies. Consequently, some states have taken a liberal view of their discretion to reject an FLM's adverse impact determination. However, EPA's Environmental Appeals Board (the Board) has ruled that state discretion in rejecting a FLM's finding of adverse impacts is not "unfettered" (see the Board's decisions regarding the permit appeals for the Old Dominion Electric Cooperative and Hadson Power projects in Virginia). Nevertheless, the appropriate role of the FLM in the PSD permit process was addressed in EPA's 1996 proposed New Source Review Reform regulations. The final regulations have not yet been promulgated.

### Visibility Protection. Subpart II, 42 U.S.C. §7491 et seq. (1997)

The Visibility portion of the CAA:

"... [D]eclares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from man made air pollution."

42 U.S.C. §7491(a)(1).

To help carry out this goal, the Secretaries of the Interior and Agriculture are charged with identifying Class I areas where visibility is an important value. EPA is charged with reporting to Congress on methods to implement the national goal and with promulgating regulations to ensure reasonable progress toward meeting the goal.

In 1980, EPA issued enforceable regulations for visibility impairment "reasonably attributable" to a specific source or small group of sources. In particular, major stationary sources emitting any pollutant which may "reasonably be anticipated to cause or contribute to any impairment of visibility" is required to install best available retrofit technology (BART). In addition, in April 1999 EPA promulgated final regulations addressing regional haze.

The regional haze rule protects air quality in Class I areas by requiring States to plan to achieve "natural" visibility conditions over a 60-year time frame.

The 1990 Amendments added a new section on visibility, which authorizes EPA in conjunction with NPS and other federal agencies, to conduct visibility research and to evaluate clean air corridors and emissions sources and source regions causing visibility impairment in Class I areas. In this regard, EPA was required to establish the Grand Canyon Visibility Transport Commission (GCVTC) by 1991 and consider the recommendations GCVTC would make (42 U.S.C. §7492(f). NPS, FS, FWS, and BLM played a vital role in the work of the GCVTC and committees in an effort to improve air quality in the Grand Canyon and other parks and wilderness areas in the "Golden Circle" on the Colorado Plateau.

As part of the visibility protection process, states are required to promulgate a plan to prevent any future, and remedy any existing impairment of visibility in Class I areas... 40 C.F.R. §51.300 (1997). EPA has defined "visibility impairment" as:

[A]ny humanly perceptible change in visibility (visual range, contrast, coloration) from that which would have existed under natural conditions.

40 C.F.R. §51.301(x)(1997).7

However, EPA has promulgated its visibility regulations to allow FLMs to use their existing authorities to address "visibility impairment" (rather than "significant impairment") so that "the affected Federal Land Manager may certify to the State, at any time, that there exists impairment of visibility in any mandatory Class I Federal area." 40 C.F.R. §51.302(c).

## Nonattainment Areas, 42 U.S.C. §7501 et seq.:

Areas that have failed to meet NAAQS for one or more criteria pollutants are designated as "nonattainment" areas. Under the 1990 Amendments, Congress provides for further classification of nonattainment areas based on severity of the nonattainment and availability and feasibility of appropriate pollution control measures and for a compliance schedule ranging from 1993 in marginal nonattainment areas to 2010 for Los Angeles.

The 1990 Amendments authorize EPA to issue control technique guidance documents (CTGs) covering a variety of topics, such as control of idling vehicles and voluntary removal of pre-1980 model year light duty vehicles (cash for clunker programs). (42 U.S.C. §7408.) EPA is authorized to issue CTGs, in lieu of regulations, to reduce "volatile organic compounds" (VOC) emissions from any consumer or commercial product. (42 U.S.C. §7511b.)

Proposed new or modified major stationary sources within nonattainment areas are required to meet emissions limits based on "lowest achievable emission rate" technology (LAER) and may be constructed only if their emissions are sufficiently offset by reductions in emissions from other sources. The 1990 Amendments also require analysis of alternative sites, sizes, production processes, and control techniques and a finding that the benefits of the source outweigh its environmental and social costs. (42 U.S.C. §7501-15.)

## General

CAA Subchapter III 42 U.S.C. §7601 et seq. contains definitions, requirements for reports to Congress, authorizations for appropriations, and procedures for EPA rule making and judicial review. Citizen suits are authorized: 1) against EPA for failure to perform a nondiscretionary duty under the CAA, or 2) against others for alleged violations of an emission limitation, standard, or order. (42 U.S.C.§7601 et seq.)

## Acid Deposition

The 1990 Amendments add Title IV, which contains requirements for electric utilities to reduce emissions associated with acid rain. To reduce the adverse effects of acid deposition, Title IV requires a reduction in annual emissions of sulfur dioxide of ten million tons from 1980 emission levels and a reduction of nitrogen oxides emissions of approximately two million tons from 1980 emission levels, in the 48 contiguous states and the District of Columbia. (42 U.S.C. §7651.) The Title creates a system of market-based emission allowances, which can be traded among sources. See (42 U.S.C. §7651a-o.)

## Operating Permits

The 1990 Amendments add Subchapter V, 42 U.S.C. §7661 et seq., which establishes a nation-wide permit program for existing stationary sources. Permit requirements will include emission limitations. EPA may veto state permits, which do not comply with provisions of the CAA. (42 U.S.C. §7661a-f.)

## Conformity, 42 U.S.C. §7506 (1997)

(Paraphrased) No federal agency may engage in, support in any way,... license or permit, or otherwise approve any activity which does not conform to an approved state (or federal) implementation plan. Conformity shall be an affirmative responsibility of the head of each agency. Conformity means:

- Conforming to the SIP's purpose of eliminating or reducing the number of NAAQS violations;
- That any such activities will not:
    - Cause or contribute to new violations in any area; or

- Increase the frequency or severity of any existing standard violation...

EPA, in its “criteria and procedures” for implementing “conformity” has decided that only those activities that “a federal agency can practicably control, and will maintain control over due to a continuing program responsibility” are subject to same. 40 C.F.R. §93.152.

Although required to comply with the conformity provisions (42 U.S.C. §7618(1997)), the FLM cannot use these provisions to protect AQRVs from adverse impacts from off site sources.

## Impact on Federal Land Managers

The CAA reinforces the FLMs’ Organic Act and Wilderness Act roles as protectors of AQRVs on public lands.

The CAA also imposes on FLMs an obligation to comply with the Act’s many provisions regarding the abatement of air pollution to the same extent as any private person (42 U.S.C. §7418).

Thus, under various authorities, FLMs are responsible for protecting AQRVs within their respective unit boundaries and taking appropriate action to do so, when reviewing emission sources both within units, and in proximity to unit boundaries.

FLMs, under the CAA, have an affirmative responsibility for protecting AQRVs (including visibility) in reviewing proposed PSD permits. However, because of the uncertainty involved in “satisfying” State permitting agencies in the PSD process, and the appropriate delegated role for FLMs in non-PSD situations, the existing framework may provide an inadequate means for FLMs to protect AQRVs from adverse impacts caused by sources outside unit boundaries.

## Endnotes

1) Clean Air Act, 42 U.S.C. §7401-7671q (as amended 1990).

2) *Clean Air Deskbook*, The Environmental Law Reporter, Environmental Law Institute, 1992.

3) *Managing National Park System Resources: A Handbook on Legal Duties, Opportunities, and Tools*, Chap. 4 “The Clean Air Act” by Molly Ross at pp. 51-65, The Conservation Foundation, 1990.

4) *Atmospheric Environment* Vol. 27B, No. 1, “The 20-Year History of the Evolution of Air Pollution Control Legislation in the U.S.A.” by Richard H. Schulze at pp. 15-25., 1993

5) Wilderness Act of 1964, 16 U.S.C. §1131 et seq, P.L. 577, 78 stat 890 as amended.

6) *The Principal Laws Relating to Forest Service Activities*, USDA - Forest Service ISBN 0-16-041927-1, 1993

7) Organic Administration Act of 1897, 16 U.S.C. §473-475, §477-482, §551.

# Appendix C: General Policy for Managing Air Quality Related Values in Class I Areas

Most Federal Land Manager (FLM) enabling legislation and regulations developed to implement Federal Laws do not directly address air quality, or air pollution effects on Parks or Wildernesses. They do, however, provide broad direction on what should be protected in Parks and Wildernesses (the earth and its community of life) and to what degree (preserve natural conditions or conserve resources unimpaired). Accordingly, FLMs have developed the following policies related to air quality and Class I areas:

1. Class I areas are not merely a commodity for human use and consumption. Park and Wilderness ecosystems have intrinsic values other than user/public concerns.
2. A principal objective of FLM management is to offer a natural user experience, rather than strictly an enjoyable one. The amount of enjoyment is purely a personal matter for the individual user to decide.
3. All Class I components are equally important; none is of lesser value than another.
4. A Class I component is important even if users of the area are unaware of its existence.
5. All life forms are equally important. For example, microorganisms are as essential as elk, wild flowers, or grizzly bears.
6. The goal of Class I management is to protect not only resources with immediate aesthetic appeal (i.e., sparkling clean streams) but also unseen ecological processes (such as natural biodiversity and gene pools).
7. The most sensitive Class I components are to be emphasized more than those of "average" or "normal" sensitivity. Sensitivity is generally determined by inertia (resistance to change), elasticity (how far the component can be stretched from its natural condition without being permanently modified), and resiliency (the number of times it can revert to its natural condition after experiencing human-caused change).
8. Each Class I component is important in itself; as well as in terms of how it interacts with other components of the ecosystem. That is, the individual parts of the Class I ecosystem are as significant as the sum of the parts.
9. The physical components of the ecosystem (for instance, lake chemistry) are as essential as its biological constituents (i.e., salamanders). That is, the earth is as essential as the community of life.
10. Class I components are to be protected from "human-caused change" rather than from "damage." Terms such as "damage" and "harm" are prejudicial, whereas "human-caused change" is value-neutral. (For example, deposits of nitrogen in a lake from nitrogen oxide, a common air pollutant, might result in more plant growth and larger fish. This would, however, be an unnatural - and therefore unacceptable - change in the aquatic ecosystem).
11. The goal of Class I management is to protect natural conditions, rather than the conditions when first monitored. That is, if initial monitoring in a Class I area identifies human-caused changes, appropriate actions should be taken to remedy them, in order to move towards a more natural condition.
12. The designation of a Park or Wilderness as Class I or II does not dictate the management goals for it; these are identified in the enabling legislation. The designation only determines which options are available to meet the goals. Class I Parks or Wildernesses, for instance, can be protected through AQRV analysis, whereas the protection of Class II Parks and Wildernesses can be achieved using BACT requirements.
13. The FLMs will do their best to manage and protect resources at every area that they administer.
14. Although monitoring is critical to many air resource management decisions, it must not interfere needlessly with Park or Wilderness. Where possible, the most intrusive monitoring and instrumentation should be conducted adjacent to the Class I area - if such areas adequately represent the area of concern.

# Appendix D: Best Available Control Technology (BACT) Analysis

Given the need to minimize emissions and their resulting air quality impacts, the FLMs recommend that the applicant conduct the BACT analysis using EPA's top-down approach. In brief, a top-down process ranks all available control technologies in descending order of control effectiveness. All of the available control systems for the source, including the most stringent, must be considered. The applicant first examines the most effective, or top, alternative. That alternative is established as the BACT unless the applicant demonstrates, and the permitting authority agrees, that technical considerations, or energy, environmental, or economic impacts justify a conclusion that the most stringent technology is not achievable in that case. FLMs utilize EPA's BACT/RACT/LAER Clearinghouse, and other information, for assessing control technologies proposed by permit applicants.

If the most stringent technology is eliminated in this fashion, then the next most stringent alternative is considered, and so on. Permit applicants should refer to chapter B of the EPA Draft New Source Review Workshop Manual for a detailed discussion of the top-down policy (EPA 1990).

The FLM reviews the applicant's BACT analysis to determine if the best available pollution control technology is being proposed, thereby minimizing the proposed emission increases and their corresponding impact on the FLM area in question. The FLM does this by comparing the proposed controls to recent BACT determinations for similar facilities. If the FLM disagrees with the applicant's BACT analysis, technical comments are submitted to the permitting authority that has the ultimate responsibility to make the BACT determination and issue the permit.

The environmental impacts analysis of the BACT review is not to be confused with the air quality-related analysis. The environmental impacts analysis of the BACT review should concentrate on impacts other than ambient air quality impacts of the regulated pollutant in question, such as solid or hazardous waste generation, discharges of polluted water from a control device, or emissions of unregulated pollutants. Thus, the fact that a given control alternative would result in only a slight improvement in ambient concentrations of the pollutant in question when compared with a less stringent control alternative, should not be viewed as a basis for rejecting the more stringent control alternative.

Regarding the economic impact analysis, given the special protection Class I areas are afforded under the Clean Air Act, FLMs believe that the need to minimize potential impacts on a Class I area should be a major consideration in the BACT determination for a project proposed near such an area. Therefore, if a source proposes to locate near a Class I area, additional costs to minimize impacts on sensitive Class I resources may be warranted, even though such costs may be considered economically unjustified under other circumstances.

# Appendix E: Maps of Federal Class I Areas

**Figure 8. National Park Service Class I Areas**
Map produced by the National Park Service Air Resources Division March 2010.

**Figure 9. Fish and Wildlife Service Class I Areas**
Map produced by the National Park Service Air Resources Division March 2010.

**Figure 10. Forest Service Class I Wilderness Areas**
Map produced by the National Park Service Air Resources Division March 2010.

# Appendix F: FLAG 2000 Participants

The individuals listed in the attached table participated in the development of the *FLAG Phase I Report* (December 2000). The contact information was not updated as part of this FLAG 2010 revision. The abbreviations for the FLAG subgroup or committee on which participants served are shown below.

LC = Leadership Committee

CC = Coordinating Committee

P = Policy Subgroup

V = Visibility Subgroup

O = Ozone Subgroup

D = Deposition Subgroup

T = Terminology (Glossary) Subgroup

**FLAG 2000 Participants**

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# Appendix G: Bibliography (Revised)

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